

Introduction	1
Section 1: Science	3
<i>Basic chemistry</i>	3
<i>Organic substances</i>	10
Aliphatic hydrocarbons	10
Aromatic hydrocarbons	11
<i>Alcohols</i>	12
<i>Polymers</i>	12
<i>Monomers</i>	13
<i>Physical properties of matter</i>	13
<i>Heat and temperature</i>	16
<i>Flammable limit range</i>	19
<i>Density</i>	20
<i>Solubility and miscibility</i>	23
<i>Energy, work and power</i>	24
<i>Motion</i>	25
<i>Chemical properties</i>	26
Chemical reactivity	33
<i>Toxic products of combustion</i>	36
<i>Heat, temperature and combustion</i>	40
Measuring temperature	41
Thermometric scales	42
Units of heat	42
Specific heat	43
Change of state and latent heat	43
Effect of change of pressure on boiling point and latent heat	44
Latent heat of fusion	44
Cooling by evaporation	44
Thermal expansion of solids	45
Thermal expansion of liquids (cubical expansion)	45
The effect of expansion on density	46
The expansion of gases	46
<i>The gas laws</i>	47
The liquefaction of gases	48
Critical temperature and pressure	48
Liquefied gases in cylinders	48
Sublimation	49
<i>Heat transmission</i>	50
<i>Combustion</i>	50
Oxidation	51

What makes a flame a flame?	52
Laminar flow and turbulent flow	52
Premixed and diffusion flames	53
Flashpoint, firepoint and sustained fires	55
Vapour cloud fires (flash fires and fireballs)	55
Vapour cloud explosions	56
Ignition	56
Section 2: General hazards	57
Legislation	58
Pre-planning	60
Gathering and use of risk information	61
Information sources	61
Scientific advisers	62
Chemsafe	63
Generic information resources	65
Site emergency plans	66
Risk assessments	67
Incident Observations	67
Information available at the incident scene	69
Product specialists	70
Safety data sheets (SDS)	70
Interpreting safety data sheets	71
Physical and chemical properties and reactivity	74
Detection, identification and monitoring (DIM) equipment	74
Electronic information sources	75
Printed information sources	78
Product-specific aid schemes	79
Acrylonitrile / medical	79
Bromaid	80
ChlorAid	80
Ethylene oxide	81
Isocyanates (ISOPA)	81
Titanium tetrachloride	82
Interpreting and using information	82
Systematic or International Union of Pure and Applied Chemistry (IUPAC)	83
Trivial (common names)	84
Commercial and trade names	85
Synonyms	85
Chemical Abstracts Service (CAS) registry numbers	85
United Nations (UN) numbers	86
EC numbers	86
Met Office Hazard Manager	87
Accessing Hazard Manager	87
FireMet	88
Chemical meteorology (CHEMET)	92

Numerical Atmospheric-dispersion Modelling Environment (NAME) dispersion model	92
Notification and marking of sites regulations (NAMOS)	93
Access marking	94
Location marking	95
The Control of Major Accident Hazard Regulations (COMAH)	97
Procedures and communications in the event of a release of radioactive material (PACRAM)	100
Transportation, packaging and supply	100
Comparison of hazard communication under CLP to the CHIP regulations	101
How does the GHS classification system work?	103
Links between CLP regulation and dangerous goods transportation regulations.	106
Regulatory background	110
The UN system	111
Road transportation	119
Emergency Action Code (EAC)	147
Road transport regulations	150
Marking of packaged goods vehicles	151
Placarding of road tankers and tank containers	154
Emergency Action Code (EAC)	156
ADR hazard identification numbers (HIN) or 'Kemler Code'	159
European ADR tanker or tank placarding	167
Switch-loading of petrol and distillate fuels	170
Registration, evaluation, authorisation and restriction of chemicals (REACH) Regulations	171
Rail transportation	172
Air transportation	175
Maritime transportation	182
Bulk storage of hazardous substances	184
Packaging	185
Labelling and signage	193
Pipelines	193
Personal protective equipment	194
Standards and markings for protective clothing	197
Materials of construction	205
Performance standards	206
Types of usage of chemical protective clothing (CPC)	208
Selection of chemical protective clothing (CPC)	209
Using chemical protective clothing at hazardous materials incidents	212
Wearing CPC in flammable or explosive atmospheres	213
Other types of CPC	214
Contamination and decontamination	215
Avoid contamination, prevent exposure	216
Surface contamination versus permeation contamination	217
Direct contamination versus cross-contamination	218

Types of contaminants	218
Decontamination methods	220
Physical methods	230
Chemical methods	231
Firefighter decontamination	233
Selection of the level of decontamination	234
Positioning of the decontamination area	234
Decontamination system	236
Initial decontamination procedure	239
Full decontamination procedure	245
Decontamination team	245
Decontamination equipment	246
Decontamination good practice	246
Emergency decontamination	249
Secondary decontamination	250
Decontamination of casualties	251
Mass decontamination	252
Improvised decontamination	253
Interim decontamination	254
Clinical decontamination	257
Powered respirator protective suit safe undressing procedures	260
Section 3: Physical hazards	261
Explosive hazards	261
Common explosives and their uses	265
Transportation and packaging	268
Road	272
Rail	273
Sea and inland waterways	275
Air	276
International Standards Organisation transport containers (ISO)	276
Storage of explosives	277
Ministry of Defence (MoD) sites	280
Response plans	280
Fire safety inspections	281
Familiarisation and exercising	282
Other hazards	282
Ammonium nitrate based fertiliser	284
Gases under pressure	287
Cylinder identification marks	290
Transportation and packaging	291
Cylinders	292
Acetylene	297
Acetylene cylinder identification	298
Acetylene cylinder procedure	302
Liquefied petroleum gas (LPG)	310

Boiling liquid expanding vapour explosion (BLEVE)	312
Bulk flammable gas firefighting considerations	313
Flammable hazards	316
Flammable liquids	317
Factors that increase fire risks from flammable liquids	317
Factors that decrease fire risks from flammable liquids	319
Substance directly involved in fire	320
Flammable solids	321
Oxidising hazards	324
Cryogenics	328
Section 4: Health hazards	331
Acute and chronic health hazards	331
Toxic substances - characteristics, classification and hazards	336
Descriptive terms used in poisoning	339
Occupational exposure limits (OEL)	341
Workplace exposure limits	342
Odour threshold concentration	343
Other systems	343
Other terms	344
Acute emergency guideline levels	344
Immediately dangerous to life and health hazards	345
Biological or infectious agents/hazards	345
Biohazard pre-planning	349
Other operational considerations for fire and rescue services	351
Health surveillance	353
Materials containing asbestos	353
Asbestos in buildings	359
Railway rolling stock	360
The environment	361
Fire and rescue service exemption	361
Planning and liaison	362
Asbestos hazard identification guidance	363
Mobilisation to incidents involving asbestos	366
Planning the response for incidents involving asbestos	367
Asbestos decontamination procedure	369
Where asbestos is discovered during an incident	371
Closing incidents involving asbestos	372
Hazards posed to the general public at serious fires involving asbestos	374
Corrosive hazards	375
Some important inorganic (or mineral) acids	378
Other halogen acids	379
Bases/alkalis - characteristics, classification and hazards	380
Other corrosives	381
Radioactive materials	382
Irradiation	386

Radioactive contamination	386
Sealed and unsealed sources	386
Damage caused by radiation	387
Use of radioactive materials	389
Transportation of radioactive materials	395
Marking and labelling	397
Documentation of radioactive materials	400
Vehicle placarding for transport of radioactive materials	401
Storage of radioactive materials	401
Dose limits	403
Emergency exposure to radioactive materials	404
Radiation dose control measures	405
Radiation dose management	409
Classified persons	410
Designated areas	411
Local rules for working with radioactive materials	411
Radiation protection adviser and radiation protection supervisor	412
Prior risk assessment	412
Dosimetry and record keeping	412
Medical surveillance	413
Equipment maintenance and calibration	413
Training	413
Emergency incident plans for radioactive materials	414
Assistance and liaison	415
Additional operational considerations when involved in fire	419



Introduction

This document is designed to complement and support the National Operational Guidance (NOG) for Hazardous materials which is intended to assist policy writers in fire and rescue services in producing their local policies or guidance for hazardous materials operations. This accompanying foundation document is aimed to provide all fire and rescue service personnel with the detail required for effective, safe and proportionate hazardous material operations to be practised and applied.

The document forms part of a risk based, technical framework produced by the National Operational Guidance Programme (NOGP). It provides the technical information and supporting material required to understand National Operational Guidance: Hazardous materials – Hazards and control measures. Fire and rescue services should consider this foundation material when developing or reviewing their policy, procedures and training programmes to safely and efficiently resolve emergency incidents involving hazardous materials, including CBRN(e).

Additional hazardous materials guidance that will enable fire and rescue service personnel to develop competence in hazardous materials operations is shown in the following table:

Name	Date	Comments
Hazardous materials NOG	APR 2016	NOGP Hazard and control measures
Environmental Protection NOG	APR 2015	NOGP Hazard and control measures
'The environmental protection handbook for the fire and rescue service', 2013, EA	2013	Environment Agency.
'Responding to a CBRN(e) event: Joint operating principles for the emergency services'	2016	Joint Emergency Services Interoperability Programme (JESIP).
'Initial Operational Response to a CBRN(E) Incident'	2015	Joint Emergency Services Interoperability Programme (JESIP).
'The dangerous goods emergency action code list 2015'	2015	National Chemical Emergency Centre (NCEC), TSO.

Name	Date	Comments
The emergency response guidebook 2016 (ERG)	2016	US department of transportation.

Table 1 Additional hazardous materials guidance

In everyday language, the term hazardous materials, also referred to as dangerous/hazardous substances or goods, means solids, liquids, or gases that can harm people, other living organisms, property or the environment. Hazardous materials not only include materials that are toxic, radioactive, flammable, explosive, corrosive, oxidisers, asphyxiates, biohazards, pathogens or allergenic substances and organisms, but also materials with physical conditions or other characteristics that render them hazardous in specific circumstances. Examples include compressed gases and liquids and hot or cold materials.

Non-fire and rescue service organisations and agencies may use more technical and specific definitions because of their own requirements, but the definition above is the most appropriate one for fire and rescue services to form their risk assessments and planning assumptions. Fire and rescue services may respond to a wide range of incidents involving hazardous materials that have the potential to cause harm to firefighters, the community and the environment. They may be called specifically to deal with emergency spillages or releases, or they may encounter hazardous materials at fires and other emergency incidents. The purpose of this guidance is to assist emergency responders in making safe, risk-assessed, efficient and proportionate responses whenever hazardous materials are encountered in the operational arena.

This foundation document is primarily aimed at five key fire and rescue service operational roles:

- Control room operators
- Firefighters
- Incident commanders
- Hazardous materials advisers (HMAs)
- Detection identification and monitoring (DIM advisers)

This foundation document is a knowledge resource intended to support the development of people in accordance with the emergency fire service role maps and the National Occupational Standards (NOS), which describe the skills, knowledge and understanding needed to undertake a particular task or job to a nationally-recognised level of competence. They should be used, in conjunction with the training specifications for hazardous materials, for job design and evaluation, training needs

analysis, learning programmes, workplace assessment and performance appraisals.

Fire and rescue services should also be aware that their organisations may require other hazardous materials specific roles to support and manage the hazardous materials response function. The number, type and specification of these roles will vary according to the fire and rescue service's risk profile and risk management plan.



Section 1: Science



Basic chemistry

Chemistry is the science of the composition of substances, their properties and reactions with each other. Substances may be solids, liquids or gases, in living or non-living systems, but they all have one common factor: they consist of chemicals.

Elements and compounds

All matter is made from a limited number of fundamental materials; these are known as elements. Elements cannot be separated into simpler substances. Less than 100 of these fundamental materials can be found naturally, although a handful of additional elements have been synthesised in laboratories.

Some elements exist in this elemental state, for example hydrogen, oxygen, iron and gold. However, most will be bonded together with other elements; these substances are called compounds. For example, simple fuels are referred to as hydrocarbons; this is because they are compounds made up of the elements carbon and hydrogen. The simplest and smallest of these compounds is methane, which is made up of one unit of carbon and four units of hydrogen. The smallest possible unit of an element is called the atom.

Atoms and molecules

An atom is the smallest unit of an element that still behaves in the same way as (has the properties of) that element. It cannot be divided any further except in nuclear reactions. Atoms are made from sub-atomic particles (protons, neutrons and electrons); the number of these present in the atom determines which element it is, and therefore the chemical and physical properties it possesses.

As mentioned above, one unit (or one atom) of carbon can react with four units (four atoms) of hydrogen to form one unit of methane. The smallest unit of a compound that still behaves as that compound is called a molecule.

Continuing with the example above using chemical terminology, one atom of carbon can react with four atoms of hydrogen to form one molecule of methane.

As atoms and molecules are infinitesimally small, reactions are usually worked out using mass (grams or kilograms). As each element has unique mass, differences in mass need to be taken into account when calculating the correct quantity of each substance (see [Atomic mass](#)).

Mixtures

A mixture may be separated into its constituents by some physical or mechanical means. For example, a mixture of salt and sand can be separated by dissolving the salt in water, leaving the sand behind. But to separate or change a single chemical substance (break the bonds between atoms in a molecule), a chemical reaction is required.

Symbols

Chemical symbols are used as a way of describing chemicals in terms of formulae, which are complete descriptions of molecules in terms of the constituent atoms. Symbols give as much information as possible, but are simple and quick to use. Formulae may also be used to describe the way that atoms in a molecule are grouped together. This information may give clues to how one chemical compound may react with another.

Every element is assigned a symbol (see table 2 periodic table of the elements), which is different from that of all the other elements. A symbol may be one letter or two; the convention is to write a second letter as a small letter. Thus the symbol for nickel is written Ni and not NI. NI would be interpreted as a molecule containing one nitrogen atom (N) and one iodine atom (I) (such a compound does not exist). In many cases the symbols are the first letter of the name of the element, often followed by a second letter taken from that name. However, several common elements have symbols that bear no relationship to their modern names, since they are based on the old Latin or Greek names. For example, the element sodium has the symbol Na which is derived from the Latin natrium, and lead has the symbol Pb, derived from plumbium (hence plumber, and plumb line).

1 H Hydrogen 1.008																	2 He Helium 4.003																	
3 Li Lithium 6.941	4 Be Beryllium 9.012											5 B Boron 10.811	6 C Carbon 12.011	7 N Nitrogen 14.007	8 O Oxygen 15.999	9 F Fluorine 18.998	10 Ne Neon 20.180																	
11 Na Sodium 22.990	12 Mg Magnesium 24.305											13 Al Aluminum 26.982	14 Si Silicon 28.086	15 P Phosphorus 30.974	16 S Sulfur 32.065	17 Cl Chlorine 35.453	18 Ar Argon 39.948																	
19 K Potassium 39.098	20 Ca Calcium 40.078	21 Sc Scandium 44.956	22 Ti Titanium 47.867	23 V Vanadium 50.942	24 Cr Chromium 51.996	25 Mn Manganese 54.938	26 Fe Iron 55.845	27 Co Cobalt 58.933	28 Ni Nickel 58.693	29 Cu Copper 63.546	30 Zn Zinc 65.38	31 Ga Gallium 69.723	32 Ge Germanium 72.631	33 As Arsenic 74.922	34 Se Selenium 78.971	35 Br Bromine 79.904	36 Kr Krypton 83.796																	
37 Rb Rubidium 85.468	38 Sr Strontium 87.62	39 Y Yttrium 88.906	40 Zr Zirconium 91.224	41 Nb Niobium 92.906	42 Mo Molybdenum 95.95	43 Tc Technetium 98.907	44 Ru Ruthenium 101.07	45 Rh Rhodium 102.906	46 Pd Palladium 106.42	47 Ag Silver 107.868	48 Cd Cadmium 112.414	49 In Indium 114.818	50 Sn Tin 118.711	51 Sb Antimony 121.760	52 Te Tellurium 127.6	53 I Iodine 126.905	54 Xe Xenon 131.294																	
55 Cs Cesium 132.905	56 Ba Barium 137.328	57-71 Lanthanides		72 Hf Hafnium 178.49	73 Ta Tantalum 180.948	74 W Tungsten 183.84	75 Re Rhenium 186.207	76 Os Osmium 190.23	77 Ir Iridium 192.227	78 Pt Platinum 195.085	79 Au Gold 196.967	80 Hg Mercury 200.592	81 Tl Thallium 204.383	82 Pb Lead 207.2	83 Bi Bismuth 208.980	84 Po Polonium [209]	85 At Astatine [210]	86 Rn Radon [222]																
87 Fr Francium [223]	88 Ra Radium 226.025	89-103 Actinides		104 Rf Rutherfordium [261]	105 Db Dubnium [262]	106 Sg Seaborgium [266]	107 Bh Bohrium [264]	108 Hs Hassium [277]	109 Mt Meitnerium [268]	110 Ds Darmstadtium [289]	111 Rg Roentgenium [272]	112 Cn Copernicium [285]	113 Nh Nihonium [284]	114 Fl Flerovium [289]	115 Mc Moscovium [288]	116 Lv Livermorium [293]	117 Ts Tennessine [294]	118 Og Oganesson [294]																
																			57 La Lanthanum 138.905		58 Ce Cerium 140.116	59 Pr Praseodymium 140.908	60 Nd Neodymium 144.242	61 Pm Promethium 144.913	62 Sm Samarium 150.36	63 Eu Europium 151.964	64 Gd Gadolinium 157.25	65 Tb Terbium 158.925	66 Dy Dysprosium 162.50	67 Ho Holmium 164.930	68 Er Erbium 167.259	69 Tm Thulium 168.934	70 Yb Ytterbium 173.054	71 Lu Lutetium 174.967
																			89 Ac Actinium 227.028	90 Th Thorium 232.038	91 Pa Protactinium 231.036	92 U Uranium 238.029	93 Np Neptunium 237.048	94 Pu Plutonium 244.064	95 Am Americium 243.061	96 Cm Curium 247.070	97 Bk Berkelium 247.070	98 Cf Californium 251.080	99 Es Einsteinium [252]	100 Fm Fermium 257.096	101 Md Mendelevium 258.1	102 No Nobelium 259.101	103 Lr Lawrencium [262]	
																			Alkali Metal Alkaline Earth Transition Metal Basic Metal Semimetal Nonmetal Halogen Noble Gas Lanthanide Actinide										Credit: Tobi Holmström, scienceartwork					

Table 2 Periodic table of the elements

1																2																																																							
H Hydrogen 1.008																He Helium 4.003																																																							
3 Li Lithium 6.941				4 Be Beryllium 9.012																				5 B Boron 10.811				6 C Carbon 12.011				7 N Nitrogen 14.007				8 O Oxygen 15.999				9 F Fluorine 18.998				10 Ne Neon 20.180																											
11 Na Sodium 22.990				12 Mg Magnesium 24.305																				13 Al Aluminum 26.982				14 Si Silicon 28.086				15 P Phosphorus 30.974				16 S Sulfur 32.066				17 Cl Chlorine 35.453				18 Ar Argon 39.948																											
19 K Potassium 39.098				20 Ca Calcium 40.078				21 Sc Scandium 44.956				22 Ti Titanium 47.867				23 V Vanadium 50.942				24 Cr Chromium 51.996				25 Mn Manganese 54.938				26 Fe Iron 55.845				27 Co Cobalt 58.933				28 Ni Nickel 58.693				29 Cu Copper 63.546				30 Zn Zinc 65.38				31 Ga Gallium 69.723				32 Ge Germanium 72.631				33 As Arsenic 74.922				34 Se Selenium 78.971				35 Br Bromine 79.904				36 Kr Krypton 83.796			
37 Rb Rubidium 85.468				38 Sr Strontium 87.62				39 Y Yttrium 88.906				40 Zr Zirconium 91.224				41 Nb Niobium 92.906				42 Mo Molybdenum 95.95				43 Tc Technetium 98.907				44 Ru Ruthenium 101.07				45 Rh Rhodium 102.906				46 Pd Palladium 106.42				47 Ag Silver 107.868				48 Cd Cadmium 112.414				49 In Indium 114.818				50 Sn Tin 118.711				51 Sb Antimony 121.760				52 Te Tellurium 127.6				53 I Iodine 126.905				54 Xe Xenon 131.294			
55 Cs Cesium 132.905				56 Ba Barium 137.328				57-71 Lanthanides				72 Hf Hafnium 178.49				73 Ta Tantalum 180.948				74 W Tungsten 183.84				75 Re Rhenium 186.207				76 Os Osmium 190.23				77 Ir Iridium 192.227				78 Pt Platinum 195.085				79 Au Gold 196.967				80 Hg Mercury 200.592				81 Tl Thallium 204.383				82 Pb Lead 207.2				83 Bi Bismuth 208.980				84 Po Polonium [209]				85 At Astatine [210]				86 Rn Radon [222]			
87 Fr Francium [223]				88 Ra Radium [226]				89-103 Actinides				104 Rf Rutherfordium [261]				105 Db Dubnium [262]				106 Sg Seaborgium [266]				107 Bh Bohrium [264]				108 Hs Hassium [277]				109 Mt Meitnerium [268]				110 Ds Darmstadtium [289]				111 Rg Roentgenium [272]				112 Cn Copernicium [277]				113 Nh Nihonium unknown				114 Fl Flerovium [289]				115 Mc Moscovium unknown				116 Lv Livermorium [293]				117 Ts Tennessine unknown				118 Og Oganesson unknown			
57 La Lanthanum 138.905																58 Ce Cerium 140.116				59 Pr Praseodymium 140.908				60 Nd Neodymium 144.242				61 Pm Promethium 144.913				62 Sm Samarium 150.36				63 Eu Europium 151.964				64 Gd Gadolinium 157.25				65 Tb Terbium 158.925				66 Dy Dysprosium 162.50				67 Ho Holmium 164.930				68 Er Erbium 167.259				69 Tm Thulium 168.934				70 Yb Ytterbium 173.054				71 Lu Lutetium 174.967			
89 Ac Actinium 227.028				90 Th Thorium 232.038				91 Pa Protactinium 231.036				92 U Uranium 238.029				93 Np Neptunium 237.048				94 Pu Plutonium 244.064				95 Am Americium 243.061				96 Cm Curium 247.070				97 Bk Berkelium 247.070				98 Cf Californium 251.080				99 Es Einsteinium [254]				100 Fm Fermium 257.095				101 Md Mendelevium 258.1				102 No Nobelium 259.101				103 Lr Lawrencium [262]															
Alkali Metal				Alkaline Earth				Transition Metal				Basic Metal				Semimetal				Nonmetal				Halogen				Noble Gas				Lanthanide				Actinide																																			
©2016 Telli Haharadze																www.telliha.com																																																							

Table 2 Periodic table of the elements

Using symbols to write formulae

When a symbol is written it represents one atom of the element. So H represents one atom of hydrogen and O represents one atom of oxygen.

A formula always represents one molecule of the substance, and shows the atoms present in the molecule and how many of them there are. So H₂O represents one molecule of water, containing two atoms of hydrogen and one atom of oxygen bound together chemically. Similarly, carbon dioxide has the formula CO₂, representing the molecule that contains one atom of carbon and two atoms of oxygen. If a molecule contains more than one atom of the same type, the number of similar atoms is written at the bottom right of the appropriate symbol, for example:

Calcium Carbonate: CaCO₃ –one atom of calcium, one atom of carbon and three atoms of oxygen.

Phosphorous Pentoxide: P₂O₅ – two atoms of phosphorus and five atoms of oxygen.

To represent more than one molecule we write a number in front of the formula: three molecules of water are represented by 3H₂O. This group of three water molecules contains six hydrogen atoms and three oxygen atoms.

2MgO represents two molecules of magnesium oxide and, therefore, a total of two magnesium atoms and two oxygen atoms.

Radicals

Certain groups of atoms common to families of related compounds are known as radicals. A radical can be defined as 'A group of atoms present in a series of compounds that maintains its identity regardless of chemical changes that affect the rest of the molecule'.

To show these radicals, formulae are often written with brackets enclosing the radical and with a number beyond the bracket to indicate how many of these radicals are in the formula.

Radicals are not complete molecules and have no independent existence. For example, the formula of one molecule of calcium hydroxide (slaked lime) is $\text{Ca}(\text{OH})_2$, indicating that it contains one calcium atom and two hydroxyl (OH) radicals. The molecule contains two oxygen atoms and two hydrogen atoms, but they are always paired, as OH.

Atomic mass

The mass of one atom or molecule is extremely small and as such is of little practical use. However because the atoms of different elements contain different numbers of protons and neutrons, knowing the mass is important in identifying to which element the atom belongs. To do this it is important to know how heavy one atom is compared with another. Chemists use relative atomic mass, some scales use different reference materials (oxygen or hydrogen). Generally, the comparison is against hydrogen, having a relative mass (rounded) to one. Substances can be compared to hydrogen to see how many times heavier they are.

Atomic mass = mass of one atom of the element \div mass of one atom of hydrogen

Molecular mass

In the same way, molecular mass is the mass of one molecule of the substance compared to the mass of one atom of hydrogen. For example, the molecular mass of water is 18 which means that one molecule of water is 18 times as heavy as one atom of hydrogen. Since a molecule consists of atoms joined together, the mass of the molecule is the sum of the masses of its component atoms. The molecular mass is found by adding together the atomic masses of those atoms present.

For example, the molecular mass of sulphur dioxide (SO_2) is 64. (atomic mass of sulphur + twice the atomic mass of oxygen: $32 + (2 \times 16) = 64$).

Valency

When atoms combine to form molecules, they do so in definite fixed ratios. For example, one sodium (Na) atom always combines with one chlorine (Cl) atom to give NaCl (common salt), but one magnesium (Mg) atom combines with two chlorine (Cl) atoms to give MgCl_2 (magnesium chloride). This 'combining power' of an atom depends on the arrangement and number of its electrons, but the mechanism is complicated.

The valency of an atom tells us how many chemical bonds the particular atom, or group of atoms (radicals) will form. When molecules are formed, the atoms or radicals generally combine in ratios in which the valencies are balanced. This enables us to work out the correct formulae of many chemical compounds. For example, in magnesium oxide Mg has a valency of two, and O has a valency of one. To balance the valencies we need one Mg atom and one O atom: hence the formula MgO.

In potassium carbonate, potassium (K) has a valency of one, while the carbonate radical has a valency of two. Potassium carbonate requires two K atoms to combine with one carbonate radical, so the formula is K_2CO_3 .

Several elements show more than one valency, including iron (Fe), copper (Cu) and nickel (Ni). The valency that the element shows depends on the particular circumstances – the other elements with which the element is combined – as well as on the conditions under which the reaction in which the compound is formed is carried out. More detailed knowledge of the chemistry of the element is required to predict which valency will be shown in any particular reaction. However, the names of the compounds formed are often adapted to help in deciding the valency state the element is in, in that particular compound, and hence to determine the correct formula.

Nomenclature (system for naming):

The suffixes -ous and -ic are used where an element shows two valencies. -ous always indicates the lower and -ic the higher valency. For example, iron with a valency of two ($FeCl_2$) is ferrous chloride, while iron with a valency of three ($FeCl_3$) is ferric chloride.

A modern approach to the problem of multiple valency is to indicate which valency is being used by inserting the appropriate Roman numeral after the name or symbol of the element concerned, e.g. Iron (II) chloride $Fe(II)Cl_2$, iron (III) chloride $Fe(III)Cl_3$

The suffix -ide is used to indicate that a compound is made up of two elements only. By convention, metals are written before non-metals in names and formulae, (e.g. magnesium oxide (MgO) has Mg valency of two and O valency two). The suffix '-ide' is also used for a small number of radicals, such as -OH hydroxide (calcium hydroxide ($Ca(OH)_2$) has Ca valency of two and OH valency of one).

The suffixes '-ite' and '-ate' are used where a compound contains more than two elements, one of which is oxygen. For two related compounds, the compound ending in '-ite' always contains less oxygen than that ending in '-ate' (e.g. sodium sulphite (Na_2SO_3) has Na valency of one, SO_3 valency of two), while sodium sulphate (Na_2SO_4) has Na valency of one and SO_4 valency of two). The suffixes '-ite' and '-ate' relate to the endings '-ous' and '-ic', which are used in the names of acids; '-ous' leads to '-ite' and '-ic' to '-ate' (e.g. sulphurous acid (H_2SO_3) gives sulphites $-SO_3$ while sulphuric acid (H_2SO_4) gives sulphates $-SO_4$; nitrous acid (HNO_2) gives nitrites $-NO_2$ while nitric acid (HNO_3) gives nitrates $-NO_3$).

The prefixes mono-, di-, tri-, tetra- and penta- are used in names to tell how many of a particular atom or radical are present:

- 'mono-' is one, e.g. carbon monoxide (CO)

- 'di-' is two, e.g. carbon dioxide (CO₂)
- 'tri-' is three, e.g. sulphur trioxide (SO₃)
- 'tetra-' is four, e.g. carbon tetrachloride (CCl₄)
- 'penta-' is five, e.g. phosphorus pentachloride (PCl₅)

The prefix 'per-' always denotes that there is more oxygen present in the compound than would normally be the case, e.g. hydrogen oxide (water) (H₂O) or hydrogen peroxide (H₂O₂)

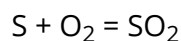
Simple equations

Consider a simple chemical reaction. When sulphur (a yellow solid element) burns in air, it combines with oxygen from the air, producing a colourless gas with a pungent, choking smell. This gas is called sulphur dioxide (SO₂).

This can be stated simply as: Sulphur reacts with oxygen to form sulphur dioxide. A further simplification can be made by replacing 'reacts with' by a + and 'to form' by with an equals sign. We then have:

Sulphur + (reacts with) oxygen = (to form) sulphur dioxide

This statement can be simplified even further by replacing the names of the chemicals with symbols and formulae (the molecules of oxygen, like those of most common elements that are gases, contain two atoms, but sulphur, like other solid elements, is assumed to consist of single atoms.) This gives:



This final statement represents the chemical equation for this reaction. It says that every sulphur atom involved reacts with one oxygen molecule to form one sulphur dioxide molecule.

Each side of the equation contains the same number of each type of atom present. This must always be the case since a chemical reaction involves only a rearrangement of atoms. Atoms do not appear or disappear; the equation must balance.

Limitations of chemical equations

Physical state: these simple equations contain no information about the physical state of the chemicals (whether they are solids, liquids or gases, whether they are pure substances or are dissolved in water or some other solvent), or whether the solutions are dilute or concentrated. Sometimes it is important to specify the physical state. For example, the reaction of hydrogen and oxygen to form water vapour is associated with the release of a certain amount of heat. If the water vapour is allowed to condense, the latent heat of vaporisation is released. Thus, if we are quoting the amount of heat released by the reaction of hydrogen and oxygen, the physical form of the water must be stated. This can be done as follows: $2\text{H}_2 + \text{O}_2 = 2\text{H}_2\text{O}(\text{g})$ and $2\text{H}_2 + \text{O}_2 = 2\text{H}_2\text{O}(\text{l})$ where 'g' and 'l' refer to the gaseous (vapour) and liquid states respectively. As written, the second reaction releases more heat than the first, by an amount equal to the latent heat of evaporation of water.

Reaction conditions: equations say nothing about the reaction conditions (whether heat must be used or pressure applied)

Heat: equations do not tell us whether heat is given out or absorbed during a chemical reaction

Rate of reaction: equations say nothing about the rate of the reaction (whether it is slow, fast or inherently violent) or whether a catalyst is necessary to make the reaction occur at a reasonable rate. A catalyst is a substance that alters the rate of a chemical reaction, but does not itself undergo a chemical change.



Organic substances

Chemistry is divided into the two branches of organic and non-organic chemistry. Organic chemistry deals with substances that contain the element carbon. Carbon atoms differ from other elements in that they can join together to form chains or rings.

Organic chemicals are divided into two classes:

- Aliphatic compounds: chains of carbon atoms
- Aromatic compounds: rings of six carbon atoms known as a benzene ring



Aliphatic hydrocarbons

Aliphatic hydrocarbons are a series of compounds containing only carbon and hydrogen. The simplest of the alkanes is methane, the main constituent of natural gas (CH_4). Although relatively unreactive as the gas methane, it is flammable in air concentrations between 5-15% by volume. It burns completely to produce carbon dioxide and water ($\text{CH}_4 + 2\text{O}_2 = \text{CO}_2 + 2\text{H}_2\text{O}$).

As the chains of carbon become longer and link to more hydrogen, the molecules become larger

and the physical properties change (boiling points, melting points and vapour densities, etc.).

In principle, the chains can extend indefinitely; the longer the chain the higher the boiling and melting points. Methane, ethane propane and butane are gases, whereas heavier molecules such as pentane are liquids. Hexadecane ($C_{16}H_{34}$) onwards are solids.

These compounds do share some similar characteristics:

- They form a series in which each differs by a $-CH_2$ unit
- They have similar chemical properties
- Their physical properties vary in a regular way

As the number of carbon atoms increases:

- Melting point, vapour density, boiling point and flashpoint increase
- Solubility in water and spontaneous ignition temperatures decrease

Another series of aliphatic compounds is known as the olefins or alkenes. The first member of the series is ethylene (C_2H_4), where there is a double bond between the two carbon atoms. Compounds containing these double bonds are known as unsaturated compounds. Unsaturated compounds are much more reactive; not only will they burn, they readily react with chlorine, hydrogen chloride, bromine and other reagents (a substance that causes a chemical reaction when added). The reactivity of ethylene makes it an important starting material in the production of synthetic materials.



Aromatic hydrocarbons

The simplest member of the aromatic hydrocarbons is benzene (C_6H_6). It has a unique structure consisting of six carbon atoms arranged in a ring, with alternating double and single bonds. The unique structure makes these substances much more stable. When these substances burn, oxidation is very difficult due to the high proportion of carbon, which causes significant quantities of thick black smoke.

The physical properties vary in a regular way as the molecular weight increases and the chemical properties remain similar. Hydrocarbons do not dissolve to any extent in water but will float as

their specific gravity is less than one. Some aromatic compounds are toxic; in some instances both as a vapour and through skin absorption, and many are carcinogens.



Alcohols

The structure of the commonest alcohol is similar to that of paraffins, but with one of the hydrogen atoms replaced by a hydroxyl group (O-H). The whole series of alcohols is formed by adding -CH_2 group to methanol.

As the molecular weight increases there is a general increase in the:

- Melting point
- Boiling point
- Flash point

This is accompanied by a decrease in:

- Solubility in water (the first few are very soluble and this gradually decreases)
- Spontaneous ignition temperature

All alcohols are less dense than water; insoluble alcohols float. Chemically, they are all similar; the first members being highly flammable, which may be used in fuels. Nearly all alcohols are toxic to a greater or lesser degree.



Polymers

Polymers

Many organic solids are polymers. The molecules they are composed of consist of many thousands of atoms. Chemists can synthesise polymer molecules by taking small molecules and linking them to create long chains. The starting product is sometimes known as the monomer, and the resulting material the polymer.

Some polymers soften and melt at certain temperatures (100-150°C); these are known as

thermoplastics.

Thermosetting plastics do not melt; they break down and char on heating. These long chains are linked together sideways by carbon-to-carbon bonds (crosslinked).

Many synthetic polymers produce more smoke than traditional materials and the rate of fire growth may be much greater. If plastics contain carbon, hydrogen and oxygen, the main toxic gas expected is carbon monoxide (CO); the amount of CO can increase if there is a lack of oxygen. Many plastics also contain nitrogen; these will give off organic nitriles, hydrogen cyanide (HCN) and nitrous oxide (NO₂). All of these are toxic, and where there is a well-ventilated fire, most of the nitrogen will convert to NO₂. Where chlorine is present, hydrogen chloride gas (HCl) will be present; all these gases are toxic and many corrosive.

The nature of the structure of polymers means that large amounts of black smoke will be produced, and thermoplastics will melt and form burning droplets.

The term 'self-extinguishing plastics' refers to plastics that, under normal conditions, will burn if subjected to a flame but will not propagate fire if the flame is removed. However, the presence of fire will allow them to burn quite readily.



Monomers

Monomers are reactive compounds capable of polymerisation. Some, like ethylene, do not polymerise very easily and need exactly the right conditions of temperature and pressure, perhaps with a catalyst. Others, like styrene, may polymerise by accident, due to the presence of impurities, water, heat or other causes; when this happens a great deal of heat may be given out. Some monomers have to be transported with an added polymerisation inhibitor to prevent the process occurring spontaneously.

As these monomers are mostly poor conductors of heat, the heat cannot get away easily, temperatures may rise and a fire may result. In addition to this problem, monomers are flammable and some are toxic. It is also possible that some monomers in bulk quantities could start to polymerise in a fire with the ensuing added hazard of the heat given out by the polymerisation reaction.



Physical properties of matter

In physics, matter can be defined as any substance that has mass and takes up space. A state of matter is one of the distinct forms that matter takes on. Four states of matter are observable in everyday life:

- Solid
- Liquid
- Gas
- Plasma

The physical state of the material will have a bearing on the risks it poses and on how it should be dealt with effectively at the incident. This refers both to the physical state of the material at ambient temperature and the state in which the material is either stored or transported. For example, gases are stored under pressure and if stored under sufficient pressure, they will liquefy.

Solid

In a solid the particles (ions, atoms or molecules) are closely packed together. The forces between particles are strong so that the particles cannot move freely but can only vibrate. As a result, a solid has a stable, definite shape, and a definite volume. Solids can only change their shape by force, as when broken or cut.

Solids need further assistance to move greater distances and in general are easier to contain. In cases of fire, the surface area of the solid is important to consider. In other words, powders will burn more easily than solid blocks of material.

The physical nature of the material also has consequences for its spread. For example, solid particulates in the form of dusts, fumes and smoke can be carried quickly by the air and present a risk to anyone in the path of dispersion

Liquid

A liquid is a nearly incompressible fluid that conforms to the shape of its container but retains a nearly constant volume independent of pressure. The volume is definite if the temperature and pressure are constant. When a solid is heated above its melting point, it becomes liquid. Intermolecular forces are still important, but the molecules have enough energy to move relative to each other and the structure is mobile. This means that the shape of a liquid is not definite but is determined by its container. The volume is usually greater than that of the corresponding solid, the best known exception being water. The highest temperature at which a given liquid can exist is called its critical temperature.

Liquids will flow with gravity when released and must therefore be contained safely to stabilise the

incident and prevent further risk to people, property and the environment. Volatile liquids will readily give off vapours (see vapour pressure) and this could present problems in creating flammable or noxious atmospheres.

Gas and vapour

A gas is a compressible fluid. Not only will a gas conform to the shape of its container but it will also expand to fill the container. A pure gas may be made up of individual atoms (e.g. a noble gas or atomic gas like neon), elemental molecules made from one type of atom (e.g. oxygen), or compound molecules made from a variety of atoms (e.g. carbon dioxide). A gas mixture would contain a variety of pure gases much like air. What distinguishes a gas from liquids and solids is the vast separation of the individual gas particles.

In a gas, the molecules have enough kinetic energy so that the effect of intermolecular forces is small, or zero for an ideal gas). The typical distance between neighbouring molecules is much greater than the molecular size. The physical behaviour of gases is described by the gas laws. A liquid may be converted to a gas by heating to the boiling point, or else by reducing the pressure.

At temperatures below its critical temperature, a gas is also called a vapour, and can be liquefied by compression alone without cooling. A vapour can exist in equilibrium with a liquid or solid, in which case the gas pressure equals the vapour pressure of the liquid or solid.

Properties, notable for those who have to manage incidents, include:

- Gases and vapours exert an increasing pressure on their containers as they are heated when a gas
- Vapour expands (perhaps as it escapes its container) and its temperature falls

Plasma

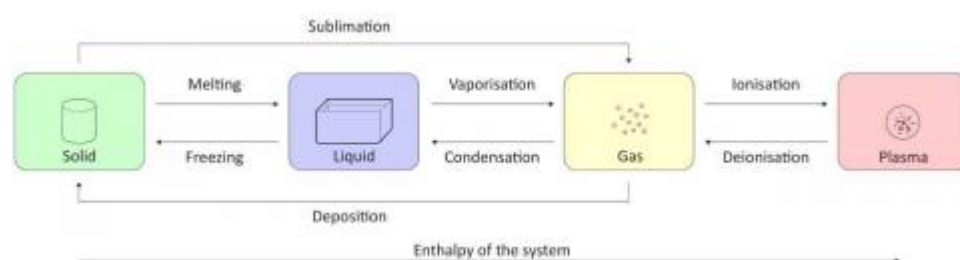
Like a gas, plasma does not have definite shape or volume. Unlike gases, plasmas are electrically conductive, produce magnetic fields and electric currents and respond strongly to electromagnetic forces. Positively charged nuclei swim in a 'sea' of freely-moving disassociated electrons, similar to the way such charges exist in conductive metal. In fact it is this electron 'sea' that allows matter in the plasma state to conduct electricity.

The plasma state is often misunderstood, but it is actually quite common. Lightning, electric sparks, fluorescent lights, neon lights, plasma televisions, some types of flame and the stars are all examples of illuminated matter in the plasma state.

A gas is usually converted to a plasma in one of two ways; either from a huge voltage difference between two points, or by exposing it to extremely high temperatures.

Phase transition

A change of state of any material due to temperature and/or pressure change is known as a phase transition. This is a physical change or reaction. Diagram 1 illustrates the key phase transitions:



Key phase transitions



Heat and temperature

The firefighter is mostly concerned with energy in the form of heat. Heat may be produced by a chemical change such as combustion, in which we say that chemical energy is released as heat energy. Mechanical energy or kinetic energy can also be converted into heat energy by friction (frictional heating of brake pads, for example).

Temperature is a measure of how hot something is, and is related to how quickly the constituent molecules are moving. Temperature also determines which way heat will flow. Heat can only move from something at a high temperature to something at a lower temperature.

The molecules that make up any substance, even a solid, are continually moving, although in a solid they vibrate around a fixed position. They also exert a force of attraction to each other, which becomes greater the closer they are together. The movement of molecules tends to spread them out while the attractive force, or force of cohesion, tends to bind them together.

If a solid is heated, heat energy is stored in the substance as the vibrational energy of the molecules. As more energy is stored, they vibrate faster and take up more space. At the same time, the temperature of the solid rises and thermal expansion occurs.

A temperature is reached when the molecules are vibrating so much that they break free of the rigid framework in which they have been held by the cohesive forces and become free enough to slide past each other, although they do not have complete freedom. At this point the solid melts and becomes a liquid.

Further heating causes the temperature to increase, and the energy is stored as kinetic energy of the molecules, which move with increasing rapidity until they are moving fast enough to overcome the cohesive forces completely. At this point, the liquid boils and turns into a gas (or more correctly, a vapour). If heat is taken away from a substance, kinetic energy of the molecules decreases and

the reverse processes occur.

Melting point

The temperature at which a solid turns into a liquid is called the melting point. If we are considering a liquid turning into a solid, the temperature is called the freezing point, though these two temperatures are the same for the same substance under the same conditions.

Boiling point

Boiling point is the temperature at which a liquid's vapour pressure equals atmospheric pressure. Low boiling point substances tend to be either gases or very volatile liquids at ambient temperature.

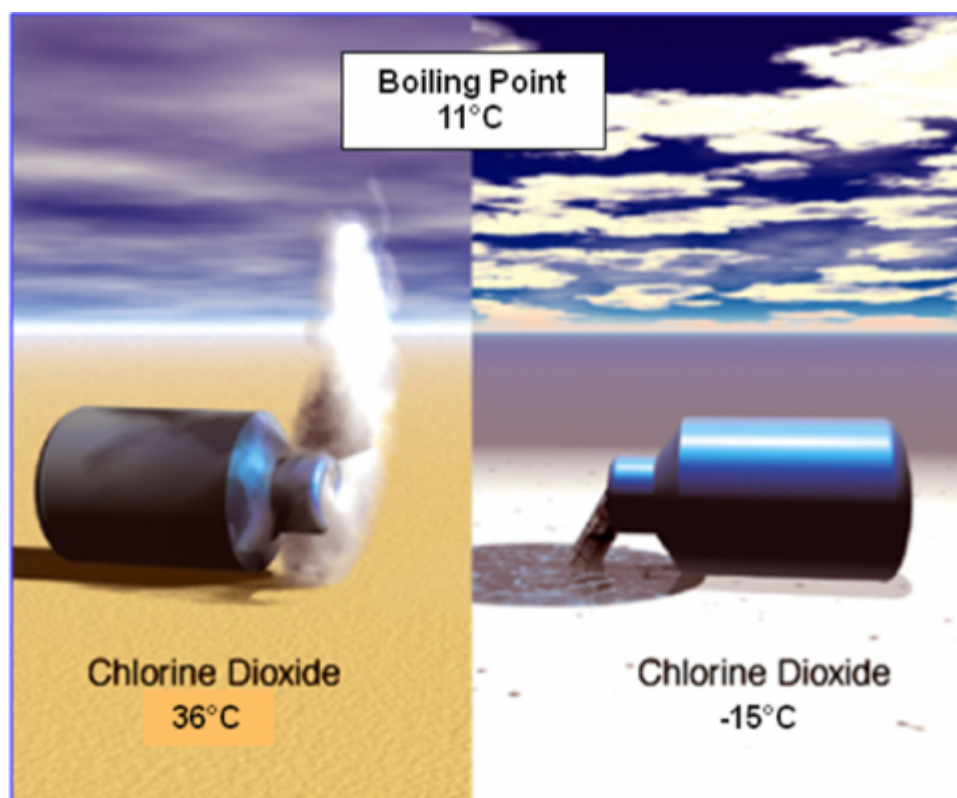


Image 1: Boiling point

Since energy is required to overcome the forces of cohesion when a substance melts or boils, the heat supplied during these processes does not cause a rise in temperature of the substance. Conversely, when a vapour condenses or a liquid solidifies, it gives up heat without any fall in temperature so long as the change is taking place. So melting or freezing for a given substance at a given atmospheric pressure, takes place at a certain temperature. The transition between water and ice, at normal atmospheric pressure, takes place at 0°C.

Boiling, for a given substance at a given atmospheric pressure takes place at another certain temperature. The transition between water and steam, at normal atmospheric pressure, takes place at 100°C.

Even at temperatures below boiling point, some molecules at the surface of the liquid may gain enough energy from colliding with other molecules for them to escape into the surrounding space as vapour. This process is called evaporation.

As an example, water in a saucepan is a liquid in an enclosed space; evaporation will take place

where there is air, even if the pan is not heated.

The evaporating molecules build up a pressure known as the vapour pressure. At the same time, some molecules will re-enter the liquid. For any given temperature below the boiling point there is a definite vapour pressure at which the number of molecules that escape is just balanced by the number that are recaptured by the liquid.

Boiling occurs when the vapour pressure has become equal to the surrounding atmospheric pressure: the pressure of air. Vapour then forms not only at the surface of the liquid, but also in the body of the liquid, and we see bubbles.

If the external pressure is increased, the vapour pressure at which boiling will take place is increased and so the temperature must increase. If the external pressure falls, the reverse is true and the temperature at which boiling occurs will be lower.

Vapour pressure

Vapour pressure is a measure of how easily a liquid evaporates or gives off vapours. It is displayed using the units of pressure such as Kilopascals (or kPa) or sometimes millimetres of mercury (mmHg) or in reference to atmospheric pressure (bar). The higher the vapour pressure the more vapour will be produced. Vapour pressure is also temperature-dependent with more vapours being produced as temperature rises. When the vapours being given off by a liquid pose a hazard (e.g. flammable vapours), they can be suppressed by covering the surface. Sheets, beads and firefighting foam are examples of materials that can be used for this purpose.

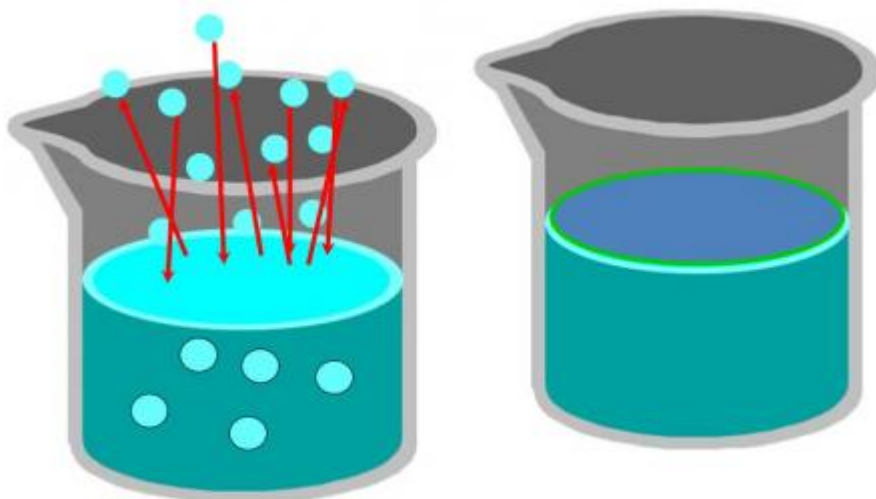


Image 2: Vapour pressure

Image 2 above illustrates that a small amount of vapour is given off at the surface of any pool of liquid. There is equilibrium between the vapour coming off (arrows up) and the vapour being re-absorbed into the liquid (arrows down). Vapours can be suppressed by covering the surface with a suitable material.

Flammability

With a flammable material, a region exists above its surface where the evaporating fuel vapour is mixed with air. At certain temperatures, this well-mixed region will become flammable; that is, the vapour concentration in air is above its lower limit of flammability, or lower explosive limit (LEL). The lowest temperature at which this occurs is called the flash point; the temperature at which the application of an ignition source will cause a flame to flash across the surface of the material. This is a premixed flame moving through the vapour/air mixture but, just above the flashpoint, it burns out, or self-extinguishes, because it has consumed the entire vapour. If heating continues, a temperature will be reached at which ignition of the vapours will lead to a flash, followed by the development of a sustained diffusion flame at the surface flame. This temperature is known as the fire point, the lowest temperature at which the rate of supply of fuel vapours (by evaporation) can sustain the flame.

The lowest temperature at which the substance will ignite without a flame or ignition source is known as the auto ignition temperature (AIT). Certain materials may react with oxygen at room temperature. Compounds containing a double carbon bond, such as linseed oil, are prone to this, but any organic material in bulk quantities may be suspect, especially if it has been stored at elevated temperatures. Sometimes the activity of bacteria on certain organic materials can cause a rise in temperature that will eventually lead to active combustion.

Smouldering only occurs in porous materials that form a solid carbonaceous char when heated. This is the combustion of a solid in an oxidising gas without the appearance of flame. The process is slow and can produce large volumes of smoke.

Flash point

Flammable liquids have a flash point of 60°C or lower. Liquids that have a flash point above 60°C are termed combustible. Highly flammable or extremely flammable liquids have flash points lower than 23°C, which is close to normal ambient temperatures. This means that an ignition source (electrical spark, static electricity, naked flame etc) can trigger a fire where there are flammable liquids present. However the likelihood also depends on the flammable limits of the flammable liquid.



Flammable limit range

The flammable limit range of a substance is the range of concentrations of the substance in air that are flammable. Flammable limits are also called flammability limits or explosive limits. The lower flammable limit (LFL) or lower explosive limit (LEL) describes the leanest mixture that is still flammable, while the upper flammable limit (UFL) or upper explosive limit (UEL) gives the richest flammable mixture. Increasing the fraction of inert gases in a mixture raises the LFL and decreases the UFL. Vapour monitoring at an incident scene can determine if the vapour cloud is within the flammable range. If the values found are above the UFL, then there will be a risk of ignition when the vapour has further dispersed so that the concentration falls below the UFL.

Substances with wider flammable ranges are more hazardous than those with narrow ranges.

Isopropyl alcohol for example, has a flammable range of 2-12 per cent in air whereas acetylene has a flammable range of 2.5-100 per cent, making vapour clouds of acetylene much more likely to be flammable in air.

Ignition (auto-ignition) temperature

The auto-ignition temperature (sometimes called the kindling point) refers to the temperature at which the substance will ignite in the absence of a source of ignition such as a spark or flame. Auto-ignition temperature decreases as the pressure increases or where oxygen concentration increases. An analogy can be given of a diesel-engine powered vehicle where the mixture of fuel and air is compressed sufficiently for the diesel to self-ignite and power the vehicle.

Pyrophoric substances such as silanes and phosphorus have low auto-ignition temperatures.



Density

Understanding density is extremely important for a firefighter. For example, the density of a gas or vapour determines whether it will tend to rise or sink in air, and therefore whether it will be found in the greatest concentrations at the upper or lower levels in a building. The density of a burning liquid partly decides whether it is possible to cover it with water to extinguish the fire, or whether the firefighter will need to use foam or other another extinguishing medium. However, another important factor is how well the burning liquid mixes with water, a property known as miscibility.

The density of a substance is its mass per unit of volume. Density may be calculated by dividing the mass of a body by the volume.

Volume or in symbols V

$$\text{Density} = \frac{\text{Mass}}{\text{Volume}}$$

or in symbols

$$D = \frac{M}{V}$$

This means that:

$$M = D \times V$$

or

$$V = \frac{M}{D}$$

The SI unit of density is kilograms per cubic metre (kg/m^3) or grammes per cubic centimetre (g/cm^3)

Water has a density of 1000 kg/m^3 whereas mercury has a density of $13,600 \text{ kg/m}^3$; this means that mercury is 13.6 times denser than water. If a substance does not mix with water and it is denser than water it will sink, and those lighter will float.

The term specific gravity or relative density is sometimes used to give a measure of density. The

relative density of a substance is the ratio of the mass of any volume of the substance to the mass of an equal amount of water.

$$\text{Relative density} = \frac{\text{Mass of any volume of the substance}}{\text{Mass of an equal volume of water}}$$

No specific units are associated with relative density, merely a ratio.

Gases and vapours have very low densities compared with liquids and solids. At normal temperatures and pressures, a cubic metre of water has a mass of about 1000 kg and a cubic metre of air has a mass of around 1.2 kg. The density of a gas or vapour (known as vapour density, usually abbreviated to VD) is given in relation to the density of an equal volume of hydrogen, air or oxygen under the same conditions of temperature and pressure.

For fire and rescue service purposes the densities of gases and vapours are compared with that of air. The reference gas should always be given to avoid confusion; for example, the vapour density of methane is 0.556 (air = 1).

Unlike many liquids, all gases and vapours are completely miscible. However, differences in density will affect the way in which they mix. For example, methane (the main component of natural gas) is a light gas with a vapour density of about 0.5 (air = 1). If methane is leaking into a room from a faulty gas appliance, it will rise to the ceiling, entraining (mixing with) air as it rises to form a layer of methane and air mixture that will eventually descend to the level of the leak (the concentration of methane in the layer will increase as the layer descends). On the other hand, a leak of propane from a propane cylinder will produce a layer of propane/air mixture at low level in a similar fashion, as the vapour density of propane is roughly 1.5 (air = 1).

All heavier-than-air gases, like carbon dioxide (VD 1.53, air = 1) and petrol vapour (VD 2.5, air = 1) will accumulate in low places such as wells and cellars, creating dangers of asphyxia (suffocation) as well as of fire or explosion in the case of flammable vapours.

Differences in density can also be created by changes in temperature. Increases in temperature causes expansion and a lowering of density.

Most gases are heavier than air. Gases that are lighter than air can be remembered based on the following mnemonics HA HA MICE or 4HMEDIC ANNA:

- H Helium (He)
- A Acetylene (C₂H₂)
- H Hydrogen (H₂)
- A Ammonia (NH₃)
- M Methane (CH₄)

- I Illuminating gases (e.g. neon Ne)
- C Carbon monoxide (CO)
- E Ethane and ethylene (C₂H₆ and C₂H₄)
- 4H Hydrogen (H₂), Helium (He), Hydrogen Cyanide (HCN), Hydrogen Fluoride (HF)
- M Methane (CH₄)
- E Ethane and ethylene (C₂H₆ and C₂H₄)
- D Diborane (B₂H₆)
- I Illuminating gases
- C Carbon Monoxide (CO)
- A Acetylene (C₂H₂)
- N Neon (Ne)
- N Nitrogen (N₂)
- A Ammonia (NH₃)

Solubility and miscibility

Soluble refers to a substance (solid, liquid or gas) that can dissolve in another solid, liquid or gas. In plain language, dissolve means one substance becomes incorporated into another (forming a homogeneous mixture). Solubility involves a saturation point, at which the substances involved can no longer dissolve any further and a mass begins to form.

In contrast, miscibility is where substances mix in all proportions, forming a homogeneous solution. Immiscible means that the liquids do not mix with each other; oil and water are examples. It is possible to shake up the liquids and get them to mix temporarily, but they soon separate. Separating immiscible liquids is usually simple to achieve. Miscible liquids are harder to separate as they dissolve in each other. Miscible liquids are often separated using fractional distillation, which is possible as miscible liquids have different boiling points.

For example, if water and alcohol are mixed together, water and alcohol can continue to be added and mixed and the resulting liquid will continue to remain in liquid form. By contrast, if you dissolve

sugar in water, the sugar will keep dissolving until it reaches saturation, but additional sugar won't dissolve; it will remain a mass in the sugary solution.



Solubility and miscibility

Soluble refers to a substance (solid, liquid or gas) that can dissolve in another solid, liquid or gas. In plain language, dissolve means one substance becomes incorporated into another (forming a homogeneous mixture). Solubility involves a saturation point, at which the substances involved can no longer dissolve any further and a mass begins to form.

In contrast, miscibility is where substances mix in all proportions, forming a homogeneous solution. Immiscible means that the liquids do not mix with each other; oil and water are examples. It is possible to shake up the liquids and get them to mix temporarily, but they soon separate.

Separating immiscible liquids is usually simple to achieve. Miscible liquids are harder to separate as they dissolve in each other. Miscible liquids are often separated using fractional distillation, which is possible as miscible liquids have different boiling points.

For example, if water and alcohol are mixed together, water and alcohol can continue to be added and mixed and the resulting liquid will continue to remain in liquid form. By contrast, if you dissolve sugar in water, the sugar will keep dissolving until it reaches saturation, but additional sugar won't dissolve; it will remain a mass in the sugary solution.

Water solubility/miscibility

Water solubility is the ability of a material (gas or solid) to dissolve in water (Water miscibility refers to another liquid mixing with water).

Solubility is expressed in a figure of g/100 ml water. Materials can be insoluble, sparingly soluble or soluble. This has implications for the nature and management of the incident in terms of containing pollution, fighting fires and the subsequent clean-up.

Soluble/miscible materials (such as acids) may be more easily dispersed in the marine and aquatic environments, but this solubility can pose threats to aquatic life. The release of quantities of soluble contaminant materials into the watercourse is very likely to have an adverse effect.

Sparingly soluble or insoluble/immiscible materials (e.g. petrol) may be spread by flowing water. This could result in vapours or fumes being transported some distance away from the incident. However, as explained above insoluble materials that float on water can be contained by using booms.

Decontaminating people and equipment of soluble materials can be carried out with water alone, otherwise detergents and/or physical removal will be required.

Chemical	Miscible with water	Specific gravity	Behaviour in water
Petrol	No	0.7	Floats
Trichloroethane	No	1.3	Sinks
Sulphuric acid	Yes	1.8	Mixes

Table 3 Behaviour due to miscibility and specific gravity

Partition constant or partial coefficient (water/octanol)

This gives an indication of relative solubility of a material (compound) in water and in octanol. These two liquids do not mix (are immiscible) and materials or compounds that are more likely to dissolve in octanol means the compound will also not mix with water and is said to be hydrophobic (literally, fear of water).

The value is expressed as a logarithmic value (e.g. $\log P_{ow}$). Negative values indicate that the compound is hydrophilic (likes water). Higher positive values indicate the substance is hydrophobic.

The hydrophobicity of a compound can give scientists an indication of how easily a compound might be taken up in groundwater to pollute waterways and its toxicity to animals and aquatic life.

Materials that are hydrophobic are more difficult to clean-up. Decontamination cannot be carried out with water alone, as water itself will not remove the material from chemical protective suits or equipment.



Energy, work and power

Energy is defined as the capacity to do work and is measured in units called joules. One joule is the amount of energy exerted when a force of one newton is applied over a displacement of one metre. Energy is never created or destroyed, it simply changes form.

Work is the application of a force over a distance. Work is done on an object when you transfer energy to that object. If one object transfers (gives) energy to a second object, then the first object does work on the second object. . Work is also measured in joules; in the case of movement, work happens when force acts on an object to move it.

Power measures how quickly work is done. This is the rate at which energy is converted from one form to another and is measured in watts. One watt is one joule of energy radiated or dissipated for one second.

Types of energy:

- Potential – stored energy (including gravitational, elasticity etc.)
- Kinetic – energy of movement
- Nuclear – energy locked in the nuclei
- Chemical – energy stored in chemical compound
- Electrical – movement of tiny sub-atomic charged particles
- Light – electromagnetic energy i.e. light from sun (infrared)
- Heat – vibration or movement of molecules (thermal energy)
- Sound – pressure waves produced by vibrations at source
- Magnetic – energy in magnets and electromagnets



Motion

When an object moves from a starting point to another point, its average speed travelled will be the distance covered divided by the time taken. That is:

Speed = distance travelled

time taken

Time taken = distance travelled

speed

Distance travelled = speed x time taken

It has units of metres per second (m/s), or if distance is measured in miles and time in hours, the units will be miles per hour (mph).

Although people tend to use speed and velocity interchangeably, there is a difference between

them. Velocity has a direction associated with it, and is called a vector quantity.

- Speed is the rate of change
- Velocity is the rate of change of displacement
- Acceleration is the rate of change of velocity

The units of speed and velocity are m/s, while those for acceleration are m/s^2 .

Momentum and force

Momentum is the product of mass and velocity and is measured in kg.m/s .

- Momentum = mass x velocity

Force is the product of mass and acceleration and the units are kg.m/s^2 known as the Newton (N).

- Force = mass x acceleration

The force of gravity provides an acceleration that acts on everything. At the earth's surface, anything that is dropped will accelerate, under gravity, at 9.81 m/s^2 (this quantity is often referred to by the symbol g). It also determines the forces that are responsible for the movement of hot, buoyant gases in fires.

The weight of a body is a measure of how strong the force of gravity is on an object. In everyday speech, we usually use mass and weight interchangeably, but just as the words speed and velocity have different meanings, so do weight and mass.



Chemical properties

The pH of an acid or base is not an indication of its strength: for example, weak acids can still show low value pH values. It is therefore important to consider the strength and concentration of acids and bases as well as the pH value.

The terms strength and concentration are frequently confused when used in the context of acids/bases or alkalis that dissociate into ions to a limited extent when dissolved in water. The confusion is caused by the fact that in common usage strength and concentration are interchangeable terms.

However, when referring to acids or bases (also called alkalis), the terms strong or weak refer to the relative amount of substance present in ionic form compared to the amount of the same substance present in (non-ionic) molecular form. An acid or base is strong if it is entirely or almost entirely present in solution in ionic form cations ($^+$) and anions ($^-$). Hydrochloric acid (HCl) is a strong acid because in water, it dissociates almost entirely as H^+ and Cl^- ions. Acetic acid (vinegar) on the other hand, is only slightly dissociated into ions when dissolved in water. Most of the acetic acid dissolved in water is present in the non-ionic molecular form.

This distinction matters. Stronger acids or bases are more reactive and corrosive and therefore pose more of a hazard to the responders, requiring measures to be taken to reduce the risks posed.

Table 4 Acid examples

Examples of strong acids	Examples of weak acids
Hydrochloric acid (HCl) Hydrobromic acid (HBr) Nitric acid (HNO_3) Sulphuric or sulfuric acid (H_2SO_4) Perchloric acid ($HClO_4$)	Organic acids such as carboxylic acids ($RCOOH$) of which acetic acid or vinegar (CH_3COOH) is a very common example. Hydrofluoric acid (HF) – note that although HF is a weak acid, it still poses very serious hazards. Hydrocyanic acid (HCN). Carbonic acid (H_2CO_3). Sulphurous or sulfurous acid (H_2SO_3). Nitrous acid (HNO_2).

Table 5 Bases examples

Examples of strong bases	Examples of weak bases
Potassium hydroxide (KOH) Barium hydroxide ($Ba(OH)_2$) Sodium hydroxide (NaOH) Calcium hydroxide ($Ca(OH)_2$) Lithium hydroxide (LiOH) Magnesium hydroxide ($Mg(OH)_2$)	Aniline, $C_5H_5NH_2$. Ammonia, NH_3 . Methylamine, CH_3NH_2 . Pyridine, C_5H_5N . Sodium carbonate $NaCO_3$.

Table 6 Examples of typical pH products and their pH value

Acidic	0	Hydrochloric acid
	1	
	2	Coffee
	3	Orange juice
	4	Beer
	5	
	6	Urine
Neutral	7	Pure water
Alkaline	8	Blood
	9	Baking soda
	10	Milk of magnesia
	11	
	12	
	13	
	14	Caustic soda

Toxic products of combustion

When a material burns (combusts) it undergoes a chemical reaction that usually involves atmospheric oxygen. This results in products of combustion, some of which may pose particular hazards to health. Hydrocarbons and many common materials such as paper, wood and plastic contain carbon. When burned they produce oxides of carbon: carbon dioxide and carbon monoxide. If smoke is produced in a fire, it will contain particulates, usually of carbon. As carbon monoxide is a toxic gas it can be assumed that all smoke is toxic and products of combustion will either be toxic or asphyxiant.

Particular concern needs to be taken when the products of combustion are corrosive or acutely toxic. These tend to be produced when the chemical products undergoing combustion contain certain elements such as halogens (fluorine, chlorine, bromine, iodine), metals and particularly alkali

metals (lithium, potassium, sodium) or certain non-metallic elements (specifically nitrogen, sulphur, phosphorus, arsenic) in their compound structure. Compounds containing these elements are commonly found in products such as detergents, fertilisers and pesticides. If in any doubt as to whether fumes are likely to contain these compounds, consult the safety data sheet (SDS) or seek further advice from the manufacturer or from a scientific adviser.

Chlorinated hydrocarbons, for example, produce hydrochloric acid (HCl) fumes when they decompose at high temperatures (when exposed to a fire or hot surfaces). If HCl fumes are inhaled by responders, this will lead to acid forming in the lungs, affect their working could lead to more serious health effects such as pulmonary oedema (which can occur up to 48 hours after exposure and can result in death). Anyone who is suspected of having breathed in toxic or corrosive fumes should seek immediate medical attention.

Toxicity

Toxicity is the intrinsic capacity of a chemical to adversely affect an organism.

The level of toxicity is distinguished in legislation according to the United Nations Globally Harmonised System for classification and labelling (GHS) system and can be highly-toxic, toxic, harmful, etc., based on the lethal dose. The most common ratings concern acute toxicity (a short-term but potentially high exposure). Substances can also have chronically toxic effects (from repeat and cumulative exposure over time). The differences between acute and chronic toxicity are reflected in the criteria for classifying products for transport and supply. For example, cancer is much more likely to develop from repeated occupational exposure to a carcinogen than a one-off acute exposure.

The dose-effect relationship is the relationship between dose and effect on the individual level. An increase in dose may increase the intensity of an effect, or a more severe effect may result. Some toxic effects, such as death or cancer, are not graded but are 'all or none' effects.

A dose is often expressed as the amount of a substance entering an organism (such as a person) and is expressed in units such as mg/kg body weight. A dose threshold is a dose level below which no observable effect occurs. Thresholds are thought to exist for certain effects, like acute toxic effects; but not for others, like carcinogenic effects or exposure to radiation. The lethal dose (LD₅₀ or LC₅₀) is the dose causing 50 percent death in an animal population. LD₅₀ is given as a measure of the acute toxicity of the chemical substance. The lower the LD₅₀ the higher the acute toxicity. There is no necessary correlation between acute and chronic toxicity.

Eco-toxicity

Further information on eco-toxicity and how to interpret the various values such as biochemical oxygen demand (BOD), toxicity, bioaccumulation and persistence can be found in the Environmental Protection Handbook.

Dispersal of chemicals in water

Table 9 Predicting dispersal of chemicals in water

Boiling point	Vapour pressure	Specific gravity	Solubility	Expected behaviour in water
Below ambient	Very high	Any	Insoluble	All liquid will rapidly boil from surface of water.
Below ambient	Very high	Below that of water	Low or partial	Most liquid will rapidly boil off but some will dissolve. Some of the dissolved liquid will evaporate.
Below ambient	Very high	Any	High	At least 50 per cent will rapidly boil off; the rest will dissolve. Some of the dissolved liquid will evaporate later.
Above ambient	Any	Below that of water	Insoluble	Liquid will float, forming a slick. Those with significant vapour pressure will evaporate over time.
Above ambient	Any	Below that of water	Insoluble	Liquid will float but will dissolve over time. Those with significant vapour pressure may simultaneously evaporate.

Boiling point	Vapour pressure	Specific gravity	Solubility	Expected behaviour in water
Above ambient	Any	Below that of water	Low or partial	Liquids will rapidly dissolve in water up to the limit (if any) of their solubility. Some evaporation may take place over time if vapour pressure is significant.
Above ambient	Any	Below that of water	High	Liquids will rapidly dissolve in water up to the limit (if any) of their solubility. Some evaporation may take place over time if vapour pressure is significant.
Above ambient	Any	Near that of water	Insoluble	Difficult to assess. May float on or beneath surface or disperse through the water column. Some evaporation may occur from surface over time if vapour pressure is significant.

Boiling point	Vapour pressure	Specific gravity	Solubility	Expected behaviour in water
Above ambient	Any	Near that of water	Low or partial	Will behave as 'insoluble' chemicals above at first and eventually dissolve. Some evaporation may take place over time.
Above ambient	Any	Any	High	Will rapidly dissolve up to the limit (if any) of their solubility. Some evaporation may take place over time.
Above ambient	Any	Above that of water	Insoluble	Will sink to the bottom and stay there. May collect in deep water pockets.
Above ambient	Any	Above that of water	Low or partial	Will sink to the bottom and then dissolve over time.
Above ambient	Any	Above that of water	High	Will rapidly dissolve up to the limit (if any) of their solubility. Some evaporation may take place from the surface over time if vapour pressure is significant.



Chemical reactivity

Whether two (or more) chemicals will react when they come into contact will depend on the properties of the chemicals concerned as well as some other factors such as:

- Temperature – an increase in temperature increases the rate of reaction
- Concentration or pressure – the higher the concentration or pressure, the faster the rate of reaction
- Surface area – gases and liquids (having the greater area for reaction) react more readily than solids
- The energy or heat content (enthalpy) needed to initiate the reaction
- Whether the net result of the reaction is to give out more heat than it consumes (exothermic) or to absorb more heat than is given out (endothermic) – exothermic reactions are more hazardous and more likely to occur

Chemical reactivity is therefore usually predictable, based on the chemicals involved and the circumstances of them mixing.

Common reactions include:

Acid + base = salt (soluble) + water

e.g. $\text{HCl} + \text{NaOH} = \text{NaCl} + \text{H}_2\text{O}$

Acid + insoluble carbonate = salt + water + carbon dioxide

e.g. $2\text{HNO}_3 + \text{CaCO}_3 = \text{Ca}(\text{NO}_3)_2 + \text{H}_2\text{O} + \text{CO}_2$

Oxidiser + organic compound = fire + water + carbon dioxide + other products

e.g. $14\text{KMnO}_4 + 4\text{C}_3\text{H}_5(\text{OH})_3 = 7\text{K}_2\text{CO}_3 + 7\text{Mn}_2\text{O}_3 + 5\text{CO}_2 + 16\text{H}_2\text{O}$

Concentrated acid + organic compound = dehydrated organic compound + water + concentrated acid

e.g. $\text{C}_{12}\text{H}_{22}\text{O}_{11} + \text{H}_2\text{SO}_4 + 1/2\text{O}_2 = 11\text{C} + \text{CO}_2 + 12\text{H}_2\text{O} + \text{SO}_2$

Base + organic compound = soap + water

e.g. caustic soda (NaOH) + stearic acid = sodium stearate + water

Other specific types of reaction pose particular hazards:

Polymerisation reactions

Polymerisation reactions involve linking molecules (monomers) together chemically. In controlled conditions, polymerisation is safe; in uncontrolled conditions it can lead to a runaway reaction resulting in an increase in heat, volume and pressure with the risk that containers of these materials can suddenly burst releasing the material and/or toxic gases. Examples include vinyl chloride, 1-toluene diisocyanate (TDI) and epichlorohydrin.

The reaction can be triggered by heat, pressure or the presence of contamination or a catalyst (a substance that initiates a chemical reaction without being changed itself).

Reactions with water

Some substances react with water to produce secondary products that are hazardous. Possible reactions include the production of flammable gas, toxic gas or a large amount of energy.

Examples include sodium that, when reacting with water, produces hydrogen gas and calcium carbide. The latter reacts with water to produce acetylene: $\text{CaC}_2 + 2\text{H}_2\text{O} = \text{C}_2\text{H}_2 + \text{Ca(OH)}_2$.

Table 7 Examples of water reactive materials

Material	Hazard of reaction
Sulphuric acid	Heat
Potassium, sodium	Flammable hydrogen gas
Calcium carbide	Corrosive and flammable products
Aluminium chloride	Hydrochloric acid and heat
Sodium peroxide	Oxygen and heat

Reactions with air (pyrophoric substances)

Pyrophoric substances ignite spontaneously in air often liberating vast amounts of energy and causing combustion which can also lead to noxious products of combustion. They are sometimes also water-reactive. Examples of pyrophoric substances include white or yellow phosphorus.

Reaction of metals

Three quarters of all elements are metals. In chemistry terms a metal is a substance that can lose electrons to form positive ions. Generally, all metals share a group of properties:

- Most metals are malleable and ductile (antimony being an exception that is very brittle)
- All (except mercury) are solids at room temperature, but melting points vary
- They form positive ions
- They are good conductors of heat/electricity
- They form alloys
- The oxides and hydroxides are basic (can be alkali in water solutions)
- Most dissolve in mineral acids (generally releasing hydrogen)

Metals range from extremely reactive (e.g. potassium (K)) to inert (e.g. gold (Au)). Metals can be

arranged in an 'activity series'; at the top of the series the metals react very vigorously and at the bottom they react slowly or not at all.

It is important to understand how metals react with water or steam, as water is the most common firefighting medium. In some instances, the application of water may be dangerous.

Table 8 Examples of the Reactivity of metals

Metal	Symbol	Occurence	Reaction with water
Potassium	K	Never found uncombined	Reacts with water to emit hydrogen
Sodium	Na		
Barium	Ba		
Strontium	Sr		
Calcium	Ca		
Magnesium	Mg	Rarely found uncombined.	Hot metals decompose water and burning metals decompose steam.
Aluminium	Al		
Chromium	Cr		
Manganese	Mn		
Zinc	Zn		
Cadmium	Cd		
Iron	Fe		
Cobalt	Co		Very little reaction unless at white heat.
Nickel	Ni		
Tin	Sn		
Lead	Pb		
*Hydrogen	H		
Bismouth	Bi	Sometimes found uncombined with other elements	Inactive with water or steam
Copper	Cu		
Mercury	Hg		
Silver	Ag		
Platinum	Pt	Found uncombined with other elements	
Gold	Au		
*Although not a metal, hydrogen is included as it also forms a positive ion.			
Some metallic dusts can burn or explode spontaneously when dispersed in the air.			

Neutralisation reactions

The most common example of neutralisation is reacting an acid with a weak base (alkali) such as soda ash (sodium carbonate).

The advantage of neutralisation is that the corrosivity of the material being neutralised is reduced, making the material (and the waste products) easier to handle.

However, distinct disadvantages of neutralisation reactions may outweigh the advantages.

For example, to neutralise a strong acid requires either a strong base or large quantities of a weak base such as soda ash. Adding soda ash to acid creates carbon dioxide and is therefore gives a frothy reaction. Neutralising concentrated acids or bases could lead to a violent reaction which becomes more violent as the concentration increases. This can be very dangerous and should only be attempted following specialist advice.

In dealing with small residues of acid after other measures (such as pumping into a separate container or absorbing in an inert material) have been taken to remove the bulk of the acid, spill neutralisation may be considered.

Concentration

The concentration of solutions can be expressed as molarity (M) or moles (a unit used to express the amount of a substance) or by mass per litre of solution. Where expressed in weight, for example grammes per litre of solution, this can also be expressed as a percentage concentration.

Molarity = mols of solute/ litres of solvent (water)

The concentration of a solution greatly influences the rate of chemical reaction. Higher concentrations mean faster reactions. More concentrated solutions (e.g. acids or bases) are therefore more reactive and more hazardous.

Dilution of concentrated acids or bases with water should only be considered following specialist advice. This is because the concentrated acid or base will react with the water added producing heat which will in turn speed up further reactions. Dilution of concentrated acids or bases can be safely carried out by adding the acid or base to water and not the other way around. Clearly in the event of a spill of an acid or base, this is not practicable.



Toxic products of combustion

When a material burns (combusts) it undergoes a chemical reaction that usually involves atmospheric oxygen. This results in products of combustion, some of which may pose particular hazards to health. Hydrocarbons and many common materials such as paper, wood and plastic contain carbon. When burned they produce oxides of carbon: carbon dioxide and carbon monoxide. If smoke is produced in a fire, it will contain particulates, usually of carbon. As carbon monoxide is a toxic gas it can be assumed that all smoke is toxic and products of combustion will either be toxic or asphyxiant.

Particular concern needs to be taken when the products of combustion are corrosive or acutely toxic. These tend to be produced when the chemical products undergoing combustion contain certain elements such as halogens (fluorine, chlorine, bromine, iodine), metals and particularly alkali metals (lithium, potassium, sodium) or certain non-metallic elements (specifically nitrogen, sulphur, phosphorus, arsenic) in their compound structure. Compounds containing these elements are commonly found in products such as detergents, fertilisers and pesticides. If in any doubt as to whether fumes are likely to contain these compounds, consult the safety data sheet (SDS) or seek further advice from the manufacturer or from a scientific adviser.

Chlorinated hydrocarbons, for example, produce hydrochloric acid (HCl) fumes when they decompose at high temperatures (when exposed to a fire or hot surfaces). If HCl fumes are inhaled by responders, this will lead to acid forming in the lungs, affect their working could lead to more serious health effects such as pulmonary oedema (which can occur up to 48 hours after exposure and can result in death). Anyone who is suspected of having breathed in toxic or corrosive fumes should seek immediate medical attention.

Toxicity

Toxicity is the intrinsic capacity of a chemical to adversely affect an organism.

The level of toxicity is distinguished in legislation according to the United Nations Globally Harmonised System for classification and labelling (GHS) system and can be highly-toxic, toxic, harmful, etc., based on the lethal dose. The most common ratings concern acute toxicity (a short-term but potentially high exposure). Substances can also have chronically toxic effects (from repeat and cumulative exposure over time). The differences between acute and chronic toxicity are reflected in the criteria for classifying products for transport and supply. For example, cancer is much more likely to develop from repeated occupational exposure to a carcinogen than a one-off acute exposure.

The dose-effect relationship is the relationship between dose and effect on the individual level. An increase in dose may increase the intensity of an effect, or a more severe effect may result. Some toxic effects, such as death or cancer, are not graded but are 'all or none' effects.

A dose is often expressed as the amount of a substance entering an organism (such as a person) and is expressed in units such as mg/kg body weight. A dose threshold is a dose level below which no observable effect occurs. Thresholds are thought to exist for certain effects, like acute toxic effects; but not for others, like carcinogenic effects or exposure to radiation. The lethal dose (LD₅₀ or LC₅₀) is the dose causing 50 percent death in an animal population. LD₅₀ is given as a measure of the acute toxicity of the chemical substance. The lower the LD₅₀ the higher the acute toxicity. There is no necessary correlation between acute and chronic toxicity.

Eco-toxicity

Further information on eco-toxicity and how to interpret the various values such as biochemical oxygen demand (BOD), toxicity, bioaccumulation and persistence can be found in the Environmental Protection Handbook.

Dispersal of chemicals in water

Table 9 Predicting dispersal of chemicals in water

Boiling point	Vapour pressure	Specific gravity	Solubility	Expected behaviour in water
Below ambient	Very high	Any	Insoluble	All liquid will rapidly boil from surface of water.
Below ambient	Very high	Below that of water	Low or partial	Most liquid will rapidly boil off but some will dissolve. Some of the dissolved liquid will evaporate.
Below ambient	Very high	Any	High	At least 50 per cent will rapidly boil off; the rest will dissolve. Some of the dissolved liquid will evaporate later.
Above ambient	Any	Below that of water	Insoluble	Liquid will float, forming a slick. Those with significant vapour pressure will evaporate over time.
Above ambient	Any	Below that of water	Insoluble	Liquid will float but will dissolve over time. Those with significant vapour pressure may simultaneously evaporate.

Boiling point	Vapour pressure	Specific gravity	Solubility	Expected behaviour in water
Above ambient	Any	Below that of water	Low or partial	Liquids will rapidly dissolve in water up to the limit (if any) of their solubility. Some evaporation may take place over time if vapour pressure is significant.
Above ambient	Any	Below that of water	High	Liquids will rapidly dissolve in water up to the limit (if any) of their solubility. Some evaporation may take place over time if vapour pressure is significant.
Above ambient	Any	Near that of water	Insoluble	Difficult to assess. May float on or beneath surface or disperse through the water column. Some evaporation may occur from surface over time if vapour pressure is significant.
Above ambient	Any	Near that of water	Low or partial	Will behave as 'insoluble' chemicals above at first and eventually dissolve. Some evaporation may take place over time.

Boiling point	Vapour pressure	Specific gravity	Solubility	Expected behaviour in water
Above ambient	Any	Any	High	Will rapidly dissolve up to the limit (if any) of their solubility. Some evaporation may take place over time.
Above ambient	Any	Above that of water	Insoluble	Will sink to the bottom and stay there. May collect in deep water pockets.
Above ambient	Any	Above that of water	Low or partial	Will sink to the bottom and then dissolve over time.
Above ambient	Any	Above that of water	High	Will rapidly dissolve up to the limit (if any) of their solubility. Some evaporation may take place from the surface over time if vapour pressure is significant.



Heat, temperature and combustion

Heat is one form of energy that can be produced by chemical means, such as by burning coal or oil, or by mechanical means such as friction. Passing a current through an electrical resistance also produces heat (for example in an electric fire). Heat can be converted into other forms of energy such as into pressure energy in a steam boiler. It is also possible to convert heat back into chemical energy or electrical energy.

The amount of heat energy in a body cannot be measured directly. When heat energy is supplied to a body, it is true that the body's temperature will rise. However, temperature is just a measure of how hot a body is, not the amount of heat energy it contains.

Heat always flows from high to low temperature. If a hot body and a cold body are placed in contact, the hot body (the one at the higher temperature) loses heat and the cold body (the one at the lower temperature) gains heat.

The rise in temperature in a body to which heat is supplied is decided by three factors:

- Amount of heat supplied (or 'transferred') to the body,
- Mass of the body
- Specific heat capacity of the material from which the body is made



Measuring temperature

The human body cannot measure temperature, it can only make comparisons. It cannot reliably tell whether something is hot or cold, it can only compare what it is currently feeling with what it felt immediately beforehand. Because it can only make comparisons, the human body cannot give a numerical value to temperature. However, temperature can be measured by making use of one of the effects of heat on materials.

The most common example is to use the way liquids expand as their temperature rises; the property of thermal expansion of a liquid. This is the principle behind the thermometer.

Other methods of measuring temperature include:

- Air or gas thermometer – instead of using a liquid, a bulb containing air or some other gas can be used. In one such thermometer, the expansion of the gas causes a short thread of mercury to move along a scale. These thermometers are very sensitive, but may require correction to compensate for atmospheric pressure.
- Using solids to measure temperature – the way that a solid expands when its temperature rises can be used to measure temperature. The expansion may be used directly, or the differing expansion of two dissimilar metals may be used.
- Thermocouples – when the junction of wires of two different metals (for example iron and copper) is heated, an electrical potential (a voltage) appears at the junction. A calibration can be made between the potential and temperature, so that temperature can be measured indirectly by measuring the potential with a sensitive voltmeter. There

are various types of thermocouple, some of which are capable of recording extremely high temperatures

- Electrical resistance – the electrical resistance of a wire increases with a rise in temperature and the change of resistance may be used to measure temperature
- Thermistors – these are semiconductor devices, which have a negative temperature coefficient of resistance, so an increase in temperature produces a decrease in resistance. They are very robust, can be made very small and so can follow rapid changes in temperature. Their range is generally from -70°C to 300°C , but they are less accurate than resistance thermometers.
- Comparison by brightness – at temperatures above about 750°C , objects start to glow, first a dull red, changing gradually to yellow and brightening as the temperature is raised to about 1250°C . Temperature measurements can be made by comparing the brightness of the object with the filament of an electric lamp where the brightness can be altered by varying the current flowing through it
- Infrared – infrared cameras and other sensors detect heat in the same way that our eyes detect light. Light represents only one portion of the electromagnetic spectrum, which is a rainbow of different types of radiation including, in addition to visible light, radio waves, microwaves, ultra-violet radiation and X-rays.



Thermometric scales

Three scales are used for measuring temperature:

- Celsius or Centigrade scale – the lower fixed point is the freezing point of water and is marked 0; the upper fixed point is the boiling point of water and is marked 100; between these two points are 100 equal divisions or degrees
- Fahrenheit scale – the lower fixed point is marked 32; the upper fixed point is the boiling point of water and is marked 212; between the two fixed points are 180 $^{\circ}\text{F}$ between the freezing point and the boiling point of water (at standard atmospheric pressure)
- Kelvin or Absolute scale – the lower fixed point is absolute zero (-273.15°C), the lowest temperature that it is possible to achieve; each division in the Kelvin scale has the same value as one degree on the Celsius scale. On the Kelvin scale water freezes at 273.15 K and boils at 373.15 K.



Units of heat

The unit that scientists and engineers use to measure heat is the same as that used for energy: the

Joule. It is defined from mechanics, where energy is the ability to perform work, so work and energy are measured in the same units. One Joule of work is done when the point at which a one Newton (1 N) force is applied moves through one metre in the direction of the force.



Specific heat

Heat energy can only flow from a body at a higher temperature to one at a lower temperature. Heat transfer continues either until both bodies are at the same temperature or until the two bodies are separated.

When heat is added to a body the temperature rises. The rise in a body's temperature depends on three things:

- Amount of heat energy supplied to the body
- Mass of the body
- Specific heat capacity of the body (the heat required to raise the temperature of 1Kg of the material by 1°C)

The surfaces of solids of low density, such as polyurethane foam, also heat up very rapidly when exposed to a heat transfer process; this is a result of low thermal conductivity. Instead of heat being rapidly transferred into the body of the solid by conduction, it accumulates at the surface, resulting in a rapid temperature rise. As a consequence, low density combustible materials can be ignited much more easily than materials of high density.

The larger the specific heat capacity of a substance, the more energy it takes to raise the temperature by a given amount. Materials with a low specific heat capacity will heat up more rapidly in a fire than those with a high specific heat capacity.

Water has an unusually high specific heat capacity. This is one of the reasons why water is good for fighting fire; a given mass of water can absorb a relatively large amount of heat energy



Change of state and latent heat

A change of state is the change between solid and liquid states (melting/freezing), liquid and gas states (boiling/condensation) and, for a relatively few pure compounds, solid and gas states (sublimation). Freezing, melting, boiling, condensation and sublimation all cause a change of state.

The temperature at which a solid turns into a liquid is called the melting point. The temperature at which a liquid turns into a solid is called the freezing point, though these two temperatures are the same for the same substance under the same conditions. The temperature at which a liquid boils and becomes a vapour is the boiling point.

The specific latent heat of vaporisation of a substance is the amount of heat energy needed to change a unit mass of the substance from the liquid to vapour without a temperature change.

Latent heat is measured in Joules per kilogram (J/kg), although it is more usually expressed in kilojoules per kilogram (kJ/kg).



Effect of change of pressure on boiling point and latent heat

Water normally boils at 100°C when the external air pressure is the standard atmospheric pressure. If the external pressure is raised, the boiling point is raised, and if the external pressure is lowered, the boiling point is lowered.

This behaviour is also used in the storage of liquefied gases such as propane and butane. At increased pressures, these gases liquefy at normal temperatures, and allow large quantities of gas to be stored in a relatively small volume.

Raising the boiling point increases the quantity of heat needed to raise the temperature of the cold liquid to the new boiling point, but it decreases the latent heat of vaporisation.



Latent heat of fusion

Just as latent heat is taken in when water changes to vapour at the same temperature, a similar thing happens when ice melts to form water. This is called the specific latent heat of fusion.

The definition of the specific latent heat of fusion of a substance is the quantity of heat required to convert the unit mass of the substance from the solid to the liquid state without change in temperature. The same units (J/kg or kJ/kg) are used as for the latent heat of vaporisation.



Cooling by evaporation

Some liquids have a low boiling point and thus change from liquid to vapour quite easily at ordinary temperatures; these are called volatile liquids and include methylated spirit and ether. If methylated spirit or ether are placed on the hand, it evaporates rapidly and the hand feels cold. Some local anaesthetics work in this way, by 'freezing' the pain.

The cooling is brought about because to change from liquid to vapour, the liquid absorbs heat energy from the hand to provide the latent heat of vaporisation of the liquid. The hand therefore feels cold.



Thermal expansion of solids

Whether solid, liquid or gas, a substance will tend to expand when it is heated as long as it is not constrained by a container, a change of state or a change in chemical composition.

When a solid is heated, it expands in length, breadth and thickness. The increase in length is often the most important for firefighters, although the increase in area and volume due to thermal expansion can be readily calculated. For practical purposes the expansion of metals in building fires leads to collapse.

The amount by which unit length of a substance expands when its temperature is raised by one degree is called the coefficient of linear expansion of the substance.

Increase in length = original length x coefficient of linear expansion x temperature rise

Cubical expansion (volume) is three times the linear coefficient

The expansion depends on the external dimensions of the solid and is not affected by any voids. The cubical expansion of a hollow metal box is the same as that of a solid block of the same metal of the same (external) volume as the box.



Thermal expansion of liquids (cubical expansion)

Since liquids have no definite shape and therefore no fixed dimensions other than volume, the only expansion that can be measured is that of cubical expansion. The coefficient of cubical expansion of liquids is considerably greater than that of solids; the expansion of a liquid is always greater than that of its container.



The effect of expansion on density

Since the density of a substance is the ratio of its mass to its volume, an increase of temperature results in a decrease of density. Conversely, the volume of a given mass of the substance increases as its temperature rises.

Water behaves in a peculiar way. Its expansion is not uniform; the expansion between 30°C and 50°C is double that of between 10°C and 30°C. On cooling below 10°C, water contracts until its temperature reaches 4°C. On further cooling it expands until its volume at 0°C is 1.000120 times greater than its volume at 4°C. It also expands further when it freezes. This means that water in ponds and lakes freezes from the top downward and, once the temperature on the surface has fallen to 4°C, further cooling of the lower level can only occur by conduction. This conduction is slow because water is a poor conductor.

Because of the relationship between pressure, volume and temperature, as liquefied gases are released (large increase in volume) there is a corresponding decrease in both their pressure and temperature.

The expansion ratio of a liquefied or cryogenic substance is the volume of an amount of that substance in liquid form compared to the volume of the same amount in gaseous form at a given temperature. Substances with large expansion ratios (e.g. nitrogen 1:694, oxygen 1:860, liquefied petroleum gas (LPG) 1:270, etc.) can produce pressures that can rupture the pressure vessel. Hence pressure relief valves and vent valves are used on LPG containers.



The expansion of gases

Since a gas expands to fill all the available space, the volume of a gas may be changed by altering the volume of its container. If the volume is decreased, the pressure is increased; the same number of molecules of the gas occupy a smaller space and, therefore, collide with each other and with the container walls more frequently. The pressure is due to these collisions and the more collisions, the higher the pressure.

In a liquid, the molecules are much closer together to start with than in a gas. The spacing of molecules in a liquid is comparable to that in a solid, but because they are moving so quickly they do not remain in the regular structure of a solid. Because molecules in a liquid are so close together to start with, they cannot be compressed further. This is why gases can be compressed but liquids, generally, cannot.

Heating a gas increases the kinetic energy of the molecules which therefore move faster and collide more frequently. So heating a gas increases its pressure – provided its volume is unchanged. By increasing its volume as it is heated, the pressure can be kept constant.

Three variables change with each other when dealing with a gas: temperature, pressure and volume. When dealing with a solid or a liquid, temperature and volume are important, but pressure is less so.



The gas laws

There are three gas laws:

- Boyle's Law – for a gas at constant temperature, the volume of a gas is inversely proportional to the pressure upon it. If V_1 and P_1 are the initial volume and pressure, and V_2 and P_2 are the final volumes and pressure, then $V_1 \times P_1 = V_2 \times P_2$
- Charles' Law – the volume of a given mass of gas at constant pressure increases by $1/273$ of its volume for every 1°C rise in temperature. The relationship between volume and temperature is: $V_1 / T_1 = V_2 / T_2$ where V_1 and T_1 are the initial volume and absolute temperature and V_2 and T_2 are the final volume and absolute temperature (the Kelvin temperature, not the Celsius temperature). In other words, the volume of a given mass of gas is directly proportional to its absolute temperature, provided that its pressure is kept constant.
- The Law of Pressures – the pressure of a given mass of gas is directly proportional to its

absolute temperature, provided that its volume is kept constant. This is expressed mathematically as $P_1 / T_1 = P_2 / T_2$

The three gas laws can be combined into a single mathematical expression (general gas law):

$$V_1 \times P_1 = V_2 \times P_2$$

$$T_1 T_2$$

It is important to remember that these gas laws apply to all gases provided that they remain as gases over the temperature and pressure range involved. When the temperature and pressure reach levels at which the gas liquefies, the gas laws no longer apply.



The liquefaction of gases

An increase in pressure raises the boiling point of a liquid. Many substances that are gases at normal temperatures and atmospheric pressure can be compressed to such an extent that their boiling point is raised above atmospheric temperature and the gas liquefies (e.g. propane, ammonia).

Other gases cannot be liquefied at atmospheric temperature no matter how great a pressure is applied. These are called permanent gases. However, if the temperature is lowered sufficiently, it becomes possible to liquefy them by compression (e.g. methane, oxygen).



Critical temperature and pressure

For each gas, there is a critical temperature above which it cannot be liquefied by increasing the pressure alone. For example, the critical temperature of carbon dioxide is 31.1°C; it can therefore be compressed to a liquid at 20°C, but at 40°C it will remain a gas.

Below its critical temperature a gas can be liquefied by increased pressure and it should properly be described as a vapour. Above this temperature it cannot be liquefied and is properly described as a gas, or, to emphasise the fact that it is above its critical temperature, a true gas.

The pressure required to liquefy a vapour at its critical temperature is called the critical pressure.



Liquefied gases in cylinders

Many materials, such as fuel gases, are liquefied under pressure and stored and transported in cylinders.

Liquefied gases in cylinders do not obey the gas laws, since below the critical temperature, any change in temperature, pressure or volume will result in either the liquefaction of gas or the evaporation of liquid. Thus the pressure in a cylinder of liquefied gas will remain constant as gas is drawn off (provided the temperature remains constant) since more liquid will evaporate to make up for the gas drawn off until all the liquid is evaporated.

For cylinders of liquefied gas, the cylinder pressure is not any indication of the amount of gas in the cylinder.

A true gas will obey the gas laws and the pressure will fall as gas is drawn off. Thus the pressure in the cylinder is an indication of the quantity of gas it contains.

When liquefied gases are stored in cylinders, allowance must be made for expansion of the liquid in case the cylinder is heated beyond the critical temperature and the liquid turns into a vapour.

This could lead to a substantial increase in pressure, with a risk of explosion. To minimise this danger, cylinders are never completely filled with liquid.

The amount of liquefied gas that may be charged into a cylinder is determined by its filling ratio, which varies from gas to gas and depends, among other things, on the density of the liquid.

Filling ratio = Weight of liquefied gas that may be charged

Weight of cylinder completely full of water

The filling ratio for ammonia is 0.5, so that a cylinder capable of holding 10 kg of water may only be charged with 5kg of ammonia. A cylinder of the same size could be charged with 12.5 kg of sulphur dioxide, for which the filling ratio is 1.25.



Sublimation

In the laboratory it is possible to produce such low pressures that the boiling point of water can be reduced to 0°C and lower. When this happens, ice does not melt to form water, but will vaporize

completely as the temperature rises.

This direct change from solid to vapour without forming an intermediate liquid is given the special name of sublimation.



Heat transmission

Heat energy always flows from regions of high temperature to regions of lower temperature. Heat will always flow when there is a temperature difference, no matter how small that temperature difference is.

There are three methods by which heat may be transmitted:

- Conduction – may occur in solids, liquids or gases, although it is most clearly present in solids; heat energy is passed on from each molecule to its nearest neighbour
- Convection – only occurs in liquids and gases, the term convective heat transfer is used to describe the transfer of heat between a fluid (gas or liquid) and a solid. For example, a hot object in air loses heat partly by convection; the layer of air next to the hot surface becomes heated and, therefore, buoyant with respect to the surrounding cold air. It then rises, carrying away the heat, which is replaced by cold air. This in turn becomes heated, and a convection current is set up that cools the solid.
- Radiation – all objects give out and take in thermal radiation, which is also called infrared radiation; the hotter an object is, the more infrared radiation it emits. It is a type of electromagnetic radiation that involves waves, no particles are involved, unlike conduction and convection. When radiant energy falls on a body, there are three possibilities:
 - Transmission – if energy passes through the body without warming it, it has been transmitted through the body; for example, transparent materials transmit light
 - Absorption – the energy is absorbed by the body, whose temperature is raised
 - Reflection – the energy may be reflected back from the surface in the way that light is from a shiny surface; reflected energy does not enter the body, it just ‘bounces off’ the surface.



Combustion

For combustion or burning to occur, oxygen (usually from the air) must combine with a fuel. A fuel may be in any one of the three states (gas, liquid or solid) initially, but for flaming combustion to occur, a solid or liquid fuel must be converted into a vapour, which then mixes with air and reacts with oxygen. Smouldering combustion, on the other hand, involves a reaction between oxygen (from the air) and the surface of the fuel: this is a complex process and in general only occurs with solid fuels that char on heating.

A flame is a region in which a sustained, heat-releasing reaction between a fuel in the vapour state and oxygen takes place. This region also emits light, usually with a strong yellow colour, though there are substances, such as methanol, that burn with a weak blue flame which cannot be seen in strong light.

Three factors are necessary for combustion to occur: heat, oxygen and fuel and this is referred to as the Fire Triangle. Combustion will continue as long as these three factors are present. Removing one of them leads to the collapse of the fire triangle and combustion stops.

All combustion reactions release heat energy and are called exothermic reactions. The quantity of heat produced per unit weight of fuel can be calculated and is known as the calorific value of the fuel. For example, when 12 grams of carbon (the gram atomic mass) are burned to carbon dioxide, 392,920 Joules of heat are produced. This is the heat of combustion: it refers to a standard amount of the fuel (the mole) and has units kJ/mol.

The calorific value for carbon is then: $392,920 / 12 = 32,743$ Joules per gram (J/g) as one mole of carbon contains 12g.

Besides calorific value, the rate of heat release is also important. For example, burning magnesium produces less heat than burning carbon, but when rates of reaction are considered, we find magnesium has a much higher rate of combustion than carbon so the heat is released much more rapidly. Heat release rate is a major factor in whether a fire will spread over materials, and a device called a 'cone calorimeter' has been developed to measure this quantity for wall linings and building materials as part of the assessment of their flammability and suitability for their intended use.



Oxidation

An oxidation reaction is a reaction that involves combination with oxygen or other oxidising agents. The following reactions are typical examples of combustion:

- The oxygen may be supplied by the air
- The combustion may take place using oxygen contained within the burning material (the combustible material and the supporter of combustion being together in the same compound)
- Oxygen may be provided by one of the materials in a mixture of compounds; the thermite reaction illustrates this principle

- Elements other than oxygen may be considered as oxidising agents, examples of these are chlorine and fluorine. Combustion may occur with these substances; for example, hydrogen will burn explosively with chlorine. Many organic materials (i.e. those based on carbon) will burn readily in halogen gases. Nitrogen is not usually thought of as an oxidising agent or even a reactive element, but some metals will burn vigorously in this gas. Magnesium, aluminium and their alloys form nitrides in combustion reactions.



What makes a flame a flame?

If a pool of paraffin is heated, its temperature will rise and combustible vapours will evaporate from the surface. When the temperature of the liquid surface reaches about 50 – 55°C, the rate of evaporation is high enough for the vapours to be ignited by a small flame or spark, and support continuous flaming above the surface. After the paraffin has been burning for some time, the surface of the fuel will be close to its boiling point, supplying flammable vapours to the flame.

Once a flame has been established and flammable vapours are rising from the fuel surface, heat and what are called chain carriers are produced where the flame reactions are occurring. A proportion of these will pass into the next layer of gas and start the oxidation and heat release processes there, rather as in a relay race. Chain carriers are believed to be atoms or fragments of molecules known as free radicals, which are extremely reactive. The type of chemical reaction that occurs in the flame is known as a chain reaction.

In fact, there are two distinct types of flame:

- Premixed flame
- Diffusion flame

The types of flame have different properties, though both are familiar from everyday experience. Understanding that each behaves differently is important. Under different circumstances fuel and air can combine in different ways to produce very different results.



Laminar flow and turbulent flow

Before discussing flames, it is useful to define two types of gas flow:

- Laminar flow - steady flow in which two particles starting at any given point follow the same path. Particles never cross each other's paths, so the particle paths are bunched together like uncooked spaghetti in a packet. At any given time, the velocities of all particles on one path are the same, but the velocities of particles in different paths might be different. Laminar flow is associated with slow flow over smooth surfaces.

- Turbulent flow – there are random changes in velocity and direction of the flow, although the flow as a whole is moving in a definite direction. When wind blows down a street on a windy day, leaves and litter may be blown up, down, across and around, revealing local changes in the flow, but the general direction of the wind is still down the street. Turbulent flow tends to occur in fast flows over rough surfaces and around obstacles.



Premixed and diffusion flames

A flame is the region in which chemical reactions take place and turn unburnt fuel vapours into burnt gases. The combustion products, for example methane and oxygen, react to give carbon dioxide and water vapour.

A certain amount of heat energy is required to start this reaction but more heat is produced by the reaction than it takes to initially start it, so the burning process is self-sustaining.

Premixed flames occur when a fuel is well-mixed with an oxidant, (e.g. 10% methane mixed with air). For ignition to occur, energy must be supplied in the form of a spark or small flame. A self-sustaining flame will then be established around the ignition source and will propagate outwards in all directions.

The flame consists of a zone where cold, unburnt gas (reactants) is transformed into hot burnt gas (products). The flame zone of a premixed flame may be less than 1 mm thick. As the volume of the hot burnt gas is greater than that of the same mass of cold unburnt gas, the flame front is pushed outwards from the ignition point, like the skin of an inflating balloon.

Not every mixture of air and fuel will burn. Depending on the type of fuel and oxidant involved (air or pure oxygen, for example), a mixture initially at room temperature and pressure will only burn if the concentration of fuel lies between certain well-defined limits, called flammability limits. For example, mixtures of methane and air will only burn if the concentration of methane in air lies between 5% and 15%, whereas hydrogen will burn in air at concentrations between 4% and 76%.

Table 10 Flammability limits

Gas	Lower limit	Upper limit
Hydrogen	4.0	76.0
Carbon monoxide	12.5	74.2
Methane	5.0	15.0
Butane	1.5	9.0

Gas	Lower limit	Upper limit
Ethylene	2.7	28.6
Acetylene	2.5	100.0
Propane	2.4	9.5

The figures quoted for limits of flammability may vary as a number of factors may slightly alter the value: pressure, temperature, dimensions of the test apparatus, direction of flame propagation and moisture content of the mixture all have some effect.

In general, the range between limits widens with increased temperature.

For each mixture of fuel and air between the flammability limits, there is a characteristic burning velocity at which a premixed flame will propagate through a stationary gas. Burning velocity is dictated by the chemical processes involved: how quickly the fuel reacts with the oxygen. The methane and oxygen molecules do not simply combine instantaneously to form carbon dioxide and water vapour, but form free radicals and intermediates such as formaldehyde and carbon monoxide along the way to completing the reaction.

If the premixture flows into a flame with a laminar flow whose velocity is equal to the burning velocity of the mixture, the flame can be held stationary. This is how premixed flames on Bunsen burners, domestic gas rings, etc. are held steady.

Local air currents and turbulence caused by obstacles can cause a flame to move at speeds much higher than the burning velocity. The speed at which a flame moves relative to an observer is the flame speed, which is different to the burning velocity. For example, the burning velocity of a methane-air flame is about 0.45 m/s. If the unburnt gases are no longer stationary, the flame propagates at the local flow speed plus the burning velocity. As the flame gets faster, the flame front wrinkles as turbulence is produced in the unburnt gas, increasing the surface area of the flame front. This increases the reaction rate, increasing the rate at which burnt gas is produced, so pushing the flame front forward faster.

In explosions, flame speeds of hundreds of metres per second can be achieved in gas-air mixtures, though the burning velocity of the mixture will be much lower than this. It is possible to achieve supersonic flame speeds, in which the combustion region is strongly coupled to a shock wave; this phenomenon is called detonation.

Diffusion flames occur at the interface where fuel vapour and air meet. Unlike premixed flames, the fuel vapour and the oxidant are separate prior to burning. The dominant process in the diffusion flame is the mixing process. The fuel vapour and oxygen mix with each other by molecular diffusion, which is a relatively slow process, though the high temperatures associated with flames increase the rate at which diffusion occurs.

Because diffusion flames exist only at the fuel-air interface, there is no equivalent of burning velocity, and no equivalent to rich or lean mixtures, or flammability limits.

Diffusion flames themselves fall into two broad types.

- Laminar diffusion flame – in slow-burning diffusion flames, such as candle flames, the

fuel vapour rises slowly from the wick in a laminar flow and molecular diffusion dominates

- Turbulent diffusion flame – in industrial burners, fuel is injected into the air at high velocity, as a spray or jet. Turbulence is induced at the interface where mixing takes place. This gives the flame an extremely large surface area in comparison to the relatively small surface area of the smooth fuel/air interface of the candle flame. In this turbulent case, it is the large interface area, rather than the rate of molecular diffusion, that determines the rate of mixing.

In a large fire (more than 1m in diameter), the flames are turbulent diffusion flames, the turbulence generated by the strong buoyancy of the flames themselves. Inside the flame, there are regions of high temperature and low oxygen concentration where the fuel vapour is subjected to a mixture of pyrolysis (chemical decomposition in the absence of oxygen) and partial oxidation, leading to the formation of soot particles and products of incomplete combustion, in particular carbon monoxide (CO). These are the source of smoke, and of the gaseous species that render the fire products toxic.



Flashpoint, firepoint and sustained fires

In a dish of flammable liquid such as paraffin, a region will exist above the liquid surface in which the evaporating fuel vapour is well mixed with air. If the paraffin is heated above about 40°C, this region will become flammable; the vapour concentration in air is above its lower flammability limit.

The lowest temperature at which this occurs is called the flash point; the liquid temperature at which application of an ignition source will cause a flame to flash across the surface of the liquid.

This is a premixed flame moving through the vapour/air mixture but, just above the flash point, it burns out (or self-extinguishes) because it has consumed all the vapour. If heating is continued, a temperature will be reached at which ignition of the vapours will lead to a flash, followed by the development of a sustained diffusion flame at the surface flame.

This temperature is known as the fire point, the lowest temperature at which the rate of supply of fuel vapours, by evaporation, can sustain the flame.



Vapour cloud fires (flash fires and fireballs)

The term flash fire is used to describe what happens if the temperature of the fuel is much greater than the firepoint and a flammable vapour/air zone exists at some distance from the liquid surface.

This may happen if there is a spillage of petrol (firepoint approx. -40°C) that forms a large pool. If an ignition source is introduced into the flammable zone, a premixed flame will flash back, igniting the fuel in the fuel-rich mixture above the liquid surface and giving rise to a large fire (turbulent diffusion flame).

In a sustained fire of this type, flames burn continuously above the surface until the fuel is consumed (or the fire is extinguished). In principle, combustible solids burn in the same way, although the formation of fuel vapours involves chemical decomposition of the solid, which requires more energy than simple evaporation. For this reason, solids tend to burn much more slowly than combustible liquids.

A fireball can occur when a mixture of vapour and mist droplets forms a cloud containing very little air; the oxygen concentration is too low for premixed combustion to take place. However if there is an ignition source at the boundary between the fuel and surrounding air, a premixed flame will flash through the flammable zone at the boundary, giving rise to a diffusion flame. A fireball is established and rises as it burns; as burning continues instabilities at the surface of the flame increase surface area and the fireball will increase in size until it uses up the fuel.



Vapour cloud explosions

After ignition, any obstacles will create turbulence in the vapour mixture, increasing the amount of burning and flame spread. This may lead to overpressures that can, in certain circumstances, cause blast damage.



Ignition

For ignition to occur, sufficient heat energy is supplied to gaseous fuel and an oxidant, either mixed to within flammability limits or at the interface between the fuel and the oxidant, to start a self-sustaining chemical reaction. This energy is generally supplied by a flame, spark or a hot surface, but ignition can occur in less obvious ways:

- Spontaneous ignition temperature – this is the lowest temperature at which the substance will ignite spontaneously, that is the substance will burn without the application of a flame or other ignition source. This is sometimes referred to as the auto-ignition temperature.
- Self heating and spontaneous combustion – certain materials may react with oxygen at room temperature. Compounds such as linseed oil, which contain carbon-carbon double

bonds are very prone to this reaction, but any organic material stored in bulk quantities may be suspect, especially if it has been stored at an elevated temperature. Sometimes the action of bacteria on certain organic materials can cause a rise in temperature, eventually leading to active combustion (haystacks were prone to this). Powdered material can lead to spontaneous combustion. In the manufacture of some plastics (e.g., polyurethane foams), the cross-linking process that creates the final molecular structure of the material is exothermic, and can lead to spontaneous combustion if slabs of foam are stored before the process is complete.

- Smouldering – this only occurs in porous materials that form a solid carbonaceous char when heated. Paper, sawdust, fibreboard and latex rubber can all undergo smouldering. Smouldering is the combustion of a solid in an oxidising gas such as air, without the appearance of a flame. The process is very slow, but smouldering fires can go undiscovered for a very long time and can produce a large amount of smoke. The smoke is flammable, but it must accumulate and reach its lower flammability limit before it can be ignited. Smouldering will undergo a transition to flaming under favourable conditions. The mechanism is not fully understood, and it is impossible to predict how long after smouldering commences that the transition will occur.

Water is most efficiently used if it is applied to a fire in liquid form and in such a way that as much as possible is converted to steam. The smothering effect of the steam produced at the seat of the fire is thought to play a part in assisting in the extinguishing process. In all firefighting operations where water is used, the aim should be to ensure the proportion of water that escapes from the building in liquid form should be as low as possible.

The role of decomposition is insignificant in the case of water. Water does not react with ordinary materials, but may prove dangerous with some fuels, evolving heat rather than absorbing it. Moreover, the reaction may result in the formation of a flammable product, thus adding fuel to the fire. The action of water on burning magnesium exemplifies both these effects, since it reacts with the metal exothermically (i.e. producing heat) forming hydrogen, which is readily ignited. For other media the reaction products may be undesirable in other senses, such as for halons, which can produce toxic gases that can be hazardous in enclosed spaces.

When it is applied to a fire, the extinguishing medium itself undergoes changes as it absorbs heat from the fire. It may:

- Increase in temperature
- Evaporate (boil)
- Chemically decompose (but not applicable to water)
- React chemically with the burning material

For the extinguishing medium to achieve maximum effect, it is clear that the quantity of heat energy absorbed when these changes occur should be as high as possible. The following properties should be as high as possible in a good coolant:

- Specific heat capacity
- Latent heat of vaporisation
- Heat of decomposition

For further information regarding the extinguishment of fire see National Operational Guidance: Fires and firefighting



Section 2: General hazards



Legislation

A hazardous materials response can be complicated by numerous pieces of legislation and regulation. In the main, most of these are the responsibility of those who produce, transport, use or store the substances. However, some do relate directly to fire and rescue services.

- Fire and Rescue Services Act 2004 (The Act) [England and Wales]
- Fire (Scotland) Act 2005 (The Scotland Act) [Scotland]
- Fire and Rescue Services (Northern Ireland) Order 2006 (The NI Order) [Northern Ireland]
- Fire (Additional Function) Scotland Order 2005 [Scotland]
- Fire and Rescue Services (Emergencies) (England) Order 2007 [England]
- Fire and Rescue Services (Emergencies) (Wales) Order 2007 [Wales]
- Fire and Rescue Services (Emergencies) (Northern Ireland) Order 2011 [Northern Ireland]
- The Civil Contingencies Act 2004 (The Act) [UK]
- The Civil Contingencies Act 2004 (Contingency Planning) Regulations 2005 (The 2005 Regulations) [UK]
- The Civil Contingencies Act 2004 (Contingency Planning) (Scotland) Regulations 2005 (The Scotland Regulations) [Scotland]
- The Civil Contingencies Act 2004 (Contingency Planning) (Amendment) Regulations 2012 (The 2012 regulations) [UK]
- The Environmental Permitting (England and Wales) Regulations 2010
- Pollution Prevention and Control (Scotland) Regulations 2000 (PPC 2000)
- Environment (Northern Ireland) Order 2002
- The Environmental Damage (Prevention and Remediation) (England) Regulations 2015
- The Environmental Damage (Prevention and Remediation) (Wales) (Amendment) (No.2) Regulations 2015
- Environmental Liability (Scotland) Regulations 2009
- The Environmental Liability (Prevention and Remediation) Regulations (Northern Ireland) 2009
- Environmental Protection Act 1990 (The Act) [England Wales Northern Ireland (some provisions do not extend) and Scotland (a few provisions do not extend)]

- The Health and Safety at Work etc. Act 1974 (The Act) [England Scotland and Wales] [very limited application to Northern Ireland]
- Health and Safety at Work (Northern Ireland) Order 1978 (The NI Order) [Northern Ireland]
- Management of Health and Safety at Work Regulations 1999 (The Regulations) [England Scotland and Wales]
- Management of Health and Safety at Work Regulations (Northern Ireland) 2000 (The NI Regulations) [Northern Ireland]
- The Personal Protective Equipment at Work Regulations 1992 (The Regulations) [England Scotland and Wales]
- Personal Protective Equipment at Work Regulations (Northern Ireland) 1993 (The NI Regulations) [Northern Ireland]
- The Provision and Use of Work Equipment Regulations 1998 (The Regulations) [England Scotland and Wales]
- Provision and Use of Work Equipment Regulations (Northern Ireland) 1999 (The NI Regulations) [Northern Ireland]
- Control of Substances Hazardous to Health Regulations 2002 (COSHH) (as amended)
- The Control of Asbestos Regulations 2012 (The Regulations) [England Scotland and Wales]
- The Control of Asbestos Regulations (Northern Ireland) 2012 (The NI Regulations) [Northern Ireland]
- Control of Lead at Work Regulations 2002 (the Regulations) [England Scotland and Wales]
- Control of Lead at Work Regulations (Northern Ireland) 2003 (the NI Regulations) [Northern Ireland]
- The Ionising Radiations Regulations 1999 (The Regulations) [England, Scotland and Wales]
- Ionising Radiations Regulations (Northern Ireland) 2000 (The NI Regulations) [Northern Ireland]
- The Radiation (Emergency Preparedness and Public Information) Regulations 2001 (The Regulations) [England Scotland and Wales]
- Radiation (Emergency Preparedness and Public Information) Regulations (Northern Ireland) 2001 (The NI Regulations) [Northern Ireland]
- Control of Major Accident Hazards Regulations 2015 (COMAH) [England Scotland and Wales]
- Control of Major Accident Hazard Regulations (Northern Ireland) 2000 (NI COMAH) [Northern Ireland]
- Notification and marking of sites regulations 1990 (NAMOS) (as amended)

The following legislation and regulation places duties and responsibilities on the hazardous materials industry:

- ADR (European agreement concerning the International Carriage of Dangerous Goods by Road)
- RID (European agreement concerning the International Carriage of Dangerous Goods by Rail)
- ADN (European agreement concerning the International Carriage of Dangerous Goods by Inland Waterways)
- Dangerous Goods Regulations 2008 - International Air Transport Association (IATA)
- International Maritime Dangerous Goods (IMDG) Code
- Registration, Evaluation, Authorisation & restriction of Chemicals Regulations 2007 (REACH)

- Dangerous Substances and Explosive Atmospheres Regulations (DSEAR)
- The Water Industry Act 1999
- The Groundwater Regulations 1998
- Environmental Protection Act 1990
- Water Resources Act 1991
- The Hazardous Waste Regulations 1996 (as amended)
- The Carriage of Dangerous Goods and Use of Transportable Pressure Equipment Regulations 2009 (CDG) (as amended)
- European Regulation (EC) No 1272/2008 Classification, Labelling and Packaging of Substances and Mixtures (CLP)
- The Chemicals (Hazard Information and Packaging for Supply) Regulations 2008 (CHIP)(as amended)
- The Air Navigation Order (ANO)2016
- The Air Navigation (Dangerous Goods) (Amended) Regulations 2006
- Radioactive Material (Road Transport) (Great Britain) Regulations (RAM Road)
- Packaging Labelling and Carriage of Radioactive Materials by Rail Regulations
- Explosives Regulations 2014

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



Pre-planning

Pre-planning for operational incidents is a safety-critical part of fire and rescue service work. Fire and rescue services must ensure they have suitable and sufficient emergency response plans to cover the hazardous materials risks within their authority's area, such as:

- Buildings and/or establishments subject to the Control of Major Accident Hazard Regulations (COMAH)
- Buildings and/or establishments known to manufacture, store or use significant quantities of hazardous materials
- Buildings registered to hold radioactive materials
- Buildings registered to hold explosives
- Buildings registered to hold biological agents
- Buildings or establishments known to have asbestos-containing materials (ACM)
- Leaking and/or heated cylinders
- Road transportation accidents, spillages or releases of hazardous materials
- Rail transportation accidents, spillages or releases of hazardous materials

- Waterborne transportation accidents, spillages or releases of hazardous materials
- Air transportation accidents, spillages or releases of hazardous materials
- Military accidents, spillages or releases of hazardous materials
- Deliberate, criminal, malicious or terrorist events resulting in the release of hazardous materials.

The extent of pre-planning individual fire and rescue services carry out depends on the likelihood and severity of foreseeable hazardous materials and/or chemical, biological, radiological, nuclear (Explosive) (CBRN(E)) emergencies within their areas.



Gathering and use of risk information

Legislation, states that a fire and rescue authority must make provision for: (a) extinguishing fires in its area, and (b) protecting life and property in the event of fires in its area. Legislation places a responsibility on fire and rescue authorities to make arrangements for obtaining the information needed for that purpose. Fire and rescue authorities have similar responsibilities in respect of road accidents and other emergencies.

To support these legislative responsibilities, Fire and Rescue Service National Framework documents require all fire and rescue authorities to have effective arrangements in place for gathering risk information and making it readily available to operational crews. These arrangements should include an effective audit and review system to ensure that the information is current and in the required format.

Identifying and managing risk is at the heart of fire and rescue service role and responsibility and must be considered as part of a holistic approach to risk management planning, whether that be through pre-planning and managing emergencies, fire safety, crime and disorder initiatives, training or undertaking other day-to-day activities.

The importance of multi-agency pre-planning for significant known or foreseeable hazardous materials risks cannot be stressed highly enough. Local emergency planning groups set up under the civil contingencies legislation are made up of the key stakeholders in the local community. They should hold details of all significant risks within their area in a community risk register.

Specific pre-planning for hazardous materials incidents includes the requirement for a written policy that outlines:

- How fire and rescue services will deal with hazardous materials incidents, using good practice for reducing the risk of contamination based on the principles of hierarchical control
- How fire and rescue services will train their staff to raise awareness, reduce the risk of exposure and protect themselves, the public and the environment
- Effective fire and rescue service decontamination procedures



Information sources

The initial response to an incident often dictates the success of the outcome. A risk assessment based on poor information is a poor risk assessment. Access to clear and accurate information at the beginning of the incident is crucial. There can be many sources of information and it is therefore important to choose the ones most appropriate to the incident in hand. This section aims to make this process more efficient by outlining some of the key sources of information available to contribute to the successful management of a hazardous materials incident, and where to obtain it.

This document does not provide an exhaustive list of such sources; neither will the available information be replicated here. Using and interpreting this information is discussed in the following section.

The role of the hazardous materials adviser (HMA) is to gather the relevant data to enable the appropriate decisions to be made by the incident commander. The hazardous materials adviser must decide what is relevant information, but there are some guiding points:

- Different sources of information will be available during site-based incident (e.g. chemical manufacturing, distribution or storage site) versus an off-site incident (e.g. on a highway or at a port)
- Common information can typically be obtained from written or electronic sources such as the safety data sheet (SDS), databases or books; this type of information may require further interpretation
- Information obtained from either a product expert or scientific adviser will not usually require further interpretation
- Each information source has advantages and disadvantages but the choice of sources is the responsibility of the hazardous materials adviser (HMA)
- Wherever possible, advice from more than one source should be gained to corroborate the information; a rule of thumb would be to corroborate information using 3 different sources (the 'rule of three' or triangulation)
- Sufficient information should be obtained at the point that a clear strategy begins to emerge in planning the response
- The importance of safe direct observations should not be underestimated



Scientific advisers

General

Scientific advisers can be a useful resource, particularly when the incident is complex or where other information cannot easily be sourced. They can also provide product information or corroboration of other information sources. Scientific advisers can also give reassurance or act as a check for the response plan that the hazardous materials adviser (HMA) or incident commander has developed.

Scientific advisers can be situated remotely (accessed by telephone, fax or email) or may attend the incident site. Scientific advisers should be able to:

- Understand the nature of the products and how this affects the actions taken
- Assess the potential for reactions
- Have an appreciation of operational response and the application of proportionate advice

Scientific advisers may have expertise in the products involved in the incident (being representatives of the manufacturers, for example) or they may have a more general chemical knowledge.

When contacting scientific advisers it is advisable to obtain as much information on the chemicals and the incident as possible before calling. This may include names, part names, company names and product markings. Where this information is not available, any information should be supplied and the scientific adviser should be called back with any subsequent information. The quality of the advice received depends on the information given to the scientific adviser.



Chemsafe

Chemsafe is the UK chemical industry's voluntary scheme for providing expert advice to the emergency services in the event of a chemical emergency.

The scheme is administered by the Chemical Industries Association and is designed to deliver a rapid and co-ordinated response following a chemical incident that minimises the risks to people, the environment, assets and reputation. Under the chemical industry's Responsible Care initiative, companies must ensure that information and practical assistance (if possible) is always available for their products during transport and distribution incidents.

Chemsafe sets out performance standards for responding to emergencies based on the following response levels:

- Level 1 - Provision of information remote from the incident scene
- Level 2 - Provision of technical advice at the incident scene
- Level 3 - Provision of practical assistance at the incident scene

Chemsafe and the National Chemical Emergency Centre (NCEC)

Funded by the Department for Transport and Chemical Industries Association, the National Chemical Emergency Centre has delivered the Level 1 emergency response component of Chemsafe for over forty years through a dedicated telephone number, free at the point of use and provided only to the emergency services and other nominated organisations. The service is permanently operational.

To help operate this service, the National Chemical Emergency Centre maintains a database of company contact details and product information such as safety data sheets for all chemicals, not just those classified as hazardous. In addition, the Centre provides training to the emergency services in hazardous materials response and how to use the Chemsafe scheme. Although Chemsafe was primarily intended to cover distribution incidents, the emergency responders at the National Chemical Emergency Centre will provide advice to the emergency services on any incident involving chemicals from minor spillages in homes and workplaces to major disasters.

Chemsafe provides:

- Free scientific advice at the point of use, available by phone 24/7/365
- Rapid access to chemical information
- Access to a team of chemical experts and a large database of chemical product information, including products no longer manufactured
- Access to information on products manufactured in other European countries due to the National Chemical Emergency Centre's association with other national response centres across Europe (Cefic's International Chemical Transport Emergency (ICE) programme)
- Activation of product specific mutual aid schemes where applicable

Eligible responders can obtain the Chemsafe number by contacting the National Chemical Emergency Centre. For more information contact Chemsafe@ricardo.com.

Additional resources available through Chemsafe

A number of Chemsafe member companies have operate a Chemsafe Response Network that will provide Level 2 assistance to the emergency services on behalf of another Chemsafe member company that is not at the scene. Normally, this assistance is available only in the event of a road transport incident and where the owner/supplier of the goods is a Chemsafe member company. The scheme can be activated directly between companies or by the Chemsafe Longstop centre.

For certain chemicals that may pose particular problems, or for details on the special equipment that may be required at an incident, there are a number of product specific mutual aid schemes. These schemes may be activated by the owner/supplier of the goods, or by the Chemsafe Longstop centre. For more information on products covered by these schemes, contact the Chemsafe Longstop centre.

The NCEC Chemsafe Longstop centre can obtain information and advice on products originating outside the UK via the International Chemical Environment (ICE) scheme, which includes a network

of chemical emergency response centres across Europe.

For further information see Chemsafe or email ncecer@ricardo.com or fax 01235 753657



Generic information resources

There are times when information may have already been collected, such as on the known risks at a site, that can be used in the all important initial phase of the incident. The location of the incident should also be considered; it is much more difficult to plan for an incident during the transport and distribution of a chemical than on the site at which it is manufactured.

Hazardous materials incidents have been broadly categorised into 'on-site' and 'off-site' (or transport) incidents. The exact definition of these categories is less important than the intended purpose of offering guidance as to the information sources available for each as the incident progresses. While certain information sources may be common to all incidents, other sources will depend on the type of incident.

On-site based incidents	Off-site or transport based incidents
En route	En route
COMAH Plans*	Notification call or report (e.g. 999
Site-specific information*	log)
Firemet**	Firemet**

On-site based incidents	Off-site or transport based incidents
Hazard recognition	Hazard recognition
Observation	Observation
Safety data sheets (SDS)	Driver*
Product experts	Vehicle markings*
Chemical databases (e.g. Chemdata®) on mobile data terminals (MDTs)	Emergency Action Code list*
Portable reference material, e.g. Emergency Response Guidebook	Dangerous goods documentation*
MDT-based systems (e.g. Chemdata)	Chemical databases (e.g. on mobile data terminals (MDT))
Scientific advisers (e.g. CHEMSAFE etc.)	Portable reference material, e.g. Emergency Response Guidebook
CHEMET**	MDT-based systems (e.g. Chemdata)
Detection Identification Monitoring equipment	Detection Identification Monitoring equipment
	Scientific adviser/team (e.g. CHEMSAFE, RADSAFE etc.)
	Product-specific aid schemes
	CHEMET**

Table 12 On-site/Off-site information sources

On-site based incidents	Off-site or transport based incidents
Substance related	Substance related
Manufacturer or supplier	Manufacturer or supplier
Scientific adviser (e.g. CHEMSAFE, RADSAFE etc.)	Scientific adviser (e.g. CHEMSAFE, RADSAFE etc.)
Safety data sheets (SDS)	Safety data sheets (SDS)
Chemical databases	Chemical databases
CHEMSAFE	CHEMSAFE
Internet sources	Internet sources
Books	Books

*where applicable to the incident

**Firemet and CHEMET are accessed via the Met Office Hazard Manager – see National Operational Guidance: Operations



Site emergency plans

Larger hazardous installations will be subject to the Control of Major Accident Hazard (COMAH) Regulations. Examples of these types of installations include chemical manufacturing, warehousing and distribution sites.

Lower-tier sites are required to document a major accident prevention policy. An upper-tier COMAH site is required to produce a full safety report demonstrating that all necessary measures have been taken to minimise risks posed by the site on the environment and the local population. In addition, upper-tier sites have an external emergency plan that is prepared by the local authority (in liaison with fire and rescue services, or in metropolitan authorities by the fire and rescue service) and tested every three years.

- These plans can therefore be a useful reference source for:
- Obtaining an inventory of the types and quantities of hazardous materials held on site
- A map showing the location of the materials
- An assessment of the known risks and remedial strategies
- The location of equipment used to fight fires or prevent the release of materials from the site



Risk assessments

Another source of information on smaller installations may have been obtained during the assessment of risks carried out as required by law. Risk inspections can also be a useful source of information on the nature and quantities of hazardous materials present on the site as well as the known risks posed by the nature of the site's operations.



Incident Observations

Direct observations from the scene of a hazmat incident will enable the full extent of hazards to be

recognised and quantified. Such observations for example, eyewitness reports, visual assessment of the size of spill, reports of odours downwind etc are equally important to other information sources to ensure an appropriate risk assessment of the incident. There are also times when marking, placarding and signs are not present, or are incorrect, damaged or obscured, such as during a fire or where hazardous materials are badly controlled or even used illicitly.

In such cases, incident observations will increase in their level of importance. Information and direct observations from site personnel, eyewitnesses (members of the public) and/or information from other responders can be very valuable in determining the objectives, hazards and controls.

To support the tactical options available to incident commanders there are a number of knowledge based considerations that are important to hazmat risk assessment:

- Remember that hazardous materials may not be visible and may not have an odour. If possible and safe to do so without additional personal protection equipment (PPE), approach the incident from higher ground, especially if hazardous liquids are known to be present.
- When approaching the vicinity of the incident use senses to assess 'incident indicators' to assist in estimating the extent of the hazard zone
 - Gas and vapour clouds or plumes
 - Visible smoke and other signs of fire
 - Liquid spills, wet areas, patches, puddles, pools and streams or flowing liquids
 - Unexplained noise (for example explosions, venting cylinders, site specific audible warnings), which may indicate a more cautious approach and larger hazard zone
 - Distinct odours (for example bleach, garlic, rotten cabbage, bad eggs)
 - Damaged containers and packages
 - Biological indicators such as dead birds, animals, fish, insects, trees and vegetation
- Use 'incident indicators' to make a rough estimate of the quantity of hazardous materials involved.
- Be able to distinguish between the quantity involved (i.e. released or spilled) and the quantity in the container or the maximum contents of the container.
- Assess the scene, consider using equipment such as: Thermal imaging equipment, Binoculars, Monitoring devices
- Locate where the release is coming from
- Understand the potential for contamination from the incident source to move
- Gather information about the emergency or accident from eye witnesses
- Gather information from people responsible for the product causing the release – if possible, for example, site personnel or driver
- Gain specific knowledge about the event, substance, site, process, treatment of casualties and containment system
- Gain information from casualties and other 'involved people' who may physically mark the hazard zone or may be able to describe it based on their experience
- Liaise with other people or agencies to gain specific knowledge about the event, substance, site, process, treatment of casualties or containment system
- Gather information on any relevant history of problems, failures, releases, similar events, etc.
- Identify site containment information, for example, drainage, sewerage, bunding separators and drain closure valves

- Identify the hazards, taking the following into account:
 - Casualty numbers (ambulant and non-ambulant)
 - Severity and type of signs and symptoms
 - The location of the incident – is it likely to be terrorism or a hazardous material incident?
 - Environment – building, open space, underground
 - Presence of perpetrators

This assessment will enable the incident commander to consider what additional fire and rescue service resources are needed based on the information already gathered and the actions known to be required, consider:

- Numbers of casualties/rescues
- Number of firefighters required
- Number and level of command roles required
- The need for hazardous materials specialists and advice
- Additional PPE requirements
- Type and amount of decontamination equipment and competent staff
- Scene safety and safety officers
- Cordoning and possible evacuation



Information available at the incident scene

After arriving at the incident, it is important to make a quick survey of the site to establish the circumstances and nature of the incident, depending on whether the incident is occurring on the site of a chemical manufacturer, storage facility or distributor (on-site) or while goods are being distributed (off-site or transport incident). The methods of ascertaining all of the relevant information will depend on the context and nature of the incident, but will typically include:

- Direct observation from a distance judged to be safe, perhaps using binoculars
- Interviewing other parties, such as the driver of the vehicle involved or the site operator
- Obtaining information from other responders, such as the police
- Obtaining information from vehicle and/or product markings (e.g. Hazchem placard)
- Obtaining information from product experts
- Safety data sheets (SDS) or other written information

Establishing whether dangerous goods are involved in transport incidents should be straightforward, providing the consignor and transporter have complied with the relevant legislation. Where dangerous goods are being carried by road vehicle, for example, plain orange plates are displayed at the front and rear of the vehicle or a Hazchem placard is displayed on the side and rear. Other similar marking schemes are in place for dangerous goods being transported by rail, air or sea.

However, some initial caution should always be shown where there is some doubt about the nature of the goods being transported or if it is unlikely that the relevant legislation has been complied

with. Examples include illicit drug- or bomb-making facilities or the illegal transport of diesel fuel in unmarked intermediate bulk containers in unmarked vehicles. International Organisation for Standardisation (ISO) shipping containers used to transport goods can also pose dangers where dangerous goods are not declared on the manifest. Due to their very nature, it is impossible to state how common these practices are. However, the likelihood of illegal practices should always be considered in the context of the incident.

The absence of UN markings does not necessarily indicate that the goods do not pose any risk to the responders or to the environment. It merely indicates that the goods do not satisfy the criteria for labelling under the UN regulations.

For transport-based incidents, the person in control of the vehicle (if available and able to do so) may be a valuable source of information on the goods being carried. For example, they may be able to give detail on where the vehicle has come from and where it is going, as well as information on what is being carried and any known hazards. People in control of vehicles carrying dangerous goods are required to undergo relevant training.

A Dangerous Goods Note (DGN) can be used when transporting goods using all forms of transport except air freight, when the IATA Dangerous Goods Declaration is normally used. The DGN should be present where the vehicle indicates that it is carrying hazardous goods.

Since July 2009, the driver of a vehicle no longer has to carry product-specific instructions in writing (IIW) on what action to take in the event of an incident. The IIW were commonly referred to as Tremcards® and were also used by emergency responders as a means of identifying the load. Instead, the driver now has to carry a generic IIW, which cannot be used to identify the load on the vehicle. Drivers can still carry product-specific information but this must be in addition to, and not attached to, the generic information.



Product specialists

Product specialists can be a useful source of advice, particularly where the product is a proprietary preparation (trade name product) or where the specialist has particular knowledge of the site processes and can make suggestions for dealing with the incident.

However, a degree of caution should be used when involving product specialists who may have a vested interest in minimising the disruption caused by the incident, perhaps at the expense of emergency responders. In addition, an organisation's assessment of risk for products in their normal use may not be appropriate for emergency response situations. Fire and rescue services should not rely on the organisation's risk assessment and should always assess the risks apparent for each operational incident. If there is any doubt as to the integrity or suitability of the advice being offered by a product expert, fire and rescue services should seek alternative advice such as from an independent scientific adviser. It is in any case prudent to seek alternative views to those of a product specialist, even when inclined to follow their advice.



Safety data sheets (SDS)

A safety data sheet is a document intended to provide occupational workers and emergency personnel with information on handling or working with a material in a safe manner.

Safety data sheets are particularly important in the case of proprietary preparations where more than one product has been mixed. Other than the manufacturer or product expert, this will be the only source of information on the product, though some chemical databases, such as Chemdata, do contain emergency response information on proprietary preparations based on the information provided by the manufacturer. This is because the act of mixing or reacting the constituent ingredients can have a marked effect on the final properties of the material. For example, both an acid and a base are corrosive but if mixed, the resulting product may have been neutralised and is no longer corrosive. I can therefore be unreliable to assess the hazards of the product based on the individual ingredients.



Interpreting safety data sheets

The format of safety data sheets (SDS) can vary according to the region in which the product is produced, but in the European Union there is a set format. The information in the SDS must be provided in the 16 standard headings shown in the following table, which also includes the type of information included in each section.

Table 14 Information found in safety data sheets

Section number	Heading	Useful information
1	Identification of the substance/preparation and company	Name of the product. Name and contact details of the manufacturer or distributor. Contact details and possibly an emergency telephone number.

Section number	Heading	Useful information
2	Composition/information on ingredients	May help to understand the nature of preparations. Should be used cautiously, as the final properties of the material may differ significantly from its constituent ingredients.
3	Hazards identification	Summarises the main hazards of the product – or indicates it does not pose a significant hazard. A good starting point when referring to the SDS.
4	First-aid measures	Should offer advice on exposure to eyes, by inhalation or ingestion. Pay particular attention to when medical intervention or assistance is recommended.
5	Firefighting measures	The writer is unlikely to be aware of the equipment and procedures adopted by the fire and rescue services, so this section should be treated with some caution. May give an indication of whether foam or water should be used to fight the fire. If unsure, physical properties like density should also be checked in section 9 or in section 14 of the EAC.
6	Accidental release measures	Should usually be considered when dealing with a smaller occupational spill or release, so the advice may not apply to the incident.
7	Handling and storage	Typically contains conditions to avoid and how best to store the material. May indicate conditions under which a reaction may occur, such as due to heat, impurities or degradation. Other phrases to look out for include ‘Fumes/vapour/powder can form explosive mixtures with air’.

Section number	Heading	Useful information
8	Exposure controls/personal protection	Exposure limits are shown if these apply to the substance. They are based on repeated occupational exposure usually on a timed average period. The levels of personal protective equipment (PPE) recommended are unlikely to be considered in the fire and rescue service context. The advice in this section should therefore be treated with caution. It may be more useful when downgrading levels of protection from chemical protective clothing (CPC).
9	Physical and chemical properties	Potentially a useful source of information, but does require interpretation of the information provided
10	Stability and reactivity	<p>Will detail any known reactions, particularly if likely to be violent or producing toxic or flammable gases. Most SDS contain phrases in this section such as 'avoid contact with strong acids, bases or oxidisers'. However, most materials will react with these substances.</p> <p>Should indicate the known products of combustion. While all smoke should be considered as toxic, particular attention should be taken to the toxicity of smoke where it contains other products of combustion in addition to carbon (e.g. Cl, HCl, S, N, P, K, F, Br, I, CN).</p>
11	Toxicological information	<p>Values are indicated by route of exposure and measured in either LC₅₀ or LD₅₀, i.e. the lethal dose per kg of bodyweight required to kill 50 per cent of the sample size (typically rats). Lower values therefore indicate more toxic substances.</p>

Section number	Heading	Useful information
12	Ecological information	Typically indicates the eco-toxicity of a material (for example, in removing dissolved oxygen in the marine or freshwater environments) or gives an indication of persistence or bioaccumulation. Best used to assess the degree of the hazard.
13	Disposal considerations	Details how to dispose of hazardous waste involving the substance. Typically, the advice will be to contact the local authority or a waste management company.
14	Transport information	If the substance has a UN number, it will be given in this section. Emergency action codes (EAC) should also be listed, if applicable.
15	Regulatory information	If the substance is classified as hazardous for supply (or use), (i.e. it has hazard and precautionary statements), then these will be listed in this section. Hazard and precautionary statements will indicate potential longer term health effects, which are not reflected in UN number criteria (e.g. carcinogens, mutagens).
16	Other information	Any other information that the author wishes to consider. Will usually contain the date and revision number of the document.



Physical and chemical properties and reactivity

Many sources of explanation of the various physical and chemical properties of materials may be found in sections 9 and 10 of a safety data sheet (SDS). For further information on physical properties see [Physical Properties of Matter](#).



Detection, identification and monitoring (DIM) equipment

Using detection, identification and monitoring (DIM) equipment should be considered in appropriate circumstances such as when:

- There is a need to quickly ascertain the possibility of a chemical, biological, radiological and nuclear (CBRN) incident
- There are few other clues to the identity of the material, e.g. an unknown substance such as a white powder is found
- Serious consequence substances (e.g. anthrax, whether hoax or false alarm) need to be ruled out so that the incident can be scaled down quickly
- Equipment is available to monitor the levels of a known substance and a particular hazard; this can support the correct establishment of safety cordons
- When dealing with incidents involving a hazardous substance, the potential time delay in obtaining and setting up DIM should be considered. Where generic response plans are deemed safe for emergency responders to intervene with no further information, response should not be delayed.
- Where the results obtained from DIM equipment are inconclusive or contradictory, further advice on their interpretation may be sought from scientific advisers. Other analytical methods such as pH paper, flammability and solubility tests etc may be used to detect, identify and monitor substances.



Electronic information sources

Many electronic and database systems are available, each with its advantages and disadvantages.

Chemdata® is a chemical hazards and identification database developed by the National Chemical Emergency Centre (NCEC) specifically with fire and rescue service users in mind. It is the most widely used chemical database in UK fire and rescue services. Chemdata® is searchable by name, part name, UN number, etc. and contains information on both hazardous (UN number) and non-hazardous products, trade name products (mixtures) and pure chemicals. Designed around the emergency action code (EAC) approach, it gives clear advice as well as information on the associated chemical hazards and required personal protective clothing, adverse chemical reactions and hazardous combustion by-products, exposure guidelines and first aid advice. Protective action distance information from the emergency response guidebook (ERG) is also included. The software is available as a standalone PC application, as part of a networked system or as an application for most fire and rescue service mobile data terminals (MDTs). Chemdata® is also available on

smartphones and palm-top personal organisers (Pocket Chemdata®) and is licenced to users on an annual subscription.

The Emergency Response Guide is an electronic application (app) database based on the Emergency Response Guidebook (ERG) that provides emergency responders with an interactive version of the book. The information contained in the electronic version is the same as in the book. The programme enables users to search by UN hazard symbol (warning diamond), UN number, class or by named substance. Information is provided in the form of numbered guides that apply to substances with similar hazards and properties. Additional tables show suggested protective action distances (these are not evacuation distances although that is what they are commonly called).

Wireless Information System for Emergency Responders (WISER) is a system to assist first responders in hazardous material incidents. WISER provides a wide range of information on hazardous substances, including substance identification support, physical characteristics, human health information and containment and suppression advice. WISER displays the appropriate advice based on designated roles (e.g. first responder, hazardous materials adviser). WISER also includes some information from the Emergency Response Guide. Where an internet connection is available, WebWISER allows the user to use their web browser to access the same functionality as the standalone applications.

Computer-Aided Management of Emergency Operations (CAMEO) is a suite of programs provided free of charge through the United States Environmental Protection Agency (US EPA) that includes:

- CAMEO itself, which contains response recommendations for over 6,000 chemicals. The database also contains over 100,000 American chemical synonyms and identification numbers, which aid emergency responders in identifying substances during an incident. The search engine gives access to datasheets on each chemical, providing physical properties, health hazards, information about air and water hazards and recommendations for firefighting, first aid and spill response.
- The CAMEO Chemicals database, which includes information about the intrinsic hazards of each chemical and whether a chemical reacts with air, water, or other materials. It also includes case histories on specific chemical incidents, with references. This free resource can be downloaded and installed on a desktop or laptop. CAMEO Chemicals uses the same chemical database as CAMEO.
- A reactivity worksheet database of reactivity information for more than 6,000 common hazardous chemicals, which details the dangers from accidental mixing.
- The Aerial Locations of Hazardous Atmospheres (ALOHA), which is an atmospheric dispersion model used for evaluating releases of hazardous chemical vapours. ALOHA allows the user to estimate the downwind dispersion of a chemical cloud based on the characteristics of the released chemical, atmospheric conditions, and specific circumstances of the release.
- MARPLOT, a mapping program developed jointly by the National Oceanic and Atmospheric Administration (NOAA) and the Environmental Protection Agency (EPA). It runs on both Windows and Macintosh computers.
- CAMEO Companion, developed by the Arizona Emergency Response Commission, is a written help resource for all CAMEO Suite users, particularly those who use the software on an occasional basis. CAMEO Companion provides explanations and step-by-step instructions to help CAMEO users perform emergency response and planning activities learned in CAMEO training classes.

Emergency Response Intervention Cards (ERICards)

Emergency Response Intervention cards is a database of initial actions for first responders when they arrive at the scene of a chemical transport accident. It is based on the UK emergency action code (EAC) and on the ADR Hazard Identification Number (HIN). ERICards are therefore intended to deal with chemical accidents involving a substantial amount of product, occurring during land transport only and may therefore not be appropriate for other incidents. They are also not available for every UN number. Searches can be made for substance name, UN Number, ADR label, the HIN or the ERICards reference if known.

Chem-Exper

The Chem-Exper website is a freely accessible, online database of chemicals. It is an open site that invites chemical manufacturers and laboratories to register their products and supply safety data sheets. The website provides links to the organisation that registered the product should further information be required by the user. The website currently contains information on over 200,000 chemicals and formulations, with 10,000 SDS and 10,000 infrared (IR) spectra. The directory can be searched by chemical name or synonyms (in different languages), registry number (CAS or EC numbers) and by physical or chemical characteristics.

ChemIDplus Advanced

This is a search engine produced by the US National Library of Medicine for databases of chemical physical and toxicological properties.

Pesticides Register of UK Approved Products

The Pesticides Register of UK Approved Products is produced by the Health and Safety Executive. This online application allows the user to search for information on plant protection products (PPPs) with on-label approvals. Searches can be made by specific approval features, changes in the pesticide register and by searches relating to products subject to phased revocation.

More internet links

Databases on toxicology, hazardous chemicals, environmental health, and toxic releases:

<http://toxnet.nlm.nih.gov/>

Profiles of some very common HazMats:

www.ccohs.ca/oshanswers/chemicals/chem_profiles/

Public Health England Compendium of Chemical Hazards:

<https://www.gov.uk/government/collections/chemical-hazards-compendium>

HSE asbestos information:

www.hse.gov.uk/asbestos/

HSE radiation information:

www.hse.gov.uk/radiation/ionising/index.htm

National Chemical Emergency Centre (NCEC):

www.the-ncec.com/

NIOSH database:

<http://www.cdc.gov/niosh/data/>

Documentation for Immediately Dangerous to Life or Health Concentrations (IDLH):

www.cdc.gov/niosh/idlh/intridl4.html

Safety Data Sheets Links:

www.ilpi.com/msds



Printed information sources

The Dangerous Goods Emergency Action Code (EAC) List

Provider: National Chemical Emergency Centre (NCEC). Published by TSO.

The book is revised every two years to be in line with any changes made to the Transport of Dangerous Goods Regulations (RID and ADR agreements). The publication provides the first responder with advice when confronted with a bulk transport incident involving hazardous materials. Duty holders are required to use the publication to apply emergency action codes (EACs) to bulk loads containing dangerous goods. This is required under the Carriage of Dangerous Goods and Use of Transportable Pressure Equipment Regulations 2009 (CDG 2009).

EACs are a valuable tool for the first responder as the codes provide immediate initial information. The document also supplies information on the additional personal protection codes (APP) that may be assigned to a hazardous material. The assignment of EAC and APP codes is based on the physical and chemical properties of a given material.

Emergency Response Guidebook (ERG)

Provider: US Department of Transportation (DOT), Transport Canada and the Secretariat of Communications and Transportation of Mexico (SCT).

This publication is written for first responders, firefighters, police and ambulance crews when responding to a transport emergency involving hazardous materials. It is updated and re-issued every four years. The book is divided into five-colour-coded sections and has been written to be used during the first thirty minutes of an emergency situation by agencies that may be the first to arrive at an incident. After identifying the substance, the relevant guide number to follow is selected. The book also contains details of initial isolation and protective action distances, which are commonly, but erroneously, referred to as evacuation distances.

A UK version of this publication is also available.

EH40 Workplace Exposure Limits and Amendments

Provider: The Health and Safety Executive (HSE)

This is the hard copy list of workplace exposure limits for use with the Control of Substances Hazardous to Health Regulations 2002 (as amended). The exposure limits it contains are therefore legally binding.

The 2005 edition of these regulations departed from the old system for setting occupational exposure limits (OELs). The old system used OELs set as maximum exposure limits (MELs) and occupational exposure standards (OESs). The new format now uses single OELs, which are workplace exposure limits (WELs).

Until 2005 it had been standard practice for the Health and Safety Executive (HSE) to publish a new edition of the EH40 document, or an amendment, each year. However, with increased internet use, the HSE no longer publishes a revised hard copy. Hence, there was an amendment to the document in 2006 and again in 2007. These revisions should have been sent out to the recipients of the hard copy published in 2005.



Product-specific aid schemes

A number of industry-led schemes are in operation for specific chemical products where, due to the nature of the hazards of the material or the specific expertise needed to effect a response, the manufacturers co-operate to provide emergency assistance to the emergency services.

In the case of the specialist aid schemes listed, general scientific advisers may have neither the expertise nor the experience to handle them in the quantities likely to be involved in an incident. Immediate contact with the specialist organisation is essential as major incident could easily result from incorrect actions

If a response from one of these schemes is required, the contact details should be used where provided; where these are not available contact the NCEC Chemsafe line (01235 836002). The schemes below are known to be operating in the UK.



Acrylonitrile / medical

For acrylonitrile/medical products, an emergency response manual and a mutual aid scheme of the European acrylonitrile/medical producers exists. All acrylonitrile/medical producers involved in transporting acrylonitrile/medical products in Europe should have an established procedure for receiving transport incident reports and for being able to give expert advice on how to minimise any danger arising from an incident on road, rail or waterway/sea.

The firm delivering the acrylonitrile/medical products (the supplying company) is under an obligation to take action when notified of any transport incident. The supplying company can request that another firm (the assisting company) take action, such as when an assisting company is closer to the scene of the incident.

The assisting company takes the place of the supplying company on its behalf until the representatives of the supplying company reach the scene of the incident.



Bromaid

Bromine (Bromaid) is a pan-European organisation of the three main bromine suppliers. It provides mutual emergency response support to the emergency services on a geographical basis, regardless of whose bromine equipment may be involved in an incident.

In the UK, the response is provided by Chemtura and its agents, who have received bromine specific training and have the appropriate equipment to provide support to the emergency services at the scene of an incident. The target is to attend the scene within four hours and for the equipment (based at Droitwich, West Midlands) to be at the scene within eight hours.

The 24-hour emergency number for Chemtura in the UK is: 0208 762 8322.



ChlorAid

Chlorine (ChlorAid) is a product-specific scheme for providing mutual assistance for incidents involving chlorine. The scheme provides three levels of emergency support:

- Level 1 – telephone advice
- Level 2 – incident attendance by a product specialist
- Level 3 – incident attendance by an emergency response team (INEOS ChlorVinyls will provide the response to the incident)

INEOS ChlorVinyls provides an external chemical emergency service (ECES), primarily for all products manufactured at its sites in the UK. This capability consists of a specially equipped vehicle and safety equipment for attending an incident involving chemicals. INEOS ChlorVinyls personnel are specifically trained in assisting with such emergencies and can be made available at the request of customers, local authorities and the emergency services.

In case of a UK distribution or chemical emergency involving exposure, leaks or spills, contact:

ChlorAid (INEOS ChlorVinyls External Chemical Emergency Service)

UK Mainland - 01928 572000

Ireland and Northern Ireland – 00353 (1)401 3500

INEOS ChlorVinyls Runcorn Site Emergency Services Department:
01928 512222

www.ineoschlor.com



Ethylene oxide

Shell Chemicals Europe (SCE) transports ethylene oxide (EO) from supply points across Europe to a number of customer sites across the United Kingdom. In the event of a distribution emergency involving EO, Shell Chemicals Europe will initiate their emergency procedures and provide assistance.

In the event of an incident involving EO, the requirement is to ensure a competent responder can be at the scene as quickly as possible. With that objective, EO customers in the UK participate in a mutual aid scheme for EO distribution emergencies. This enables a more rapid response.

Shell Chemicals Europe accepts the general obligation to respond to EO distribution emergencies and remains in charge of the overall incident response and co-ordination. The mutual aid company acts on behalf of Shell Chemicals Europe until a nominated responder reaches the scene.



Isocyanates (ISOPA)

Isocyanates (ISOPA) represents European manufacturers of aromatic diisocyanates and polyols, the main raw materials for polyurethanes. The European isocyanate and polyol producers who are members of ISOPA have established a system of mutual aid to deal with potential emergencies arising during the transportation of toluene diisocyanate (TDI), diphenylmethane diisocyanate (MDI), or their derivatives, in Europe. ISOPA have produced an emergency response manual for the transport of TDI and MDI, which is designed to strengthen existing national and company communications when dealing with TDI and MDI.

If any difficulty occurring during transportation of a shipment of either TDI (UN Number 2078) or MDI (UN Number 2489), or their derivatives, is forwarded by one of the participating companies, it request another company closer to the scene of the incident to intervene on their behalf.

In this context, transportation is taken to mean all of the activities associated with the transport unit, including unloading.

Each of the companies may be requested to provide assistance from an appropriate emergency response centre. For further details, see:

www.isopa.org



Titanium tetrachloride

Assistance in the event of incidents involving titanium tetrachloride, TiCl_4 or 'tickle' is organised by the Titanium Dioxide Manufacturers Association (TDMA). The main UK member is Huntsman Pigments (Teesside). The scheme can be invoked by contacting the National Chemical Emergency Centre Chemsafe number.



Interpreting and using

information

The first step in obtaining information on the nature of the hazardous materials involved in the incident is their correct identification.

Identifying chemical substances can be difficult, not least because of the range of names, numbers and symbols used to identify them. Various types of chemical names are used to describe both pure chemical substances (those not containing a mixture) and preparations (usually a mixture of other chemical substances).

Emergency responders should always use the phonetic alphabet to spell any chemical or product name; the misspelling of a single letter can have significant safety implications.

United Nations (UN) numbers

UN numbers are discussed earlier in this document (The UN system). These four digit numbers can be a means to identify either a specific substance or a group of substances sharing the same characteristics (e.g. flammable liquids that are not listed individually). The numbers can then be used to access emergency response advice from reference sources such as Chemdata or Emergency Response Guidebook (ERG).

EC numbers

The European Commission number, or EC number, also known as EC-No and EC#, is the code assigned to chemical substances that are commercially available within the European Union.

The EC number is made up of seven digits according to the pattern xxx-xxx-x, with the single digit operating as a check digit as in the CAS system (but using a different check algorithm). The EC inventory includes substances from the following inventories:

European Inventory of Existing Commercial Chemical Substances (EINECS)

- European List of Notified Chemical Substances (ELINCS)
- No Longer Polymers (NLP)
- Interpreting safety data sheets



Systematic or International Union

of Pure and Applied Chemistry (IUPAC)

These names are designed to give the fullest possible information about the molecular structure of a substance. Systematic naming of an organic compound generally requires the identification and naming of a parent structure. This name may then be modified by prefixes, infixes, and suffixes, which convey precisely the structural changes required to generate the actual compound from the parent structure.

Systematic names for complicated molecules can be very complex and many attempts have been made in the past to tackle the problem. The most important system of systematic names currently in use is that devised by the International Union of Pure and Applied Chemistry (IUPAC).

For example, the name 1,1,1 - trichloroethane tells us that the substance is a chloroalkane (chloro - means it contains chlorine and the - ane ending means it is an alkane) with two carbon atoms (- eth-, short for ethyl) and three chlorine atoms (trichloro-), all situated on the first of the two carbon atoms (1,1,1-) denoting their position.

The exact spelling of systematic names may be important when retrieving chemical information from electronic databases, although some databases are able to cope with, for example, missing numbers or similar spellings as well as trivial name alternatives.



Trivial (common names)

These are names given to a substance that may be in common use but do not usually describe the chemical structure of the substance. Trivial names are used because they are simpler to remember and often shorter.

Examples (with their systematic names) are shown in table 13 below:

Table 13 Trivial and systematic naming of substances

Trivial (common) name	Systematic name
Formic acid	Methanoic acid
Common salt	Sodium chloride
Formaldehyde	Methanal

Trivial (common) name	Systematic name
Toluene	Methyl benzene
MEK or methyl ethyl ketone	2-butanone



Commercial and trade names

These are names that have been designated by a chemical manufacturer, usually to describe a proprietary preparation although sometimes they can be used to describe a pure chemical substance. Some have entered into common usage, for example nylon, aspirin and Teflon®. These names have the advantage of being unique and usually more memorable than systematic or even trivial names.

Other examples of trade names include:

- Roundup
- Jeyes Fluid
- Castrol GTX

The only sources of information on trade name products is often a safety data sheet completed by the manufacturer or a product expert. However the chemical database used in the UK - Chemdata - contains information on a number of trade-named products.



Synonyms

A synonym is an alternative name for a substance. Synonyms can be a combination of systematic, trivial or even trade names. A possible difficulty encountered when seeking information about a substance is that it may have many synonyms and some reference sources may list the information under a different synonym with no cross-referencing given. Better reference sources list the various synonyms and offer cross-referencing.



Chemical Abstracts Service (CAS) registry numbers

Chemical Abstracts Service (CAS) registry numbers are unique numerical identifiers for chemical elements, compounds, polymers, biological sequences, mixtures and alloys. They are commonly referred to as CAS numbers. CAS is a division of the American Chemical Society and assigns these identifiers to every chemical that has been described in the literature. The intention is to make database searches more convenient, as chemicals often have many names. A CAS registry number is separated by hyphens into three parts, the first consisting of up to seven digits, the second consisting of two digits, and the third consisting of a single digit serving as a check digit. The numbers are assigned in sequential order and do not have any inherent meaning.



United Nations (UN) numbers

UN numbers are discussed earlier in this document (The UN system). These four digit numbers can be a means to identify either a specific substance or a group of substances sharing the same characteristics (e.g. flammable liquids that are not listed individually). The numbers can then be used to access emergency response advice from reference sources such as Chemdata or Emergency Response Guidebook (ERG).



EC numbers

The European Commission number, or EC number, also known as EC-No and EC#, is the code assigned to chemical substances that are commercially available within the European Union.

The EC number is made up of seven digits according to the pattern xxx-xxx-x, with the single digit operating as a check digit as in the CAS system (but using a different check algorithm). The EC inventory includes substances from the following inventories:

European Inventory of Existing Commercial Chemical Substances (EINECS)

- European List of Notified Chemical Substances (ELINCS)
- No Longer Polymers (NLP)
- Interpreting safety data sheets



Met Office Hazard Manager

The Met Office provides a range of services that help authorities prepare for and respond to emergencies that are caused or influenced by the weather. These services are linked to advice available from teams of Met Office forecasters, specialist scientists and advisers on the interpretation and impact of the weather during an emergency. This service is co-ordinated through the Met Office team of regionally-based public weather service (PWS) advisers who can be called on to provide advice at a strategic command and control centre.

As these systems are all models, they will all have certain limitations for example, height at which wind direction is taken, location of weather stations and their proximity to the incident. Therefore these systems should be used in conjunction with local visual indicators for example, windblown tree foliage, improvised weather socks etc. This should be established on arrival at any incident so that crews are not exposed to hazardous vapours or gases. Always bear in mind that wind strength and direction can change, so ensure personnel and vehicles have clear, immediately available means of egress

Hazard Manager is intended to be a one-stop information source for the emergency response community, allowing access to all services in one location by using a single username and password.

The services currently available on Hazard Manager are:

- Flood Forecasting Centre with Extreme Rainfall Alert updates
- Interactive Map Viewer with weather information
- National Severe Weather Warning Service
- Emergency Support
- FireMet and CHEMET services

Hazard Manager is designed to supplement the role of the public weather service PWS advisers in providing consistent weather-related information and interpretation for the UK emergency response community.



Accessing Hazard Manager

Accessing Hazard Manager

Anyone who works for a Category 1 or Category 2 organisation (as defined in the Civil Contingencies Act 2004) can access Hazard Manager. However, some of the services available through this portal are restricted to approved users. For example, Flood Forecasting Centre products are only available for England and Wales, and FireMet and CHEMET are only available for subscribed users.

Users need to register to access the services required. This is confirmed by an email with an activation link.



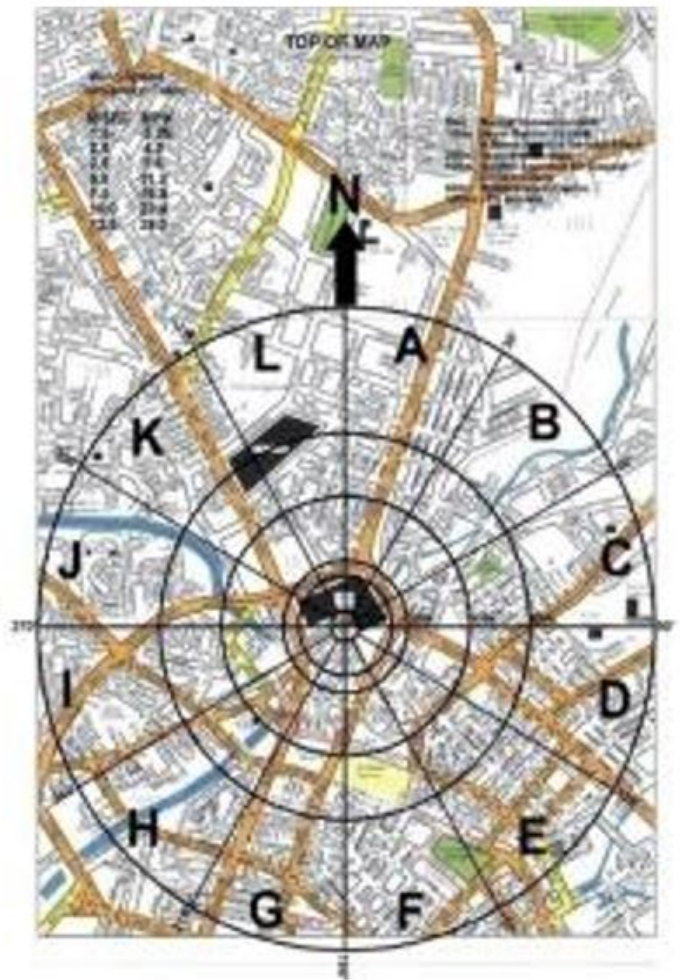
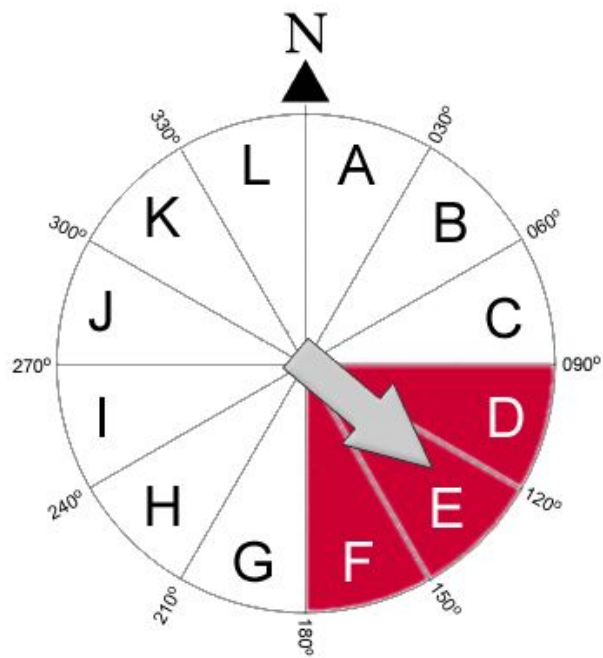
FireMet

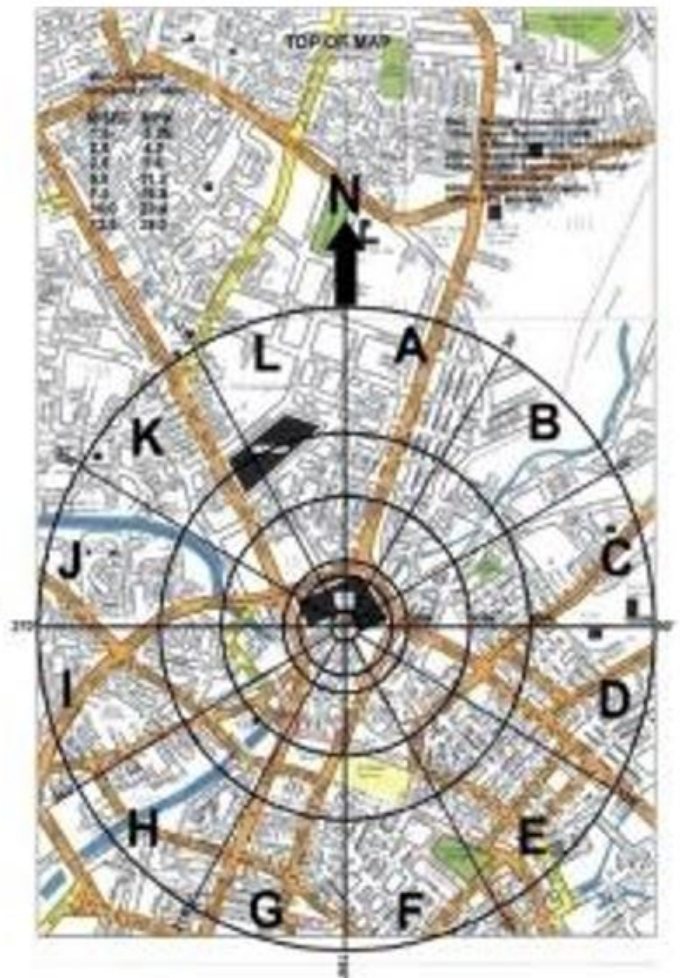
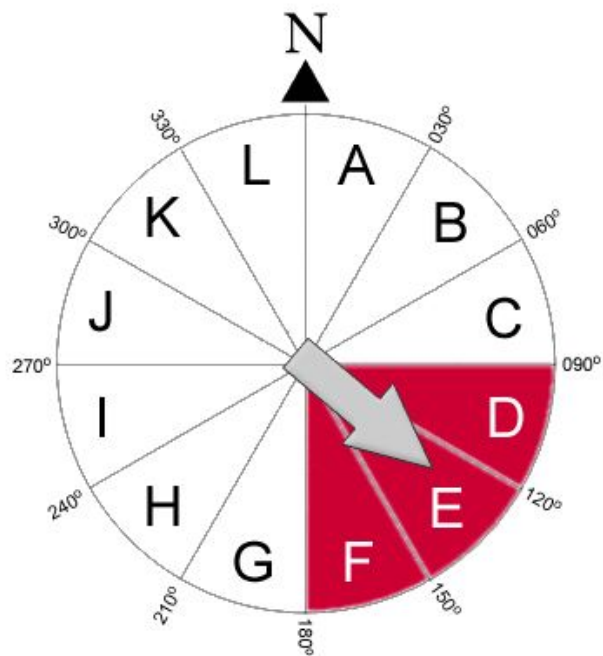
FireMet is a weather system designed by the UK's Met Office in collaboration with the Department for Communities and Local Government (DCLG) to provide fire and rescue service responders with the latest weather information to help them identify a safe approach when dealing with a major incident. FireMet is a password-protected, web-based system available to all fire and rescue service incident command units, fire control rooms and detection, identification and monitoring DIM units, as well as the National Co-ordination Centre. It is not available to the general public or other users.

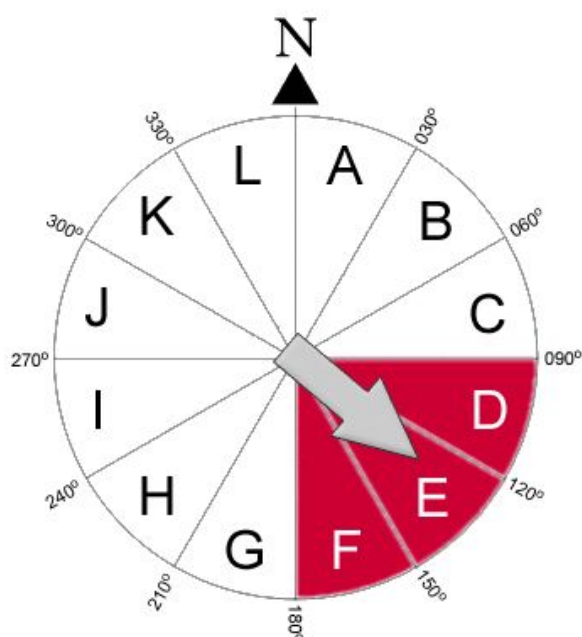
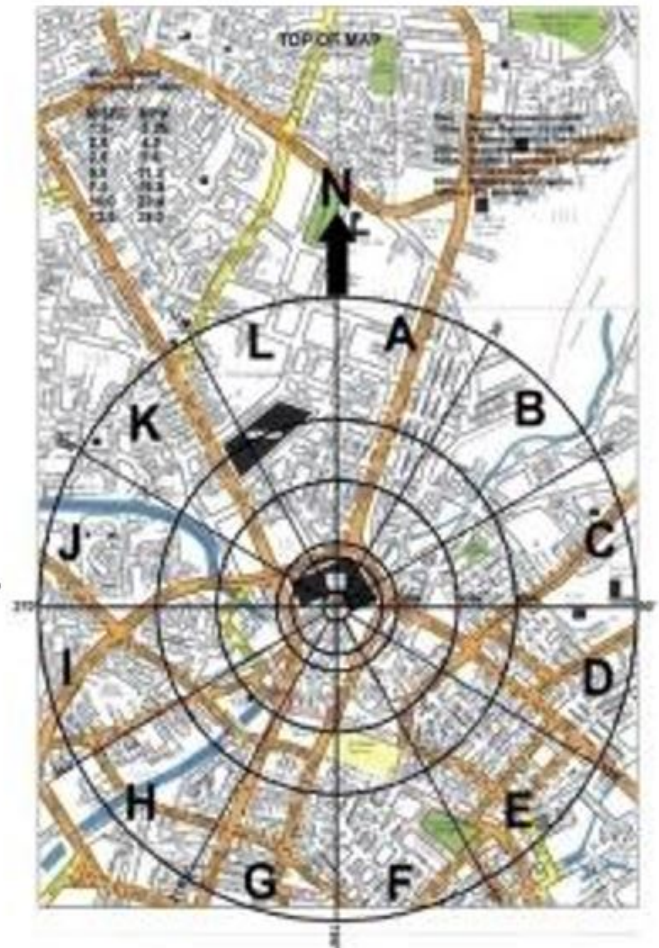
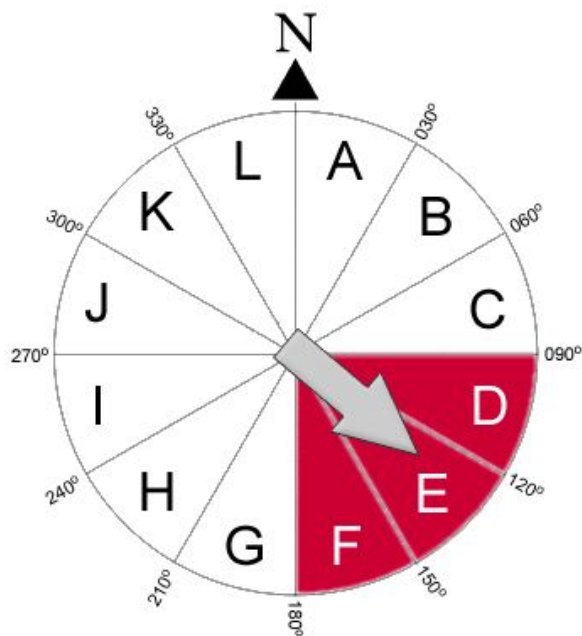
FireMet aims to provide immediate access to forecast conditions, while waiting for a more detailed CHEMET report. It also provides three hours' of hindcast (backward looking) data, as well as three hours of forecast data.

Users log in to the site using a previously obtained username and password. They are then required to enter location information based on postcode, GB or NI OS grid reference or numerical grid reference. The output indicates the direction of the wind and sectors most likely to contain any wind-borne hazard, which are coloured red. This can be overlaid on a map to indicate the routes of approach offering the least risk to fire and rescue service responders.

The images below show the web-site examples of Firemet:









Chemical meteorology (CHEMET)

At an incident involving hazardous chemicals, local fire and rescue services and police services can contact the Met Office, Environment Monitoring and Response Centre (EMARC). Typical scenarios could be a chemical spillage, a fire at a chemical plant or oil refinery or a road traffic collision in which a hazardous substance has been released. For small-scale events, EMARC produces meteorological guidance and a plume prediction as a chemical meteorology (CHEMET) report. For larger release events, such as the Buncefield Oil Depot fire, more sophisticated plume-modelling techniques are used.

A CHEMET report has two parts.

CHEMET Form A contains the input data, which consists of the incident details including grid reference of the location, time of the event and any additional information on the chemicals involved. If available it can also include details of the current weather at the site. The Form A is completed by the emergency services and forwarded to EMARC.

CHEMET Form B contains the weather forecast information along with an area at risk map. Image 6 gives one example of a risk map.

The advantages of using CHEMET are:

- Quick response – typically within 20 minutes of providing Form A information
- Delivered by fax or email
- Easily identifiable area of risk
- Sufficient for most short-lived incidents

The limitations of CHEMET are:

- It will not give information on chemical concentrations and therefore dilution down-wind
- It does not take into account extreme heat
- It does not take into account topography of the area (e.g. where the land down-wind is raised and thus has may divert the plume from the predicted area)
- No information is given on deposition
- It only provides 'short period' information; the wind direction or weather can change suddenly



Numerical Atmospheric-

dispersion Modelling Environment (NAME) dispersion model

Numerical Atmospheric-dispersion Modelling Environment (NAME) dispersion model

Numerical Atmospheric-dispersion Modelling Environment (NAME) is an atmospheric pollution dispersal model that is a much more sophisticated tool than CHEMET for pollution forecasting. It can:

- Simulate the effect of fires
- Forecast air quality up to 36/48 hours ahead
- Take into account the chemical involved
- Show deposition, air concentration and height of the plume
- Predict long-standing air pollution problems such as acid rain
- Forecast international movement of pollutants

NAME would generally be used for prolonged incidents, as models take longer to produce than CHEMET. It is ideally suited for incidents involving extreme heat, explosive releases where the contaminant is forced above the boundary layer (e.g. Buncefield Oil Depot fire) and nuclear incidents.



Notification and marking of sites regulations (NAMOS)

Notification and marking of sites regulations (NAMOS) regulations came into force on 1 September 1990 and were amended in 2013 when the Notification of Installations Handling Hazardous Substances Regulations 1982 (NIHHS) were repealed.

Under the regulations, if a total of 25 tonnes or more of dangerous substances is present on-site at any time the site controller must notify the fire and rescue authority and the enforcing authority in writing. For the purpose of the regulations, 'dangerous substances' means any substance that falls within the definition of the current edition of the Carriage of Dangerous Goods and Use of Transportable Pressure Equipment Regulations.

In addition to this general requirement, from 2013 sites with 150 tonnes or more of 'relevant ammonium nitrate mixtures' must inform the fire and rescue authority but not the enforcing authority. Relevant ammonium nitrate mixtures are those with a nitrogen content greater than 15.75% but do not meet the requirement to be labelled as oxidising. Once mixtures meet the requirements as an oxidiser, the general 25 tonnes threshold will apply.

The fire and rescue authority is the enforcing authority for these regulations, except that under Regulation 4: Notification, the enforcing authority will be either the Health and Safety Executive (HSE) or the local authority.

Under Regulations 5: Access marking, Regulation 6: Location marking and Regulation 7: Signs to be kept clean, etc., the enforcing authority will be the local fire and rescue authority, with the exception of:

- Local authority, fire or police premises
- Crown property (except the Health and Safety Executive (HSE))
- UK Atomic Energy Authority (UKAEA) property
- Military establishments (UK or visiting)

In these cases the Health and Safety Executive (HSE) will be the enforcing authority.

Sites with only 'Relevant ammonium nitrate mixtures' are exempted from the regulations requiring marking and they are not required to display signage.

Although the person in control of a site does not have to notify the total quantities on site, they will be required to assess total quantities to know whether they are required to make a notification under the regulations. They should therefore take into account any quantities present in:

- Vehicles or vessels used for storage purposes (tanks, containers, drums) after unloading
- Vehicles used for on-site transportation
- Materials used for cleaning, etc.
- Process, manufacture or storage



Access marking

If there are more than 25 tonnes of dangerous substances on-site at any one time, the person in control of the site should ensure that safety signs displayed are sufficiently clear so they give adequate warning to firefighters in an emergency. Image 3 shows the safety sign for access marking.



Image 3: Access sign

Signs should be placed in conspicuous positions close to site entrances that could reasonably be expected to be used by firefighters. They may be free-standing or fixed to fences, railings, faces of buildings, etc.



Location marking

At a site storing a total of 25 tonnes or more of dangerous substances, an inspector may direct the person in control of the site to display safety signs at specified locations. These directions will only be given where the inspector is satisfied, on reasonable grounds that:

- 25 tonnes or more of dangerous substance are, or are liable to be, present
- Signs are necessary to warn firefighters of the presence of dangerous substances at these locations in an emergency

Safety signs deemed to be necessary shall:

- Be warning signs as defined by paragraph 3.2 of part II of schedule 1 to the Health and Safety (Safety Signs and Signals) Regulations 1996
- Bear the hazard warning symbol and hazard warning text

The access marking sign bearing the exclamation mark should be displayed with the text 'Dangerous Substance' where two or more substances with different classifications are stored at the same site

Signs do not have to be displayed at the site when dangerous substances are not present



Reference to 'the site' means at or in the vicinity of the site location.

The person in control of the site shall, as far as is reasonably practicable, ensure that any safety signs displayed at the site (to provide access and location marking) are kept clean and free from obstruction.

These regulations do not apply to nor bear relation to:

- Dangerous substances buried or deposited in the ground as waste
- Radioactive substances (only hazard)
- Substances that are classified as Class 1 goods under the Classification and Labelling of Explosives Regulations 1983, within the meaning of:
 - The Carriage of Dangerous Goods and Use of Transportable Pressure Equipment regulations
 - The International Maritime Dangerous Goods Code
 - The Technical instructions for the Safe Transport of Dangerous Goods by Air
- Aerosol dispensers (unless labelled in accordance with the Carriage of Dangerous Goods and Use of Transportable Pressure Equipment Regulations)
- Access and location marking regulations do not apply to petroleum filling stations.

The Health and Safety Executive (HSE) has the power to grant general or special exemptions and to impose conditions and time limits on them. Before granting any exemption, the HSE would have to consider the circumstances of the case and consult any bodies likely to be affected.

Classification	Hazard warning symbol and text
Non-flammable compressed gas	Compressed gas
Toxic gas	Toxic gas
Toxic substance	Toxic
Flammable gas	Flammable gas
Flammable liquid	Flammable liquid
Flammable solid	Flammable solid
Spontaneously combustible substance	Spontaneously combustible substance
Substance that emits flammable gas when it comes into contact with water	Dangerous when wet
Oxidising substance	Oxidising agent
Organic peroxide	Organic peroxide
Corrosive substance	 Corrosive
Harmful substance Other dangerous substance Mixed hazards	 Dangerous substance



The Control of Major Accident Hazard Regulations (COMAH)

The Control of Major Accident Hazards Regulations (COMAH) implemented the Seveso-III (Directive 2012/18/EU) in Great Britain (Control of Major Accident Hazards Regulations (Northern Ireland) 2015), except for land-use planning requirements, which are implemented by changes to planning legislation. They replaced the Control of Industrial Major Accident Hazards Regulations 1984 (CIMA) which implemented the original Seveso Directive (82/501/EEC). They came into force on 1 April 1999, were amended by the Control of Major Accident Hazards (Amendment) Regulations 2005 and subsequently replaced by the current Control of Major Accident Hazards Regulations 2015.

Their purpose is to prevent major accidents involving dangerous substances and limit the consequences to people and the environment of any that do occur. COMAH applies mainly to the chemical industry, but also to some storage activities, explosives and nuclear sites, and other industries where threshold quantities of dangerous substances identified in the Regulations are kept or used.

COMAH is enforced by the Health and Safety Executive (HSE) and the relevant environment agencies – the Environment Agency (EA), the Scottish Environment Protection Agency (SEPA), and Natural Resources Wales (NRW) - working together as the COMAH Competent Authority (CCA). Operators will generally receive a single response from the CCA on all matters relating to COMAH.

The mechanism for determining whether COMAH applies has been simplified: an establishment with any listed substance present above the qualifying quantity is subject to the Regulations. There are two thresholds, known as lower-tier and top-tier. Further details can be found in the COMAH regulations and accompanying guidance.

Even if substances are not present at an establishment in threshold quantities, the establishment may still be subject to the Regulations if specified dangerous substances could be produced in threshold quantities as a result of the loss of control of an industrial chemical process.

Where the Secretary of State holds an exemption with respect to COMAH, the Major Accident Control Regulations (MACR) for the Ministry of Defence (MoD) are intended to discharge the Secretary Of State for Defence requirement to have arrangements in place that are at least as good as those required by statute

More information on the Regulations and how to comply with them can be found on the Health and Safety Executive website.

Lower-tier duties

If the lower-tier threshold is equalled or exceeded, operators must notify the competent authority. The local Health and Safety Executive office should be notified; they will pass the details to the relevant environment agency office.

Operators of all establishments subject to the Regulations must notify certain basic details to the competent authority. The key points that must be included in the notification are:

- Name and address of the operator
- Address of the establishment
- Name or position of the person in charge
- Details of the dangerous substances on site (a breakdown is required for petroleum products)
- Site activities
- Environmental details

Site operators must take all necessary measures to prevent major accidents and limit their consequences to people and the environment.

This is the general duty on all operators and underpins all the regulations. It is a high standard and applies to all establishments within scope. Requiring measures both for prevention and mitigation recognises that all risks cannot be completely eliminated. This in turn implies that proportionality must remain a key element in the enforcement policy of the Health and Safety Executive and the environment agency. Thus, the phrase 'all measures necessary' will be interpreted to include this principle and a judgment will be made about the measures in place. Where hazards are high, then high standards will be required to ensure risks are acceptably low, in line with Health and Safety Executive and environment agency policy that enforcement should be proportionate. Prevention should be based on the principle of reducing risk to a level as low as is reasonably practicable (ALARP) for human risks and using the best available techniques (BAT) for environmental risks. The ideal should always be to avoid a hazard altogether wherever possible.

The Regulations require lower-tier site operators to prepare a document setting out their policy for preventing major accidents; this is known as a major accident prevention policy or MAPP.

The MAPP will usually be a short and simple document setting down what is to be achieved but it should also include a summary and further references to the safety management system that will be used to put the policy into action. The detail will be contained in other documentation relating to the establishment (e.g. plant operating procedures, training records, job descriptions, audit reports) to which the MAPP can refer.

The MAPP must also address issues relating to the safety management system. The key areas are:

- Organisation and personnel
- Identification and evaluation of major hazards
- Operational control
- Planning for emergencies

- Monitoring, audit and review

Top-tier duties

If any top-tier threshold is equalled or exceeded, the operator must comply with additional requirements.

Site operators must prepare a safety report; a safety report is a document that provides information to demonstrate to the competent authority that all measures necessary to prevent and mitigate major accidents have been taken.

The safety report must include:

- Policy on how to prevent and mitigate major accidents
- Management systems for implementing that policy
- Effective methods for identifying any major accidents that might occur
- Measures (such as safe plant procedures and safe operating procedures) to prevent and mitigate major accidents
- Information on the safety precautions built into the plant and equipment when it was designed and constructed
- Details of measures (such as firefighting, relief systems and filters) to limit the consequences of any major accident that might occur
- Information about the emergency plan for the site, which is also used by the local authority in drawing up an external emergency plan

Safety reports will be available to the public via the competent authority registers, subject to safeguards for national security, commercial and personal confidentiality.

Site operators must update the safety report after significant changes, new knowledge about safety matters or every five years.

Safety reports need to be kept up to date. If there are any modifications to the plant or the way it is operated or if new facts or information become available, the safety report must be reviewed and, if necessary, revised at the time. It must be reviewed after five years even if there have not been any changes. The operator must notify the competent authority of any revision, and also if the five-year review does not lead to a revision.

Site operators must prepare and test an on-site emergency plan

Top-tier operators must prepare an emergency plan to deal with the on-site consequences of a major accident.

Site operators must supply local authorities with information for off-site emergency planning purposes.

Local authorities (the fire and rescue service in London and other metropolitan areas) play a key role by preparing, reviewing, revising and testing external emergency plans for dealing with the off-site consequences of major accidents at top-tier sites. To fulfil this role they need information from

operators. Operators will need to hold discussions with their local authorities to determine their exact needs.

Site operators must provide certain information to the public about their activities

People who could be affected by an accident at a COMAH establishment must be given information without having to request it. Safety reports must also be made available to the public via public registers.

Operators planning to build new top-tier establishments must submit information in advance of construction and wait for the competent authority response before starting to build safety-critical parts of the establishment. This is to ensure that safety is considered fully at the design stage.

The COMAH regulations specifically require operators to consult their employees or employees' representatives about the preparation of the on-site emergency plan. Consultation with those doing the work is crucial in raising awareness of the importance of health and safety and environmental protection. It can make a significant contribution to creating and maintaining a safe and healthy working environment and an effective health and safety culture. In turn, this can benefit the business, making it more efficient by reducing the number of accidents and the number of work-related ill-health incidents.

On receipt of the safety report the competent authority should inform employee representatives and provide the name of the assessment manager. If the competent authority finds serious deficiencies in the safety report, it will copy any related correspondence it has with operators to employee representatives. Similarly, the competent authority will copy the letter informing the operator of its conclusions of the assessment of the safety report, to employee representatives.



Procedures and communications in the event of a release of radioactive material (PACRAM)

As part of the procedures and communications in the event of a release of radioactive material (PACRAM), a weather forecast is prepared by the Met Office and sent to the site in question or to an off-site emergency room. The response is similar to that for a chemical incident using CHEMET.

The PACRAM form is similar to that used for CHEMET; it provides details of the incident and may be sent to the Met Office when completed. The Met Office will then complete Part 2, which provides forecast meteorology and an area at risk map like those used for CHEMET.



Transportation, packaging and supply

Supply classification and labelling

There have been significant changes to the legislation that controls how the hazards of chemical products are classified and communicated. The purpose of supply classification and labelling is to consider the end user of a product. It should ensure they have sufficient information on the hazards of products to enable them to fully assess the risks the product presents in the process in which they use the product. This may be an industrial user, such as an employee in the chemical manufacturing industry or a professional user, such as a hair-stylist or professional gardener who uses chemical products as part of their role. The end user could also be a member of the public, as household products such as bleach and washing detergents can also contain hazardous chemicals. The scope of supply regulations are therefore wider than the transportation regulations, and also include a wider range of hazards, particularly for health hazards where long-term or chronic health effects are also considered.

The changes in supply regulations have been driven by the adoption of the United Nations Globally Harmonised System for classification and labelling, typically referred to as UN GHS or just GHS. UN GHS is an international agreement developed to create global standards in two key areas. Firstly, on the criteria for classifying chemicals according to their physical, health, environmental hazards, Secondly on hazard communication requirements through labelling and safety data sheets.

UN GHS is a non-legally binding international agreement; countries, or trading blocks such as the European Union, have to create legislation to implement it. In the EU this has been done through the Classification, Labelling and Packaging of Substances and Mixtures Regulation, EC1907/2006, typically referred to as the CLP regulation.



CLP replaces previous EU directives that set out the requirements for classification and labelling in Europe, the Dangerous Substances Directive 67/548/EEC and Dangerous Preparations Directive 1999/45/EC. These directives were implemented in the UK under the Chemical Hazard Information and Packaging for Supply Regulations, commonly referred to as the CHIP regulations. The overall concept of CLP has many crossovers with the CHIP regulations: the hazards of the products are classified into specific groups and this information is communicated through a label. However there are some differences between the classification groups and the content of the label information.



Comparison of hazard communication under CLP to the CHIP regulations

The label is a primary method of hazard communication under both the old CHIP regulations and under CLP. Table 15 shows how the structure of the labels are effectively quite similar, but there are some differences to how the data is presented as described:

Table 15 CHIP and CLP label comparison

CHIP Label	CLP Label
Indications of Danger: <ul style="list-style-type: none">• Explosive• Oxidising• Extremely flammable• Highly flammable• Very toxic• Toxic• Harmful• Corrosive• Irritant• Dangerous for the environment	Signal Word: <ul style="list-style-type: none">• Danger• Warning• (None)
Symbols 	Pictograms 
Risk phrases: <ul style="list-style-type: none">• Highly flammable• Very toxic by inhalation• Causes burns	Hazard statements: <ul style="list-style-type: none">• Highly flammable liquid and vapour• Fatal if inhaled• Causes severe skin burns and eye damage

CHIP Label

Safety phrases:

- Keep container tightly closed
- Avoid contact with skin and eyes
- Wear suitable protective clothing

CLP Label

Precautionary statements:

- Keep container tightly closed
- Do not get in eyes, on skin or on clothing
- Wear protective clothing



How does the GHS classification system work?

GHS splits the hazards from chemical products into three types – physical, health and environmental hazards. Within these hazard types are hazard classes that describe the nature of the physical, health or environmental hazard. Using physical hazards as an example, the following hazard classes are given:

- Explosives
- Flammable gases
- Aerosols
- Oxidising gases
- Gases under pressure
- Flammable liquids
- Flammable solids
- Self-reactive substances and mixtures
- Pyrophoric liquids
- Pyrophoric solids
- Self-heating substances and mixtures
- Substances and mixtures that emit flammable gases when in contact with water
- Oxidising liquids
- Oxidising solids
- Organic peroxides
- Corrosive to metals

Each hazard class is then further divided into a number of hazard categories. These are represented by numbers, and are used to indicate the severity within the hazard class. A hazard category 1 represents the most severe hazard. The severity of the hazard then decreases as the number increase. The table below shows how the hazard categories are differentiated using flammable liquids as an example.

Table 16 Flammable liquids hazard category

Hazard category	Criteria
1	Flash point < 23°C and initial boiling point ≤ 35°C
2	Flash point < 23°C and initial boiling point > 35°C
3	Flash point ≥ 23°C and ≤ 60°C

Table 17 below demonstrates when a product has been confirmed to meet the criteria for a hazard class and category. The CLP regulation indicates the pictogram, signal word, hazard statements and precautionary statements that have to be used on the product packaging. For a liquid product with a flashpoint measured at 31°C, and boiling point measured at 60°C the product would be classified as a Flammable liquid, category 2. The regulation then provides the following hazard communication information:

Table 17 CLP hazard and precautionary statements

<p>Pictogram:</p>  <p>Signal word: Danger</p> <p>Hazard statement: H225 Highly flammable liquid and vapour.</p> <p>Precautionary statements:</p> <ul style="list-style-type: none"> • P210 Keep away from heat, hot surfaces, sparks, open flames and other ignition sources. No smoking • P233 Keep container tightly closed. • P240 Ground/bond container and receiving equipment • P241 Use explosion-proof electrical/ventilating/lighting/equipment • P242 Use only non-sparking tools. • P243 Take precautionary measures against static discharge. • P 280 Wear protective gloves/protective clothing/eye protection/face protection. • P303 + 361 + 353 IF ON SKIN (or hair): Take off immediately all contaminated clothing. Rinse skin with water/ shower. • P370 + 378 In case of fire: Use water to extinguish. • P403 + 235 Store in a well-ventilated place. Keep cool. • P501 Dispose of contents/container to ...
--

In practice, a maximum of six precautionary hazard statements should be used on a product label,

and the regulation provides further guidance on how to refine the precautionary statements so that an acceptable number are used on the label.

Once the full range of physical, health and environmental hazards of a product have been classified according to the CLP classification rules, a label for the product can be created. The following information must be included on the label:

- Name, address and telephone number of the supplier(s)
- Nominal quantity of the substance or mixture in the package made available to the general public, unless this quantity is specified elsewhere on the package
- Product identifiers (name)
- Hazard pictograms
- Signal word
- Hazard statements
- Precautionary statements

The label must also be in the official language for the country it will be sold in. So for any product supplied into the UK, the language used on the label must be English.

Table 18 below describes how the label used must also meet minimum size requirements.

Table 18 CLP label, minimum size requirements

Capacity of package	Minimum dimensions of the label (mm)
Not exceeding 3 litres	52 x 74
Greater than 3 litres, but not exceeding 50 litres	At least 74 x 105
Greater than 50 litres, but not exceeding 500 litres	At least 105 x 148
Greater than 500 litres	At least 148 x 210

XYZ Chemicals
 Address line 1,
 Address line 2,
 Town
 Country
 Telephone: +xx (0)xxxx xxx xxx

METHANOL
 EC Number: 200-659-6

Instructions For Use
 xxxxxxxxxxxxxxxxxxxxxxxx
 xxxxxxxxxxxxxxxxxxxxxxxx
 xxxxxxxxxxxxxxxxxxxxxxxx
 xxxxxxxxxxxxxxxxxxxxxxxx
 xxxxxxxxxxxxxxxxxxxxxxxx
 xxxxxxxxxxxxxxxxxxxxxxxx
 xxxxxxxxxxxxxxxxxxxxxxxx
 xxxxxxxxxxxxxxxxxxxxxxxx
 xxxxxxxxxxxxxxxxxxxxxxxx
 xxxxxxxxxxxxxxxxxxxxxxxx
 xxxxxxxxxxxxxxxxxxxxxxxx
 xxxxxxxxxxxxxxxxxxxxxxxx



DANGER

Highly flammable liquid and vapour.
 Toxic if inhaled.
 Toxic in contact with skin.
 Toxic if swallowed.
 Causes damage to organs.

Keep away from heat/sparks/open flames/hot surfaces. – No smoking.
 Avoid breathing fume, mist, vapours or spray.
 Wear protective rubber or PVC gloves, rubber or PVC apron and chemical goggles.

IF INHALED: Remove to fresh air and keep at rest in a position comfortable for breathing. Call a POISON CENTER or doctor/physician.

IF ON SKIN (or hair): Remove/Take off immediately all contaminated clothing. Rinse skin with water/shower.

Call a POISON CENTER or doctor/physician if you feel unwell. Wash contaminated clothing before reuse.

IF SWALLOWED: Immediately call a POISON CENTER or doctor/physician. Rinse mouth.

Store in a well-ventilated place. Keep cool. Keep container tightly closed.

Dispose of contents/container in accordance with local/regional/national/international regulations.

Supplemental information:

Risk of explosion if heated under confinement.

CLP label example



Links between CLP regulation and dangerous goods transportation regulations.

The UN GHS classification guidelines are issued through a UN document referred to as the purple book. They form the basis for the European supply regulation, the Classification, Labelling And Packaging Of Substances And Regulations (CLP). Diagram 2 below describes the classification rules used by UN GHS, which also form the basis for the classification rules used in transportation regulations:

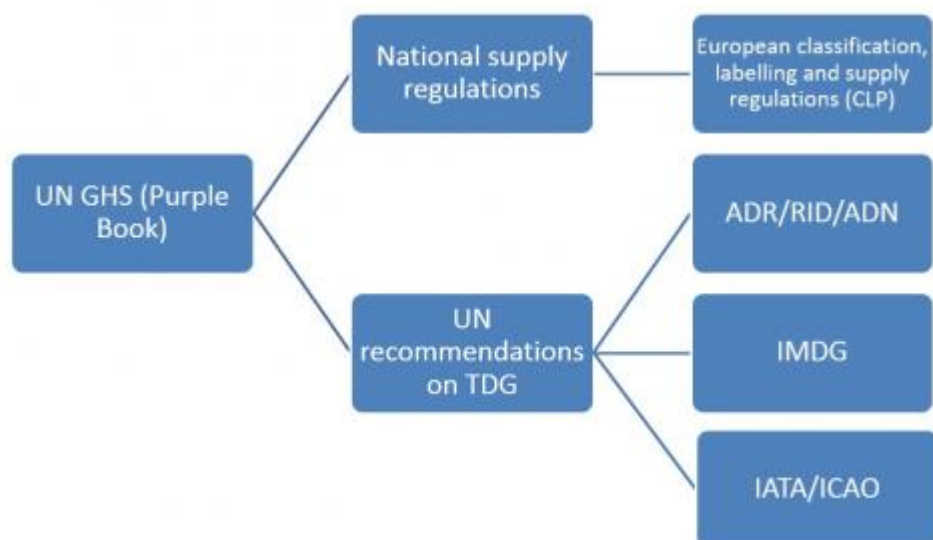



























Diagram 2 Classification rules used by UN GHS







This ensures that the classification rules match between the different regulations. However, as the supply regulations are written for people who use chemicals as part of their job or members of the public, rather than just for transportation purposes, there are differences in the classification groups included. This is seen most significantly as the long term, or chronic, health effects that are included in the CLP regulation, but not in transportation regulations.

The tables below provide more information on the classification groups included in the CLP and transport regulations.




Table 19 CLP and CHIP classification groups for transportation of hazardous materials

GHS class	GHS symbol	CHIP symbol	Transport class	Symbol
Explosive			1	
Flammable gases			2	
Aerosol			2	 

GHS class	GHS symbol		CHIP symbol	Transport class	Symbol
Gases under pressure			N/A	2	
Flammable liquids				3	
Substances that emit flammables on contact with water				4.3	
Oxidising solids, liquids and gases				5.1	
Organic peroxides				5.2	



GHS class	GHS symbol		CHIP symbol	Transport class	Symbol
Acute toxicity				6	
Skin corrosion / irritation				8	

GHS class	GHS symbol		CHIP symbol	Transport class	Symbol
Serious eye damage / irritation				Not regulated	
Respiratory or skin sensitisation				Not regulated	
Germ cell mutagenicity				Not regulated	
Carcinogenicity				Not regulated	
Reproductive toxicity				Not regulated	
Specific target organ toxicity					

GHS class	GHS symbol	CHIP symbol	Transport class	Symbol
Hazards to the aquatic environment			9	

Two classification groups are included in the transportation regulation but not included in the CLP regulation, as other areas of EU regulation cover these groups: radioactive materials and biological hazards.

Table 20 CLP Non-regulated classification groups

GHS Class	Symbol	Transport class	Symbol
Not regulated		6.2	
Not regulated		7	



Regulatory background

The regulatory framework for the global transport of dangerous goods is agreed by the UN Sub-Committee of Experts for the Transport of Dangerous Goods. Its provisions are set out in the UN model regulations ('Recommendations on the Transport of Dangerous Goods', commonly known as the orange book), which are revised and republished every two years and form the basis of the

internationally agreed mode-specific requirements. The regulations do not apply to the bulk transport of dangerous goods in seagoing or inland navigation bulk carriers or tank-vessels, which is subject to special international or national regulations.

Detailed rules for the international transport of dangerous goods by road are set out in the United Nations Economic Commission for Europe (UNECE) publication known, from its French title, as Accord Dangereux Routier (ADR). The text for each edition of ADR (re-issued every two years) is agreed by a UNECE committee which usually meets bi-annually in Geneva; the UK is represented at these meetings by the Department for Transport, which consults key dangerous goods interest groups before the UK position on the various agenda items is decided. This agreement has no overall enforcing authority; in practice checks are carried out by contracting parties and non-compliance is dealt with by national authorities in accordance with domestic legislation.

Detailed provisions for the international transport of dangerous goods by rail are published under the Organisation Intergouvernementale pour les Transports Internationaux Ferroviaires (OTIF) convention in a document known from as reglement International concernant le transport de marchandises dangereuses par chemin de fer (RID). OTIF is an inter-governmental organisation with a mainly European membership that includes the UK. The RID committee of experts usually meets every two years, at different locations, and the UK is again represented by the Department for Transport. The text of RID is almost identical to that of ADR, varying only to reflect modal differences.

The EU has adopted the UNECE/OTIF rules in a series of directives which extend the scope of ADR and RID to apply to national as well as intra-community transport. A combined directive for the inland transport of dangerous goods (covering road, rail and inland waterways) – 2008/68/EC – is transcribed into UK domestic legislation via The Carriage of Dangerous Goods and Use of Transportable Pressure Equipment Regulations 2009.

- The model regulations lay out the requirements for the carriage of dangerous goods for the specific mode of transport. In summary they are:
- The European Agreement concerning the International Carriage of Dangerous Goods by Road (ADR)
- The EU Regulation concerning the Carriage of Dangerous Goods by Rail (RID)
- The European Agreement concerning the International Carriage of Dangerous Goods by Inland Waterways (ADN)
- The International Maritime Dangerous Goods Code (IMDG), published by the International Maritime Organisation (IMO)
- Restricted Articles Regulations published by the International Air Transport Association (IATA)
- International Civil Aviation Organisation (ICAO) Regulations.



The UN system

The UN model regulations (Recommendations on the Transport of Dangerous Goods, commonly known as the orange book) establishes a basic system for the safe transport of dangerous goods.

The system is designed to reduce the risk of serious incidents involving dangerous goods and the impact of such incidents when they do occur.

- Dangerous goods are substances that meet the criteria for one or more classes.
- The regulations stipulate that dangerous goods are:
- Classified (identified) according to their hazard(s)
- Packaged to the required standards
- Marked
- Labelled
- Documented
- The regulations also state that relevant personnel should be properly trained.

Classification

- Classification is a fundamental part of the UN system incorporating:
- UN class
- UN packing group
- UN number
- Proper shipping name

Dangerous goods are firstly assigned to one of nine hazard classes, known as UN classes, according to their primary hazard. Secondly, an assessment is made of the relative hazard of a substance within the same class and the substance is assigned to one of three packing groups. Each substance is then allocated a substance identification number which is designed to allow identification of the substance in transit. These code numbers are commonly known as UN numbers. The UN recommends that UN numbers appear on all transport documents and are displayed on packages, containers, vehicles, along with a description of the substance called the proper shipping name.

Diagram 3 below shows how the nine UN hazard classes are numbered and sub-divided into divisions. The Regulations also contain rules on identifying the hazards and danger of the substances. Each class (and sometimes division) is therefore assigned a hazard symbol.

Class 1 Explosives



(Divisions - 1.1, 1.2, 1.3, 1.4, 1.5, 1.6 (1.6 not used in the UK))

Class 2 Gases



Division 2.1 Flammable gases



Division 2.2 Non-Flammable, compressed gases



Division 2.3 Toxic gas

Class 3 Flammable liquids



Class 4 Flammable solids



Division 4.1 Flammable solids, self-reactive substances and solid desensitised explosives



Division 4.2 Substances liable to spontaneous combustion



Division 4.3 Substances that in contact with water emit flammable gases.

Class 5 Oxidising substances



Division 5.1 Oxidising substances other than organic peroxides





used until 2009

Division 5.2 Organic peroxides

Class 6 Toxic and infectious substances



Division 6.1 Toxic substances



Division 6.2 Infectious substances

Class 7 Radioactive material



Category I, Category II, Category III and fissile material (capable of nuclear explosion)

Class 8 Corrosive substances



Class 9 Miscellaneous dangerous substances and articles



Diagram 3 United Nations class, division and hazard symbol

United Nations packing groups

The UN system identifies substances in a particular class or division according to the degree of danger. This is known as the packing group:

- Packing group I: high danger
- Packing group II: medium danger
- Packing group III: minor danger

Goods are assigned to one of these groups based on the criteria. Packing groups do not apply to explosives (class 1), gases (class 2), organic peroxides (class 5.2), infectious substances (class 6.2), radioactive material (class 7) or self-reacting substances found in class 4.1. Instead there are special packaging and transport provisions for these materials.

The international agreements for the carriage of dangerous goods require packaging to be of a design type certified by a national competent authority. This involves testing the packaging to ensure its suitability for the carriage of certain dangerous goods. Such packaging is often referred to as a type-approved or UN-certified and is marked in particular ways, prefixed by the UN logo and followed by a set of codes that detail the standard of packaging.

UN number

Once a product has been assigned to an appropriate hazard class and packing group, it is assigned a UN number. The United Nations (UN) number is a means of identifying a chemical substance or an article containing a chemical. A list of UN numbers can be found in the current version of the [Dangerous Goods Emergency Action Code List](#).

Several other organisations publish lists of additional numbers for use in their countries, or by a particular mode of transport:

The North American 8000 series, published by the International Air Transport Association (IATA) includes entries for some additional substances and articles that are to be transported by air.

The North American 9000 series also contains many additional numbers for substances and articles not otherwise classified for transport.

UN numbers also divide into four types. Precedence is given to the most specific entry that is applicable to the substance, mixture, preparation or article in the following order:

- Single entries for well-defined substances or articles (for example, UN 1090 ACETONE)
- Generic entries for well-defined groups of substances or articles (for example, UN 1133 ADHESIVES containing flammable liquids or UN 1263, PAINT)
- Specific entries not otherwise specified (N.O.S.) covering a group of substances or articles of a particular chemical or technical nature (for example, UN 1987 ALCOHOLS, N.O.S. or UN 1224, KETONES, LIQUID, N.O.S)
- Generic entries not otherwise specified (N.O.S.) covering a group of substances or articles meeting the criteria of one or more classes or divisions (for example, UN 1993 FLAMMABLE LIQUIDS, N.O.S. or UN 1992, FLAMMABLE LIQUID, TOXIC, N.O.S)

Proper shipping name

The name immediately following the UN number is the proper shipping name (PSN) and is the one that should be quoted on packages, tanks and in documentation. Even when the substance is known by more than one name, it is the PSN that should always be used. Examples include UN 1035 Ethane and UN 1993 Flammable liquid, N.O.S.

Segregation

There are rules on segregation as a means of keeping incompatible goods apart from one another using a barrier or intervening space. Chemicals must be segregated when either stored or transported to reduce the likelihood of them mixing if an accident occurs. This is an essential element of the safe system of work designed to prevent fires, explosions and the release of harmful gases, etc. The rules for sea transport (i.e. International Maritime Dangerous Goods IMDG code) are more strict than for road or rail.

The regulations contain segregation tables that can be referenced to see if two materials can be transported together, or if conditions apply if they are transported in the same shipment. These

tables can be a useful guide for establishing some common incompatibilities, or where additional hazards will result from chemicals mixing (for example, a flammable material and an oxidising agent which could result in a fire if mixed).

Documentation

Slightly different rules apply when describing the load on the documentation that must accompany consignments of dangerous goods for each mode of transport. However, they are all based on the same principles. These documents are a valuable means of identifying the load and hence obtaining hazard information that can be used to develop the incident response plan.

The documentation should contain the following information for each dangerous substance, material or article being carried:

- United Nations number preceded by the letters 'UN'
- Proper shipping name (PSN) supplemented with the technical name in brackets, when applicable
- Packing group for the substance preceded by the letters 'PG' (e.g. PG II), or the initials corresponding to the words 'packing group' for other languages
- Total quantity of dangerous goods for different UN number, proper shipping name or packing group (shown as by volume or mass (weight) as appropriate)
- Number and description of the packages, when applicable
- Total quantity of dangerous goods contained in dangerous goods in machinery or equipment
- Name and address of the consignor (i.e. where it was sent from)
- Name and address of the consignee(s) (i.e. where it is going to); if this is not possible (e.g. a consignment with multiple delivery addresses) then the words 'delivery sale' may be shown instead.

There are special provisions for explosives (Class 1) and radioactive material (Class 7).

The most common form of transport document likely to be encountered is the dangerous goods note (DGN) accompanying the movement of dangerous goods by road. Since July 2009 and the removal of product-specific instructions in writing for the driver (commonly known and referred to as Tremcards®), which emergency responders used as a means of identifying the load, the DGN is the main means of identifying the contents of a vehicle carrying packaged dangerous goods.



Road transportation

Packaged goods transport labelling

Different regimes are used to placard and label dangerous goods transported in packages.

Following classification, the manufacturer or importer will be able to produce an appropriate label

for the substance. For transport purposes, this label will include:

- The designation of the product or its proper shipping name (PSN); this is the official description listed in the regulations for a particular UN number
- The UN number
- Appropriate hazard warning symbols

If a product is not specifically listed in the Regulations, or the hazardous properties and emergency response procedures for a solution or mixture differ significantly from those of the pure substance, then one of the generic (N.O.S.) entries must be used. In such cases, the PSN must be supplemented with the technical name of the goods. The technical name should be a recognised chemical name for the substance or substances which caused the product to be classified as hazardous. Normally not more than two ingredients are named (for example, gasoline and carbon tetrachloride mixture UN 1992 flammable liquid, toxic, N.O.S. or trimethyl gallium UN 2003 metal alkyl, N.O.S.).



Image 8 Transportation label for packaged methanol

There are different requirements for labelling products for supply and use, which are covered separately. However, for some containers the labels for transport and supply can be combined.

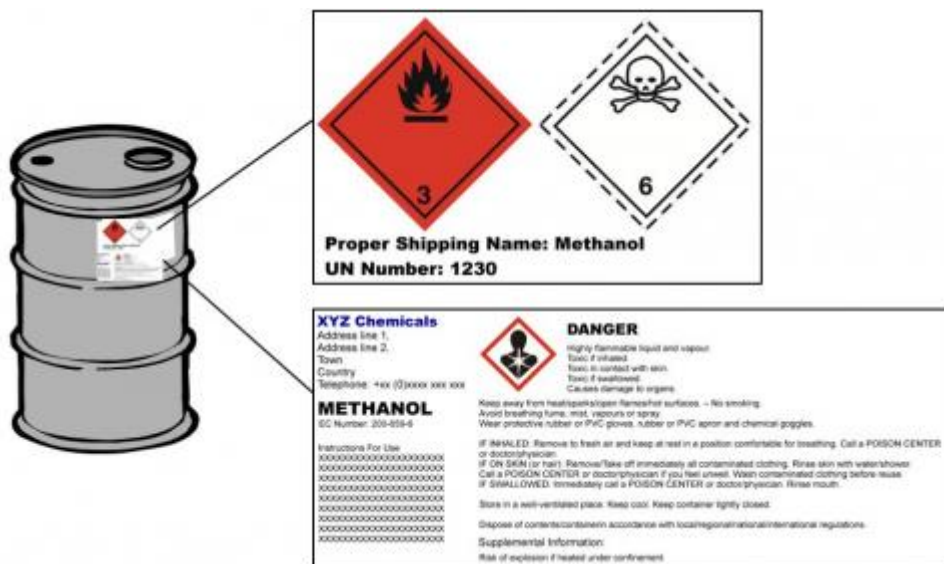


Image 9 A combined label for transport and supply

Combination packages

Packaged goods are usually transported in a combination package consisting of inner packages of a size intended for supply (usage), packed into an outer box convenient for transport.

Packages for transporting hazardous goods are required to be fit for purpose and be tested and marked with a UN symbol to show this (for example: 4G/Y25/S/03/GB/PRL271). For further information regarding packaging see [HSE Packaging](#).

The inner package will be labelled for supply purposes, while the outer package will be labelled for carriage. Because the regulations for transport and supply of hazardous goods cover different hazards, the labels that have to be provided on each layer of the package can be different for each.

This can cause some confusion, particularly where the inner containers of a package may be labelled as toxic because of their potential to cause adverse effects with long-term exposure, while the outer containers may not be labelled at all because the product does not have an effect with short-term exposure.

Combination Packages

Inner bottles
labelled for
supply



Outer package
labelled for
transport

Image 10 Combination package

[ADR](#) hazard identification numbers (HIN) or 'Kemler Code'

The hazard identification number consists of two or three figures indicating the following hazards:

Table 22 Hazard identification numbers

No.	Hazard
2	Emission of gas due to pressure or chemical reaction
3	Flammability of liquids (vapours) and gases or self-heating liquid
4	Flammability of solids or self-heating solid
5	Oxidising (fire-intensifying) effect
6	Toxicity
7	Radioactivity
8	Corrosivity
9	Risk of spontaneous violent reaction

Duplication of a figure (e.g. 55) indicates an intensification of that particular hazard.

Where the hazard associated with a substance can be adequately indicated by a single figure, this is

followed by a zero.

A hazard identification number prefixed by letter X indicates that the substance will react dangerously with water.

Table 23 below shows the meanings of hazard identification number combinations:

(*Water must not be used except by approval of experts

Table 23 Hazard identification number meanings

Number	Meaning
20	Asphyxiant gas or gas with no subsidiary risk
22	Refrigerated liquefied gas, asphyxiant
223	Refrigerated liquefied gas, flammable
225	Refrigerated liquefied gas, oxidising (fire intensifying)
23	Flammable gas
238	Gas, flammable corrosive
239	Flammable gas, which can spontaneously lead to violent reaction
25	Oxidising (fire-intensifying) gas
26	Toxic gas
263	Toxic gas, flammable
265	Toxic gas, oxidising (fire-intensifying)
268	Toxic gas, corrosive
28	Gas, corrosive
285	Gas, corrosive, oxidising Flammable liquid that reacts with water, emitting 30 flammable gases
30	Flammable liquid (flash-point between 23°C and 60°C inclusive) or flammable liquid or solid in the molten state with a flash point above 60°C, heated to a temperature equal to or above its flash point, or self-heating liquid

Number	Meaning
323	Flammable liquid that reacts with water, emitting flammable gases
X323	Flammable liquid that reacts dangerously with water, emitting flammable gases
33	Highly flammable liquid (flash point below 23°C)
333	Pyrophoric liquid
X333	Pyrophoric liquid, which reacts dangerously with water*
336	Highly flammable liquid, toxic
338	Highly flammable liquid, corrosive
X338	Highly flammable liquid, corrosive, which reacts dangerously with water*
339	Highly flammable liquid that can spontaneously lead to violent reaction
36	Flammable liquid (flash point between 23°C and 60°C inclusive), slightly toxic or self-heating liquid toxic
362	Flammable liquid, toxic, which reacts with water, emitting flammable gases
X362	Flammable liquid, toxic, which reacts dangerously with water, emitting flammable gases*
368	Flammable liquid, toxic, corrosive
38	Flammable liquid (flash point between 23°C and 60°C inclusive), slightly corrosive or self-heating liquid, corrosive
382	Flammable liquid, corrosive, which reacts with water, emitting flammable gases
X382	Flammable liquid, corrosive, which reacts dangerously with water, emitting flammable gases*
39	Flammable liquid, which can spontaneously lead to violent reaction
40	Flammable solid, or self-reactive substance, or self-heating substance

Number	Meaning
423	Solid that reacts with water, emitting flammable gas, or flammable solid which reacts with water, emitting flammable gases or self-heating solid which reacts with water, emitting flammable gases*
X423	Solid that reacts dangerously with water, emitting flammable gases, or flammable solid that reacts dangerously with water, emitting flammable gases, or self-heating solid that reacts dangerously with water, emitting flammable gas Flammable solid, in the molten state at an elevated temperatures*
43	Spontaneously flammable (pyrophoric) solid
X432	Spontaneously flammable (pyrophoric) solid that reacts dangerously with water, emitting flammable gases*
44	Flammable solid, in the molten state at an elevated temperature
446	Flammable solid, toxic in the molten state, at an elevated temperature
46	Flammable or self-heating solid, toxic
462	Toxic solid that reacts with water, emitting flammable gases
X462	Solid that reacts dangerously with water, emitting toxic gases*
48	Flammable or self-heating solid, corrosive
482	Corrosive solid that reacts with water, emitting corrosive gases
X482	Solid that reacts dangerously with water, emitting corrosive gases*
50	Oxidising (fire-intensifying) substance
539	Flammable organic peroxide
55	Strongly oxidising (fire-intensifying) substance
556	Strongly oxidising (fire-intensifying) substance, toxic
558	Strongly oxidising (fire-intensifying) substance, corrosive

Number	Meaning
559	Strongly oxidising (fire-intensifying) substance, which can spontaneously lead to violent reaction
56	Oxidising substance (fire-intensifying), toxic
568	Oxidising substance (fire-intensifying), toxic, corrosive
58	Oxidising substance (fire-intensifying), corrosive
59	Oxidising substance (fire-intensifying) that can spontaneously lead to violent reaction
60	Toxic or slightly toxic substance
606	Infectious substance
623	Toxic liquid, which reacts with water, emitting flammable gases
63	Toxic substance, flammable (flash point between 23°C and 60°C inclusive)
638	Toxic substance, flammable (flash point between 23°C and 60°C inclusive), corrosive
639	Toxic substance, flammable (flash point not above 60°C inclusive), which can spontaneously lead to violent reaction
64	Toxic solid, flammable or self-heating
642	Toxic solid, which reacts with water, emitting flammable gases
65	Toxic substance, oxidising (fire-intensifying)
66	Highly toxic substance
663	Highly toxic substance, flammable (flash-point not above 60°C inclusive)
664	Highly toxic substance, flammable or self-heating
665	Highly toxic substance, oxidising (fire-intensifying)
668	Highly toxic substance, corrosive

Number	Meaning
669	Highly toxic substance that can spontaneously lead to a violent reaction
68	Toxic substance, corrosive
69	Toxic or slightly toxic substance, which can spontaneously lead to a violent reaction
70	Radioactive material
78	Radioactive material, corrosive
80	Corrosive or slightly corrosive substance
X80	Corrosive or slightly corrosive substance, which reacts dangerously with water*
823	Corrosive liquid which reacts with water, emitting flammable gases
83	Corrosive or slightly corrosive substance, flammable (flash point between 23°C and 60°C inclusive)
X83	Corrosive or slightly corrosive substance, flammable (flash point between 23°C and 60°C inclusive), which reacts dangerously with water*
839	Corrosive or slightly corrosive substance, flammable (flash point between 23°C and 60°C inclusive), which can spontaneously lead to violent reaction
X839	Corrosive or slightly corrosive substance, flammable (flash point between 23°C and 60°C inclusive), which can spontaneously lead to violent reaction and which reacts dangerously with water*
84	Corrosive solid, flammable or self-heating
842	Corrosive solid which reacts with water, emitting flammable gases
85	Corrosive or slightly corrosive substance, oxidising (fire-intensifying)
856	Corrosive or slightly corrosive substance, oxidising (fire-intensifying) and toxic
86	Corrosive or slightly corrosive substance, toxic

Number	Meaning
88	Highly-corrosive substance
X88	Highly-corrosive substance, which reacts dangerously with water*
883	Highly-corrosive substance, flammable (flash-point between 23°C and 60°C inclusive)
884	Highly-corrosive solid, flammable or self-heating
885	Highly-corrosive substance, oxidising (fire-intensifying)
886	Highly-corrosive substance, toxic
X886	Highly-corrosive substance, toxic, which reacts dangerously with water*
89	Corrosive or slightly-corrosive substance, which can spontaneously lead to a violent reaction
90	Environmentally hazardous substance; miscellaneous dangerous substances
99	Miscellaneous dangerous substance carried at an elevated temperature

UK bulk vehicle placarding

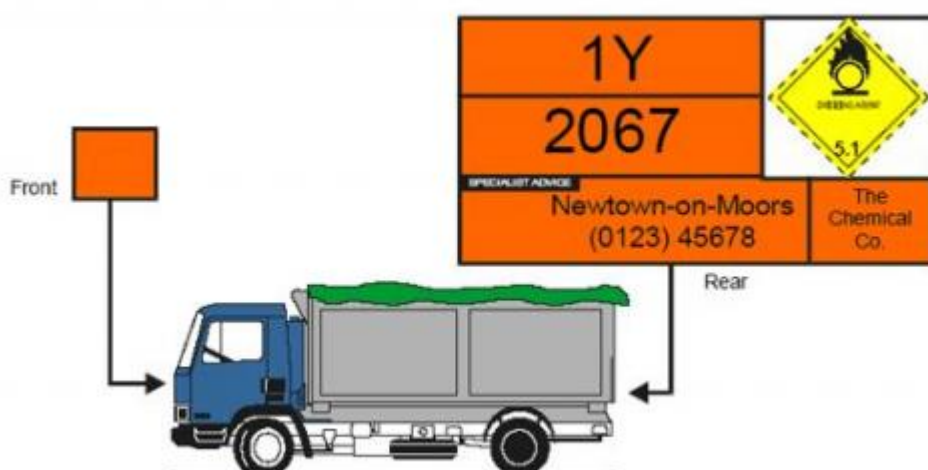


Image 19 UK Hazchem hazard warning panel - single bulk load

Single bulk load

Image 19 above shows the signage for a bulk single load (in excess of three cubic metres). The detailed signage will be on the sides and rear of the vehicle.

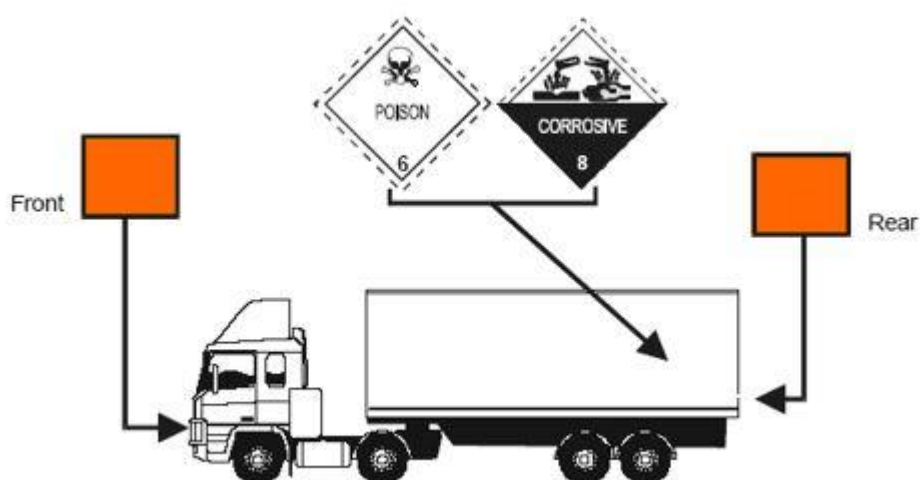


Image 20 Single load in packages in a freight container

Image 20 above shows signage for a vehicle carrying dangerous goods in packages in a demountable freight container. In addition to orange panels on the front and rear of the vehicle, all sides of the container will have the standard warning symbols, according to the hazards posed by the load.

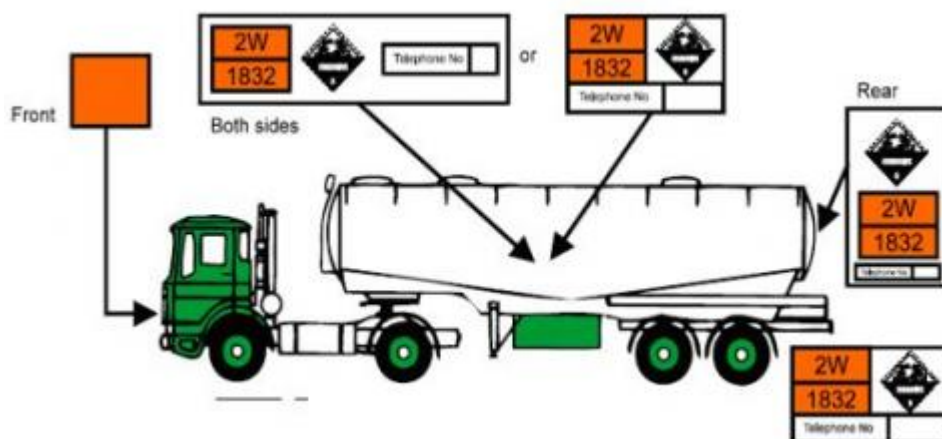


Image 21 Single load tanker

The image above shows a single load tanker. Note the variations in showing the key information.

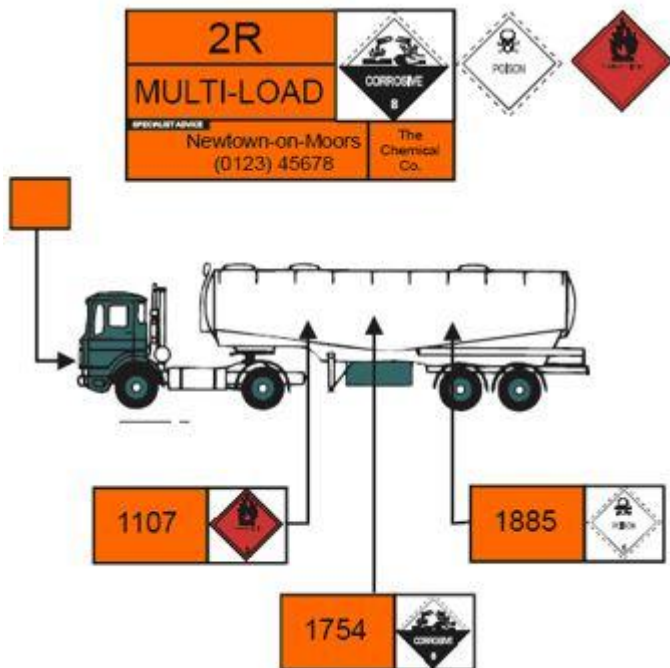


Image 22 Multi load tanker

Image 22 above shows the signage for a multi load tanker. The main placard will state multi-load but the hazard symbol(s) will show the hazard(s) of the load. Each individual compartment of the tanker will have its own sign giving the UN number for the substance and the hazard symbol denoting its specific hazard.

European ADR vehicle bulk placarding

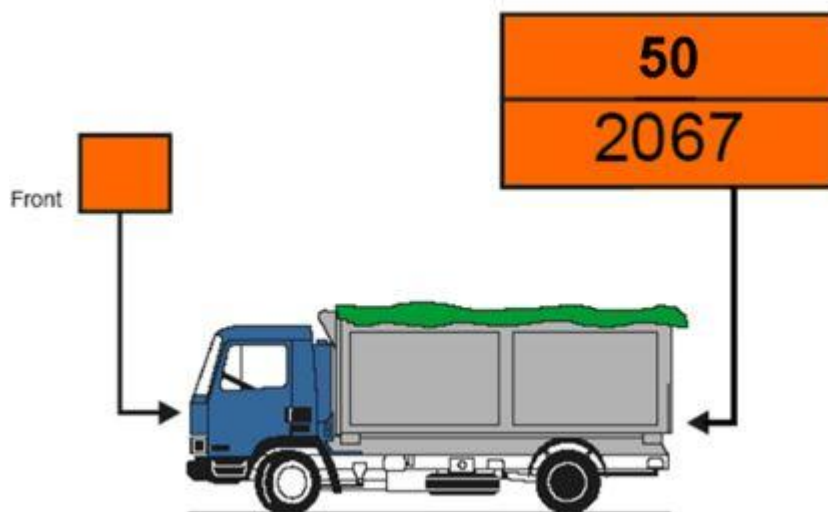


Image 23 Single bulk load showing ADR markings for a bulk single load

European ADR tanker or tank placarding

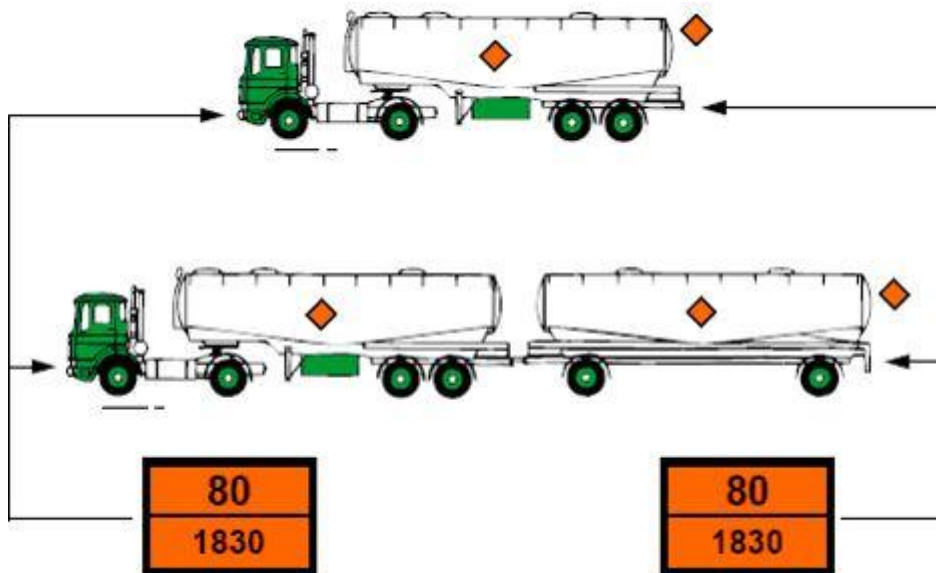


Image 24 Single load tanker showing ADR markings

Single load tanker

For tank vehicles carrying only one substance, as shown above, the identification numbers can be shown on the orange plates at the front and rear of the vehicle. Hazard warning symbols are located on each side of the vehicle and at the rear (as indicated).

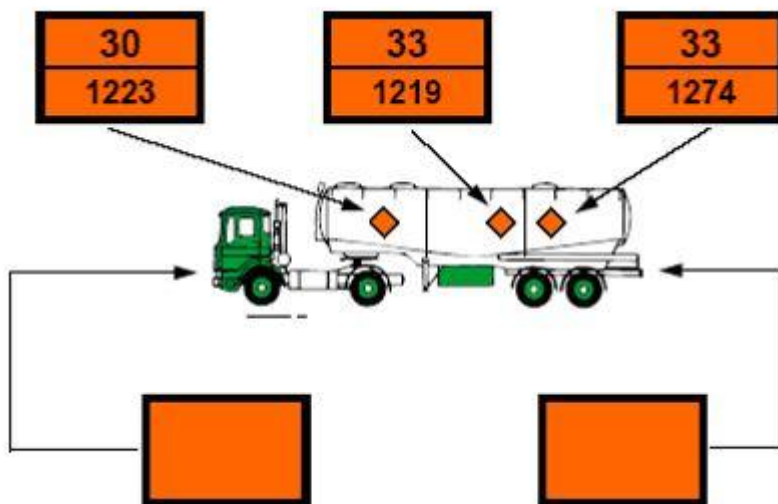


Image 25 Bulk load tanker

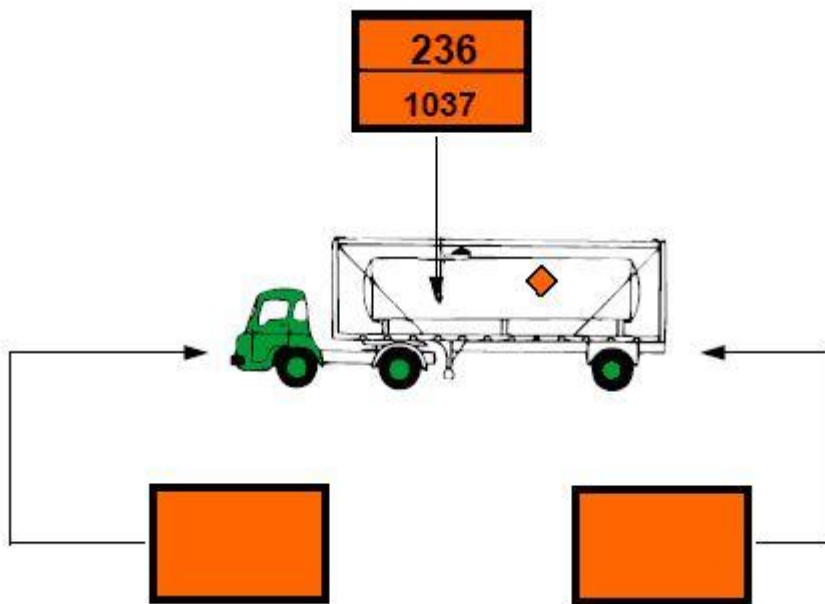


Image 26 Tank vehicle carrying a multi load will display signage as shown above

Tank container

Vehicles carrying tank containers must display orange plates on each side of the tank, or tank compartments, giving hazard and substance identification numbers. A blank plate is displayed at the front and rear. Hazard warning symbols are located on each side of the compartment adjacent to each ADR placard.

Tank containers must have the identification numbers on the tank itself to remain in sight when the tank is offloaded from the vehicle.

Elevated temperature marking

Tank vehicles, tank containers, portable tanks, special vehicles or containers or specially-equipped vehicles or containers carrying elevated temperature substances are required under ADR to display an elevated temperature mark on both sides and at the rear for vehicles, and on both sides and at each end for containers, tank-containers and portable tanks. Image 27 below shows the elevated temperature marking displayed according to ADR,



Image 27 Elevated temperature marking

Environmentally hazardous substances marking

When required to be displayed in accordance with the provisions of ADR, containers, tank-containers, portable tanks and vehicles containing certain environmentally hazardous substances are to be marked with the environmentally hazardous substance mark shown below.



Image 28 Environmentally hazardous substances marking

Switch-loading of petrol and distillate fuels

Switch-loading is the terminology used to describe the practice of loading a distillate fuel (e.g. diesel or gas oil), into a tank compartment that has previously contained petrol. Switch-loading can also be practiced between petrol and kerosene but this practice is normally discouraged because of the risk of residual petrol (liquid or vapour) lowering the flash point of the kerosene.

In the UK the practice of switch-loading road tankers is very common, undertaken by perhaps as many as 95% of petrol/distillate fuel tankers to minimise unnecessary journeys (e.g. by discharging one load and returning with another). Compartments of tankers that have been switch-loaded will not only contain the liquid distillate product but also an amount of petrol vapour remaining from the previous load or loads.

Road tankers that transport petrol are designed and constructed for bottom loading with vapour recovery and in addition to the compartment ullage spaces, petrol vapour will be retained in the associated vapour manifold and pipework, together with small amounts of petrol in other associated pieces of equipment.

Distillate fuels have a greater density than petrol and in many cases a nominal full load of distillate will require a tanker to run with an empty or partially filled compartment, to ensure that the vehicle does not exceed its maximum authorised mass on the road.

Large volumes of petrol vapour will be retained in the empty and/or partially-filled compartments of a tanker carrying distillates in which petrol has been previously loaded. Even in compartments not previously loaded with petrol there is a risk that vapour will be present. This is due to the inter-compartment connection afforded by the vapour manifold and the vapour transfer valves, all of which are open during the bottom loading process. It is possible that a tanker may arrive at a site with a full load of diesel and leave with a full load of petrol vapour.

Where a mixed load of liquid products comprises petrol, diesel, kerosene or aviation fuels the tanker will be marked with the UN number of the product with the greatest hazard i.e. the lowest flashpoint. In the case of empty, uncleaned tanks, the tanker is marked as if it still contained the original product. However, there are no specific marking provisions where the transport of a single substance with the residual vapour of a product with a greater hazard (lower flashpoint) is undertaken, even though this may present a similar hazard to that of an empty uncleaned tanker.

Under the current regulations, a compartment that was previously filled with petrol and then refilled with diesel and subsequently emptied of the diesel would have to be marked UN 1202 (diesel) to reflect the last load in the uncleaned tank, but in fact could be filled with petrol vapour.

These hazards are recognised by the petroleum industry and as a result it has become widespread practice in the UK for road tanker operators to retain the petrol marking (UN 1203) on tankers for a number of full loads of diesel or gas oil (UN 1202) after carrying petrol, to reflect the presence of the retained petrol vapour and the greater danger this may pose.

Actions for fire and rescue services

Fire and rescue services should be aware that, when dealing with incidents involving petrol/distillate tankers, any of the tank compartments may contain mixtures of distillate and petrol vapour. Therefore, all the tanks should be treated as if they contained petrol vapour until information to the contrary is obtained.

This also means that tanks may contain diesel/gas oil as the main load but may still be marked as petrol to better reflect the greater danger from any residual petrol vapours.

The emergency action code (EAC) for all such tankers should therefore be taken to be 3YE (indicating a possible public safety hazard beyond the immediate area of the incident) even though the emergency action code for the distillates will be 3Y and some tankers may still be marked as such.

As there are no movements of petrol/distillate tankers to and from Europe this will not be an issue for non-UK registered tankers (i.e. those marked with ADR hazardous identification numbers).

Registration, evaluation, authorisation and restriction of chemicals (REACH) Regulations

Registration, evaluation, authorisation and restriction of chemicals (REACH) is a European Union regulatory framework for chemicals, which came into force on 1 June 2007. REACH has several aims and puts greater responsibility on industry to manage the risks from chemicals and to provide safety information that will be passed down the supply chain.

REACH will require some 30,000 chemical substances to be registered over a period of 11 years, excluding the following;

- Radioactive substances
- Substances under customs supervision
- The transport of substances
- Non-isolated intermediates
- Waste
- Some naturally occurring low-hazard substances

The registration process requires anyone manufacturing more than one tonne per year of these substances within the EU, or importing this amount into the EU, to generate data for all chemicals produced or imported, whether on their own or in one or more preparations. This information must be registered with the European Chemicals Agency. The registrants must also identify appropriate risk management measures and communicate them to the users.

In addition, REACH will allow the further evaluation of substances where there are grounds for concern and foresees an authorisation system for the use of substances of very high concern. This

applies to substances that cause cancer, infertility, genetic mutations or birth defects, and to those that are persistent and accumulate in the environment. The authorisation system will require companies to switch progressively to safer alternatives where a suitable alternative exists. All applications for an authorisation need to include an analysis of alternatives and a substitution plan where a suitable alternative exists. Current use restrictions will remain under the REACH system.

Rail transportation

All classes of hazardous substances are carried on the UK rail network (except in Northern Ireland). The carriage of dangerous goods regulations apply to rail transport, with detailed guidance coming from the [Carriage of Dangerous Goods Manual \(HSE\)](#).

The only exceptions to the regulations are:

- Substances carried with the sole purpose of being used on, or by, the train (e.g. fuel)
- Radioactive materials; these have their own Regulations (Packaging Labelling and Carriage of Radioactive Material by Rail Regulations)

The regulations require that sufficient information is supplied with the load to ensure that all involved with the transportation process can:

- Identify what is being carried
- Be aware of the potential hazards
- In the case of the fire and rescue service, respond quickly and efficiently

The information is supplied to the train operator and the rail infrastructure controller, therefore if there is an incident and the information cannot be obtained from the train driver, it can be obtained from the operator.

The information given includes:

- Designation and classification of the dangerous goods
- UN number
- Packaging group
- Compatibility and division for explosives
- Consignor and consignee details
- Specialist advice
- Mass and volume of the:
 - Package
 - Tank, tank container, or tank wagon
 - Bulk load in container or wagon
 - Total consignment.

Containers, tank container, tank wagons and wagons must display relevant signage related to their contents, using the UK Hazchem system for UK-only journeys or the RID marking provisions for international journeys (these mirror those of ADR for road vehicles), as shown above.

Total operations processing system (TOPS)

The total operations processing system (TOPS) is a computerised system that enables Network Rail to keep a constant check on the position and availability of every rail vehicle on their system and provide specific information of the various loads that are being hauled.

It consists of a central computer system connected to regional control offices, marshalling yards and depots throughout the country. The system is based on a main computer, which is linked to input points at area freight offices throughout Network Rail.

From these control centres, details of all the wagon and freight details, whether they are loaded or unloaded, freight train movements and type of traffic conveyed are fed into the computer. On request by an incident commander via fire service control and Network Rail control office can obtain any specific information from the system, on any wagon or freight train and its cargo. Each wagon is clearly marked with an individual identification number on its side. This number will be recorded on the TOPS computer so that information on the load can be made readily available for operational staff in the event of an incident.



Image 29 Location of identification numbers and hazard warning plates on wagon

Additional tank wagon identification schemes

Tank wagons carrying certain classes of dangerous goods can be identified by specific colour schemes. For example, tank wagons carrying Liquefied petroleum gas (LPG) will have a white barrel with a horizontal orange stripe round the barrel at mid height. Tank wagons carrying flammable liquids are painted dove grey and the sole bars are painted signal red (sole bars are the two horizontal metal bars on which the bottom of the tank rests).

In addition, all wagons containing dangerous goods will have a Network Rail dangerous wagon label displayed on each side. This label indicates the class of substance being carried and the principal hazard that could be encountered. Containers that are hauled by rail are exempt from being labelled in this manner.

The emergency code for the label consists of a six digit number. The first four numbers are the substance identification number for the substance carried or the class, division and compatibility group in the case of explosives. The remaining two letters are referred to as the alpha code. This

code has been allocated to firms and enables Network Rail to ascertain the telephone number that should be used to request specialist assistance in the event of an emergency.

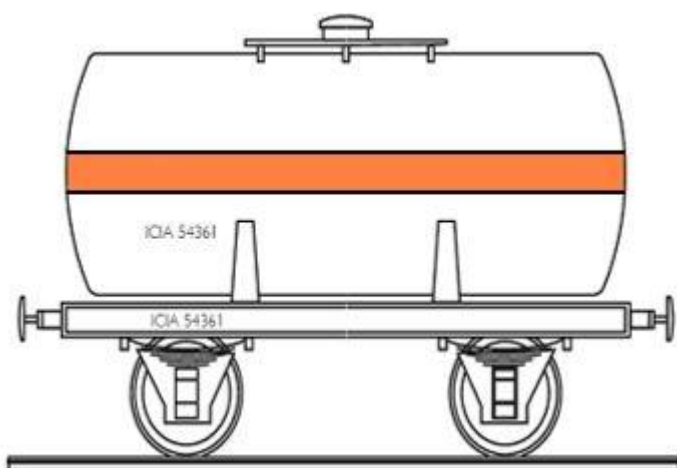


Image 30 Example of tank wagon designed to carry LPG

Information available from the rail vehicle crew

The rail vehicle crew holds information on the specific details of each wagon and the details of their individual loads. This is recorded on an information sheet known as the consist. It will contain the following information:

- Position of every wagon from front to rear
- Train identity number
- Locomotive identity number
- Wagon numbers
- Dangerous goods emergency codes
- UN number plus specialist advice contact code

It would be advisable for the incident commander to obtain the consist as it will provide immediate information on the type of loads being carried and give interim guidance on a course of action to follow until further information is secured either from TOPS or from a designated specialist adviser.

The [2018 Network Statement: Network Rail](#) gives further information on Exceptional Transports and Dangerous Goods.

Irradiated fuel flasks

If an incident involving an irradiated fuel flask occurs, NAIR will be activated immediately. However, some operational priorities need to be considered whilst the NAIR scheme is instigated. For further information see [National Operational Guidance: Health hazards](#).



Image 31 Irradiated fuel transport flask being loaded onto a train

Air transportation

Unlike road and rail transportation of hazardous materials, all air transport is classed as international and therefore is governed by international regulations and agreements.

The worldwide system used to control the transportation of dangerous goods by air is based on the same United Nation's Emergency Response Guidebook (ERG) requirements placed on all other modes of transport. International requirements for the safe air transportation of radioactive material also relate to UN standards. Because of the particular nature of air transportation, restrictions on the **type** and **quantities** of dangerous goods transported are strictly enforced.

Worldwide harmonisation

Worldwide harmonisation of the transportation of dangerous goods by air is overseen by an agency of the UN. The principles of the international requirements are contained in the International Civil Aviation Organisation (ICAO) technical instructions and include:

- Classification
- Identification (marking, labelling and documentation)
- Acceptability for air transport
- Packaging and packing
- Loading and stowage
- Information
- Training
- Reporting of incidents and accidents
- Inspection and investigation

International agreement

The Convention on International Civil Aviation (Chicago Convention) and its annexes set out the international standards and principles for air transportation throughout the world. Annex 18 to the Convention contains the principles applied to dangerous goods. They require that:

- States ensure compliance with the technical instructions
- There must be inspection surveillance and enforcement procedures
- Dangerous goods accidents and incidents must be reported
- Dangerous goods accidents and incidents must be investigated
- ICAO technical instructions and IATA dangerous goods regulations
- The ICAO technical instructions are produced in English and are the source of the legal rules.

The International Aviation Transportation Association (IATA), the aviation trade organisation, publishes a set of Dangerous Goods Regulations that incorporate the ICAO technical instructions. The only real difference between the two documents is the order of the information, although the IATA document is more restrictive than the technical instructions. The IATA document is a field document and is more commonly referred to in aviation circles.

UK law

The UK's legal obligations under the Chicago Convention are fulfilled by the following:

The Air Navigation Order 2016, which permits the making of regulations to control the carriage of dangerous goods by air.

The Air Navigation (Dangerous Goods) Regulations 2002 (As amended 2017) that contain detailed requirements and refer to the need for airlines to comply with the latest edition of the ICAO technical instructions.

The Air Navigation (Dangerous Goods) Regulations apply to:

- Shippers
- Freight agents
- Handling agents
- Couriers
- The Post Office
- Passengers
- Operators

The regulations require the above operators and users to comply with the technical instructions and to have permission to carry dangerous goods from the Civil Aviation Authority (CAA).

Cargo aircraft

These aircraft are designed or modified for the carriage of cargo only, both in the under-floor hold and on the main deck. Aircraft specifically designed to carry cargo may have nose-opening or tail-opening cargo doors to allow loading of large or specialist cargoes. Other cargo aircraft have large main-cabin freight doors, usually positioned aft of the nose area on the port side.

Dangerous goods can be carried on cargo aircraft either in the under-floor holds or on the main deck. Those in the under-floor holds will be in passenger aircraft quantities, whereas those on the main deck will usually be cargo aircraft only items.

Passenger aircraft with under-floor holds (only)

These aircraft (examples include the Boeing 737, 747 and Airbus 3 series) are designed primarily for carrying passengers. Cargo (and baggage) will be carried in holds that are below the main deck (under floor). The introduction of wide-bodied passenger aircraft means there is a great deal of capacity in the under-floor holds for carrying cargo. Dangerous goods may be carried in the under-floor holds in passenger aircraft in limited quantities.

Passenger aircraft with holds on the same deck as passengers (combi-aircraft)

These aircraft have also been designed primarily for carrying passengers. There are two types:

- The holds are on the same deck as the passengers
- The holds are on the same deck as the passengers and there are also under-floor holds

In aircraft with holds on the same deck as the passengers, the holds may be little more than areas of the cabin separated from the passengers by curtains. In others they may be surrounded by sealed bulkheads with access from outside the aircraft only or through doors in the cabin that are kept locked in flight. Aircraft with holds on the same deck as passengers have come to be known as combi-aircraft.

Dangerous goods in passenger aircraft quantities may be carried on combi-aircraft in under-floor holds and on the main deck holds. When dangerous goods are carried, the hold must be totally separated from passengers by a bulkhead. Some low-hazard dangerous goods (i.e. those that would not lead to a serious safety or health problem in the event of a leakage) may be carried in the main deck cargo hold on other types of combi-aircraft, with approval from the Civil Aviation Authority.

Convertible aircraft (quick change aircraft)

A number of aircraft are designed to be converted quickly so that during the day they can carry passengers and at night carry cargo; they are known as quick change (QC) aircraft. Dangerous goods can be carried on QC aircraft as permitted for passenger or cargo aircraft, depending on the configuration at the time

Principles of safe transportation of dangerous goods by air

According to the hazard posed by the substance, dangerous goods may be:

- Carried on passenger and or cargo aircraft
- Restricted to cargo aircraft only
- Forbidden on both passenger and cargo aircraft (but exemption to carry may be possible)
- Totally forbidden in all circumstances
- Packaged: no bulk transportation
- Carried in limited quantities per package for passengers and cargo

Dangerous goods integral to the aircraft

Many systems and items of equipment on board an aircraft are considered to be hazardous materials; these include:

- Aircraft equipment:
- Life rafts, aerosols
- Fire extinguishers
- Dry ice
- Batteries
- Alcohol
- Oxygen generators
- Perfumes and colognes
- Fuel, matches and lighters
- Passenger baggage

Packaging for transport by air

The requirements for packaging are similar to those required by ADR and the Chemicals (Hazard Information and Packaging for Supply) Regulations, except that packages must also take into account:

- Temperature variations
- Pressure differences
- Vibration

Packages are therefore required to undergo the following tests:

- Drop test
- Stacking test
- Leak-proof test (drums only)
- Hydraulic (pressure) test (drums only)

Marking and labelling

Packaged goods are marked and labelled in accordance with UN recommendations. Both primary and secondary hazard symbols are displayed if appropriate.

Where goods are designated as being excluded from passenger aircraft, an aircraft-specific CAO (cargo aircraft only) orange label **must** be displayed.



Image 32 Cargo aircraft-only label

Shipper's declaration

All dangerous goods must be accompanied by a shipper's declaration. The shipper's declaration for dangerous goods can be distinguished from other flight documents by the red and white hatching on each side of the document. The declaration should contain the following information:

- Proper shipping name
- UN number
- UN class, division and subsidiary risk(s)
- Packing group (if applicable)
- Packing instructions and type of packaging
- Net quantity and number of packages
- Radioactive materials must additionally carry the:
 - Name or symbol of radionuclide
 - Activity
 - Package category and transport index

The image below shows an example of the shipper's declaration, which is produced by the shipper. There should be one copy at the originating point with one other travelling with the dangerous goods.

DANGEROUS GOODS IN EXCEPTED QUANTITIES

This package contains dangerous goods in excepted small quantities and is in all respects in compliance with the applicable international and national government regulations and the IATA Dangerous Goods Regulations.

Signature of Shipper

Title

Date

Name and address of Shipper

This package contains substances in Class(es)
(check applicable copies)

Class	2	3	4	5	6	7	8	9
	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

and the applicable UN Numbers are

Image 33 Shipper's declaration

Notification to the commander (NOTOC)

A special load form must be given to the commander of the aircraft, identifying the dangerous goods that have been placed on board in the cargo and where they have been loaded. This form is known as a notification to the commander (NOTOC) and must be on the aircraft in the possession of the commander. There should also be a copy of the NOTOC at the loading airport although, unlike the commanders copy, this is not a legal requirement.

Loading of dangerous goods

- Packaged dangerous goods could be loaded into aircraft:
- As individual packages
- On pallets
- Within transport loading units (known as unit load devices (ULD))

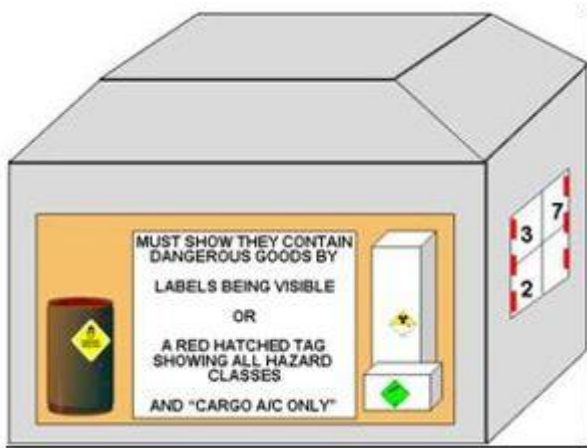


Image 34 Example of an air transport unit load device

Image 34 above illustrates a typical unit load device (ULD). This refers to any type of container with an integral pallet, or an aircraft pallet, whether or not owned by an IATA member, and whether or not considered to be aircraft-equipped. These units interface directly with an aircraft loading and restraint system. Such units become an integral part of the aircraft structure when loaded.

If the labels on packages are not visible when they are on pallets or in ULDs, a red hatched tag showing the hazard classes present must be displayed on the outside of the pallet or ULD. The cargo aircraft only (CAO) label must also be displayed or be visible where appropriate.

Loading restrictions

Packaged dangerous goods:

- Must not be stowed in the passenger cabin or on the flight deck
- Must not be on passenger aircraft if labelled 'cargo aircraft only' (CAO)
- Cargo aircraft only (CAO) packages must be accessible in flight
- Packages of liquids with orientation arrows must be upright
- Packages must be secured to prevent movement
- Damaged packages must not be loaded
- Incompatible dangerous goods must not be stowed to allow interaction
- Most explosives must be segregated from other dangerous goods
- Some types of radioactive materials must be separated from persons
- Magnetized material must be loaded so that the compass cannot be affected.

Incidents

Incidents can be categorized into those:

- On the ground
- Occurring during flight

If an incident involving dangerous goods occurs during the flight, the aircraft's commander will refer to Emergency Response Guidance for Aircraft Incidents Involving Dangerous Goods. This publication is produced by ICOA and provides emergency response details including an in-flight checklist for each dangerous substance category hazard. For incidents on the ground, the airport

fire service will usually deal with the incident, supported by the airport's local fire and rescue service.

As a requirement of Annex 18 to the Chicago Convention, all incidents must be investigated.

See National Operational Guidance: [Transport](#).

Maritime transportation

Much of the cargo transported by sea may be classed as dangerous. Incidents involving dangerous substances at sea can be divided into two main areas:

- Incidents off-shore
- Incidents in harbour

The main difference between these two types of incident is that for an incident located in a harbour, the hazardous materials adviser (HMA) must liaise with the harbour master when advising on the operational plan.

Vessels carrying dangerous goods will display a red warning flag between sunrise and sunset. Between sunset and sunrise (and during the day in restricted visibility) vessels will display an all-round, uniform and unbroken red light visible for at least two nautical miles in good night time conditions when moored or anchored.

International Maritime Dangerous Goods Code (IMDG) code

Transporting dangerous goods by sea is an international industry and is governed by an international standard; the International Maritime Dangerous Goods Code (IMDG).

The Code is used by all areas of the shipping industry that carries dangerous goods, and covers all aspects of their transportation, from the construction of the vessels to limiting quantities of substances carried.

IMDG has three volumes:

- Volume 1 includes general provisions such as definitions, training requirements, etc.
- Volume 2 includes the dangerous goods list and limited quantities exceptions
- The supplement contains the emergency schedules and medical first aid guidance; it also contains two sections that are of specific interest to the hazardous materials adviser (HMA)

Marine pollutants

A number of dangerous substances are also identified as substances harmful to the marine environment; these are known as marine pollutants. Substances classified as marine pollutants are carried in packages or transport containers identified with a marine pollutant symbol. Amendment 23 of the IMDG introduced a new marine pollutant symbol of a dead fish and a tree, which replaced the previous triangle containing a dead fish and crossed lines.

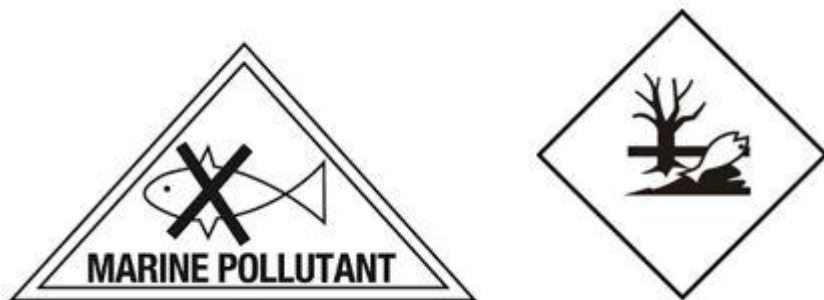


Image 35 New (right) and previously used (left) marine pollutant symbols

Emergency schedule (EMS)

This is the emergency schedule for dealing with incidents involving dangerous goods that are on fire or have been spilled.

Fire

A series of generic tables with the prefix F give guidance on the specific hazards of a substance when involved in fire and the firefighting tactics that should be employed in various locations on the ship.

Spillage

A series of generic tables with the prefix S give guidance on the hazards associated with various spills, personal protection and tactics for different sized packages and spills in various locations on the ship.

Medical first aid guidance (MFAG)

This section contains a flow chart to assist in the initial assessment of a casualty and refers the reader to generic numbered tables for specific conditions. In each case, casualty signs and symptoms are described and detailed treatments given. In many cases the treatments are significantly more involved than for normal first aid and are designed to preserve life whilst at sea, using the vessel's on board medical facilities. This information can prove to be of considerable value when attempting to assess whether the casualty has been exposed to a particular substance.

However, the guidance given under EMS and MFAG is designed for use when the vessel is at sea and to assist the survival of the ship and casualties whilst awaiting help. As a result, some of the tactics and procedures outlined, such as ditching the material overboard, may not be appropriate when the ship is in port.

The EMS is reproduced as a section in Chemdata. When accessing Chemdata for incidents involving ships, the user should ensure they refer to the sections on emergency schedules. This information is not only essential when formulating a plan but also will give an understanding of the actions that may have been taken by the ship's crew prior to the arrival of the fire and rescue service.

Bulk storage of hazardous substances

The bulk storage of hazardous substances presents fire and rescue service personnel with specific problems, which are:

- Quantities of substances stored
- Variety of substances being stored
- Variety of storage media
- Proximity of other bulk storage of hazardous substances (for example, at Buncefield there were approximately 29 bulk storage tanks and three pipelines)
- Size of the consequence area in terms of the plume, firefighting media run off, potential proximity of residential areas, etc.

The Health and Safety Executive has issued regulations and approved codes of practice for aspects of the storage of hazardous substances. The regulations and approved codes of practice require that the owner/occupier carry out a detailed risk assessment on the premises storing hazardous materials, and subsequent safety systems be implemented. It is recommended that the hazardous materials adviser refers to these documents for details on safety systems.

The safety systems are based on the assessment of the risks from:

- Release of dangerous substances
- Ignition sources
- Separation of product
- Elimination or reduction of risks from dangerous substances through:
 - Ventilation
 - Control of ignition
 - Separation of product
 - Fire resistance of the storage media
 - Fire reaction



Emergency Action Code (EAC)

On arrival at an incident, emergency responders may have to make rapid decisions and actions, the consequences of which may determine the success of the operations carried out. However, information gathering is time consuming and it is often necessary for responders to act only on the information immediately available.

The emergency action code (EAC) (also known as the Hazchem code) is designed to cover the first vital step and gives an immediate indication of any actions that could be taken should it be necessary to proceed immediately without waiting for reference materials or expert advice.

Once any immediate action has been taken to save life, protect the environment and prevent the incident escalating, the next phase can involve more detailed information from the operator or driver, the company, paperwork from the vehicle cab and various data sources.

There is more information on EAC in the latest version of the Dangerous Goods Emergency Action Code list book. But the code can be explained as follows:

1	COARSE SPRAY		3	FOAM	
2	FINE SPRAY		4	DRY AGENT	
P	V	Liquid Tight Chemical Suits		DILUTE SPILLAGE	
R					
S	V				
T					
W	V	Liquid Tight Chemical Suits		CONTAIN SPILLAGE	
X					
Y	V	Breathing Apparatus & Fire Kit			
Z					
E	PUBLIC SAFETY HAZARD				

Image 18 Interpretation of the emergency action code

The firefighting extinguishing medium is determined by reference to the first character of the [EAC](#) as follows:

1. Denotes coarse water spray
2. Denotes fine water spray
3. Denotes normal foam i.e. Protein based foam that is not alcohol resistant
4. Denotes dry agent – water should not to come into contact with substance

Where the second character of the EAC is 'S', 'T', 'Y' or 'Z' normal firefighting clothing is appropriate (i.e. self-contained, open circuit, positive pressure, compressed air breathing apparatus (BA) conforming to BS EN 137 worn in combination with fire kit conforming to BS EN 469, firefighters' gloves conforming to BS EN 659 and firefighters' boots).

Where the second character of the EAC is 'P', 'R', 'W' or 'X', liquid-tight chemical protective clothing (CPC) conforming to BS 8428 should be used, in combination with breathing apparatus (BA) specified as above are to be used.

An 'E' following the first two characters of an EAC indicates that there may be a public safety hazard outside the immediate area of the incident and that the following actions should be considered:

- People should be warned to stay indoors with all doors and windows closed, preferably in rooms upstairs and facing away from the incident
- Ignition sources should be eliminated and any ventilation stopped
- Effects may spread beyond the immediate vicinity; all non-essential personnel should be instructed to move at least 250 metres away from the incident
- Police and fire and rescue service incident commanders should consult each other and a product expert, or with a source of product expertise
- The possible need for subsequent evacuation should be considered, but it should be remembered that in most cases it will be safer to remain in a building than to evacuate

Where the EAC contains a 'P', 'S', 'W' or 'Y' there is a danger that the substance can be violently or explosively reactive or that there could be:

- A violent or explosive decomposition of the material involved, including ignition or friction
- The ignition of a flammable gas or vapour cloud (this danger exists for all flammable gases and liquids with a flash point below 60°C)
- The rapid acceleration of combustion due to the involvement of an oxidiser
- A reaction with water, which is itself violent and may also evolve flammable gases.

In some cases, a higher level of personal protection is required than the one indicated on the emergency action code (EAC) displayed on a vehicle or tank. In the list of EACs. This is indicated by the presence of an additional personal protection (APP) code of 'A' or 'B' in column four of the EAC list. This information also appears on the Chemdata database entries for the material.

Code letter A indicates that fire kit (to the specified standards as indicated in the EAC list) should be worn in combination with gas-tight chemical protective clothing (CPC), again as specified. The fire kit is intended to protect against one or more of the following additional hazards that are indicated in the list by the appropriate character(s) in brackets, following the A:

(c) Liquefied gas with a boiling point below -20°C

(fg) Flammable gas

(fl) Flammable liquid

(cf) Liquefied flammable gas with a boiling point below -20°C

(h) The substance may be carried above 100°C

(co) Oxidising gas with a boiling point below -20°C

(!) The substance may have a particularly deleterious effect on chemical protective clothing (CPC)

An APP code letter B indicates that the chemical protective clothing (CPC) should be gas-tight conforming to BS EN 943 part two, in combination with the breathing apparatus (BA), as specified in the [EAC](#) list.

When directed to apply additional personal protection code (APP) code A, the most vulnerable

areas of potential exposure will probably be the hands and feet. Appropriate hand protection for the particular hazard should be taken into consideration when conducting the risk assessment of any task to be undertaken. Structural firefighting kit is specified as tunic, overtrousers, fire hood and firefighting gloves, all conforming to the relevant British or European standard.

Most firefighting gloves cannot be worn with gas-tight suits. Even if crews are wearing gloves that meet the additional requirements of additional personal protection code (APP) code A, they will still not be fully protected against the extremely low temperatures encountered with cryogenic substances

Consider the following when selecting the most appropriate personal protective equipment (PPE) ensemble:

- Physical properties of the substance
- Form (gas/vapour, liquid, solid)
- Toxicity and/or infectivity
- Concentration levels
- Quantity of product involved or potentially involved
- Likelihood of direct contact
- Type of hazardous material incident (fire, potential fire, leak or spillage)
- Limitations of personal protective equipment (PPE) on identified tasks
- Nature and extent of proposed actions
- Location within the environment (open air, enclosed compartment or structure)
- Prevailing weather conditions
- Potential decontamination strategy

Consider the following when personnel are wearing chemical protective clothing in potentially flammable or explosive atmospheres:

- A risk/benefit assessment should be carried out to establish if it is necessary to enter the risk area in chemical protective clothing
- Always have firefighting media and covering sprays immediately available
- The build-up of electrostatic charge on the fabric with the potential to ignite a flammable atmosphere or cause an explosion
- Sparks can also be caused by stones or grit embedded in the soles of boots and the use of metal tools
- In circumstances where the relative humidity is below 25%, the likelihood of sparks is increase
- Wetting the suit before entry to reduce electrostatic build up



Road transport regulations

The regulations concerning the carriage of dangerous goods by road apply from when the goods are being loaded on to a vehicle until they are removed. In some cases they apply until any receptacle containing dangerous goods and/or the vehicle itself has been cleaned to a set standard so that there is no risk from the original product. For example, the hazards associated with a receptacle containing flammable liquids such as petroleum products will be present even when the receptacle is empty due to flammable vapours remaining until it has been cleaned.

Duties are placed on different people. There are those consigning dangerous goods for carriage, vehicle operators, drivers and others such as those involved in the design and construction of vehicles. Many of the requirements in the regulations are placed on the operator of the vehicle, i.e., the person who has the management of the vehicle (has the vehicle operator's licence).

The requirements of the legislation only apply above certain quantity thresholds. These depend on whether the dangerous goods are being carried in packages, tanks or in bulk. The consignor of a load has a duty to classify the dangerous goods, in accordance with strict guidance, and correctly package and label them.

Before responsibility for the safe carriage of these goods passes to the operator of the vehicle, the consignor needs to fulfil further important requirements. They must:

- Provide the operator with information
- Ensure that the rest of the transport chain; from the operator to the vehicle carrying the goods to the driver and the person who finally receives the consignment (the consignee) – has the necessary information to enable them to:
 - Identify what is being carried and the hazards the goods pose
 - Ensure appropriate precautions are taken to prevent, as far as possible, any risk to the health and safety of anyone who might be affected by the carriage of the goods
 - Respond quickly and effectively in the event of an accident involving the carriage of dangerous goods and, in particular, provide the information to the emergency services so that they can act appropriately.



Marking of packaged goods vehicles

The image below shows a vehicle that is used to transport dangerous goods in packages that is within the scope of the regulations by displaying plain orange placards at both the front and rear. While this is an indication that the vehicle is carrying dangerous goods, it gives no indication of their nature. Further information regarding the load would need to be found on the driver's delivery schedule, dangerous goods note (DGN) or on the packages themselves.



Image 11 Vehicle carrying packaged dangerous goods

Voluntary marking of packaged goods vehicles

Two examples of voluntary vehicle marking schemes are currently operated by transport carriers of dangerous goods in the UK with the agreement of the Health and Safety Executive, the Police Carriage of Dangerous Goods (CDG) Practitioners Forum and the Department for Transport.

Hazchem Emergency Response Service (HERS)

The HERS is a group of member carriers that use a central hub depot and satellite depots to transport packaged dangerous goods on pallets. This system displays a decal on the rear of its member vehicles showing the name of the scheme and a contact emergency telephone number. The telephone number can be used to access emergency advice, to potentially access details of what the vehicle is carrying (if the registration number is known) and to access clean-up arrangements already put in place.



Image 12 Hazchem Emergency Response Service (HERS) Decal used by the Hazchem Network palletised dangerous goods carriers in the

DHL Hazchem Emergency Response Service

A similar decal is displayed on the back and sides of vehicles used to transport dangerous goods. These vehicles are sometimes used to carry radioactive materials but the Hazchem Emergency Response Service (HERS) decals are used when the vehicles are carrying packaged dangerous goods but not radioactive materials.

These decals will only be displayed if the vehicle is carrying dangerous goods of sufficient quantities that the vehicle is subjected to the requirements of the [ADR](#) Regulations. In other words, if the vehicle is carrying goods that fall under the limited quantity exemptions to [ADR](#), or the vehicle is not carrying dangerous goods at all, then the decals will not be displayed.



Image 13 Hazchem Emergency Response Service (HERS) decal used by some DHL vehicles while carrying dangerous goods in the UK



Image 14 Type of vehicle used by DHL to transport packaged dangerous goods in the UK. The class 7 and 'Radsafe' labels would be



Placarding of road tankers and tank containers

Although the UK is a signatory to the international agreements on road transport movements ([ADR](#)) there are different requirements for placarding tankers and tank containers for purely domestic journeys (UK Hazchem). These do not apply to international movements of dangerous goods either starting or completing their journey in the UK.

Images 15 and 16 below illustrate the difference between the two systems.



Table 21 Comparison of UK Hazchem and ADR placarding

Information	UK Hazchem	ADR
UN number	Yes	Yes
Hazard symbol	Yes	Yes
Emergency action code (EAC)	Yes	
Emergency telephone number	Yes	
Hazard identification number (HIN)		Yes

UK Hazchem hazard warning panel

UK Hazchem hazard warning panels or placards used in the United Kingdom contain information on the hazardous substance being carried by the vehicle.

UK Hazchem hazard warning panels or placards are not the [ADR](#) hazard identification number (HIN), also known as the Kemler Code; this is a different warning placard. The main difference is the [ADR](#) HIN details the nature of the hazard presented by the goods as opposed to the actions to be taken when dealing with them.

Image 17 below shows a UK Hazchem hazard warning placard. The top-left section of the panel gives the emergency action code (EAC) that advises fire and rescue services on the actions to take if there is an accident. The middle-left section gives the UN substance identification number. The lower-left section gives the telephone number that should be called if special advice is needed. The warning symbol at top-right indicates the UN hazard class of the load. The bottom-right of the plate carries a company logo.

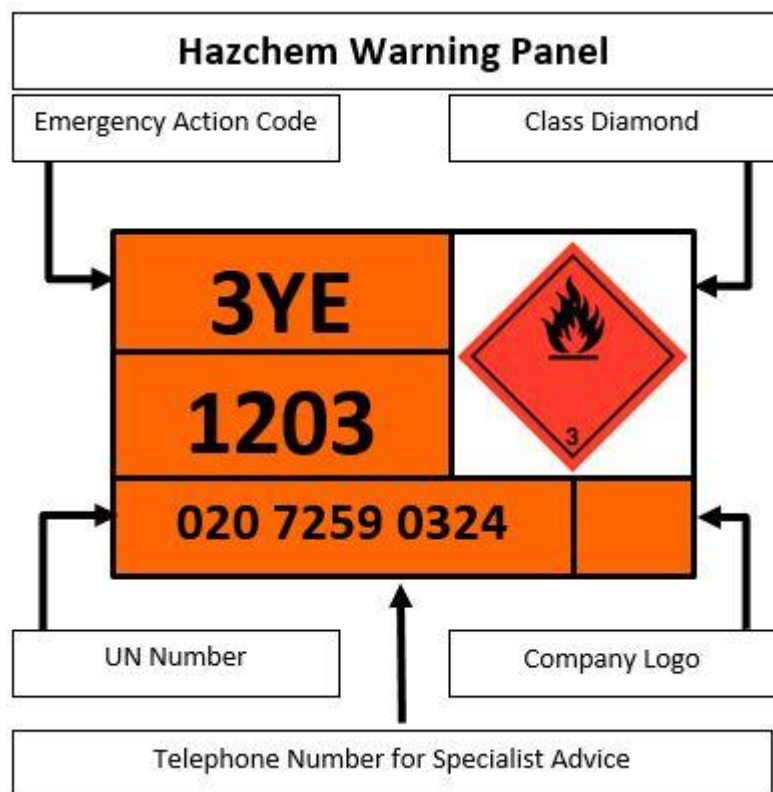


Image 17 UK Hazchem hazard warning panel



Emergency Action Code (EAC)

On arrival at an incident, emergency responders may have to make rapid decisions and actions, the consequences of which may determine the success of the operations carried out. However, information gathering is time consuming and it is often necessary for responders to act only on the information immediately available.

The emergency action code (EAC) (also known as the Hazchem code) is designed to cover the first vital step and gives an immediate indication of any actions that could be taken should it be necessary to proceed immediately without waiting for reference materials or expert advice.

Once any immediate action has been taken to save life, protect the environment and prevent the incident escalating, the next phase can involve more detailed information from the operator or driver, the company, paperwork from the vehicle cab and various data sources.

There is more information on EAC in the latest version of the Dangerous Goods Emergency Action Code list book. But the code can be explained as follows:

1	COARSE SPRAY	3	FOAM
2	FINE SPRAY	4	DRY AGENT
P	V	Liquid Tight Chemical Suits	DILUTE SPILLAGE
R			
S	V	Breathing Apparatus & Fire Kit	
T			
W	V	Liquid Tight Chemical Suits	CONTAIN SPILLAGE
X			
Y	V	Breathing Apparatus & Fire Kit	
Z			
E	PUBLIC SAFETY HAZARD		

Image 18 Interpretation of the emergency action code

The firefighting extinguishing medium is determined by reference to the first character of the [EAC](#) as follows:

1. Denotes coarse water spray
2. Denotes fine water spray
3. Denotes normal foam i.e. Protein based foam that is not alcohol resistant
4. Denotes dry agent – water should not to come into contact with substance

Where the second character of the EAC is 'S', 'T', 'Y' or 'Z' normal firefighting clothing is appropriate (i.e. self-contained, open circuit, positive pressure, compressed air breathing apparatus (BA) conforming to BS EN 137 worn in combination with fire kit conforming to BS EN 469, firefighters' gloves conforming to BS EN 659 and firefighters' boots).

Where the second character of the EAC is 'P', 'R', 'W' or 'X', liquid-tight chemical protective clothing (CPC) conforming to BS 8428 should be used, in combination with breathing apparatus (BA) specified as above are to be used.

An 'E' following the first two characters of an EAC indicates that there may be a public safety hazard outside the immediate area of the incident and that the following actions should be considered:

- People should be warned to stay indoors with all doors and windows closed, preferably in rooms upstairs and facing away from the incident
- Ignition sources should be eliminated and any ventilation stopped

- Effects may spread beyond the immediate vicinity; all non-essential personnel should be instructed to move at least 250 metres away from the incident
- Police and fire and rescue service incident commanders should consult each other and a product expert, or with a source of product expertise
- The possible need for subsequent evacuation should be considered, but it should be remembered that in most cases it will be safer to remain in a building than to evacuate

Where the EAC contains a 'P', 'S', 'W' or 'Y' there is a danger that the substance can be violently or explosively reactive or that there could be:

- A violent or explosive decomposition of the material involved, including ignition or friction
- The ignition of a flammable gas or vapour cloud (this danger exists for all flammable gases and liquids with a flash point below 60°C)
- The rapid acceleration of combustion due to the involvement of an oxidiser
- A reaction with water, which is itself violent and may also evolve flammable gases.

In some cases, a higher level of personal protection is required than the one indicated on the emergency action code (EAC) displayed on a vehicle or tank. In the list of EACs. This is indicated by the presence of an additional personal protection (APP) code of 'A' or 'B' in column four of the EAC list. This information also appears on the Chemdata database entries for the material.

Code letter A indicates that fire kit (to the specified standards as indicated in the EAC list) should be worn in combination with gas-tight chemical protective clothing (CPC), again as specified. The fire kit is intended to protect against one or more of the following additional hazards that are indicated in the list by the appropriate character(s) in brackets, following the A:

(c) Liquefied gas with a boiling point below -20°C

(fg) Flammable gas

(fl) Flammable liquid

(cf) Liquefied flammable gas with a boiling point below -20°C

(h) The substance may be carried above 100°C

(co) Oxidising gas with a boiling point below -20°C

(!) The substance may have a particularly deleterious effect on chemical protective clothing (CPC)

An APP code letter B indicates that the chemical protective clothing (CPC) should be gas-tight conforming to BS EN 943 part two, in combination with the breathing apparatus (BA), as specified in the [EAC](#) list.

When directed to apply additional personal protection code (APP) code A, the most vulnerable areas of potential exposure will probably be the hands and feet. Appropriate hand protection for the particular hazard should be taken into consideration when conducting the risk assessment of any task to be undertaken. Structural firefighting kit is specified as tunic, overtrousers, fire hood

and firefighting gloves, all conforming to the relevant British or European standard.

Most firefighting gloves cannot be worn with gas-tight suits. Even if crews are wearing gloves that meet the additional requirements of additional personal protection code (APP) code A, they will still not be fully protected against the extremely low temperatures encountered with cryogenic substances

Consider the following when selecting the most appropriate personal protective equipment (PPE) ensemble:

- Physical properties of the substance
- Form (gas/vapour, liquid, solid)
- Toxicity and/or infectivity
- Concentration levels
- Quantity of product involved or potentially involved
- Likelihood of direct contact
- Type of hazardous material incident (fire, potential fire, leak or spillage)
- Limitations of personal protective equipment (PPE) on identified tasks
- Nature and extent of proposed actions
- Location within the environment (open air, enclosed compartment or structure)
- Prevailing weather conditions
- Potential decontamination strategy

Consider the following when personnel are wearing chemical protective clothing in potentially flammable or explosive atmospheres:

- A risk/benefit assessment should be carried out to establish if it is necessary to enter the risk area in chemical protective clothing
- Always have firefighting media and covering sprays immediately available
- The build-up of electrostatic charge on the fabric with the potential to ignite a flammable atmosphere or cause an explosion
- Sparks can also be caused by stones or grit embedded in the soles of boots and the use of metal tools
- In circumstances where the relative humidity is below 25%, the likelihood of sparks is increase
- Wetting the suit before entry to reduce electrostatic build up



ADR hazard identification numbers (HIN) or 'Kemler Code'

The hazard identification number consists of two or three figures indicating the following hazards:

Table 22 Hazard identification numbers

No.	Hazard
2	Emission of gas due to pressure or chemical reaction
3	Flammability of liquids (vapours) and gases or self-heating liquid
4	Flammability of solids or self-heating solid
5	Oxidising (fire-intensifying) effect
6	Toxicity
7	Radioactivity
8	Corrosivity
9	Risk of spontaneous violent reaction

Duplication of a figure (e.g. 55) indicates an intensification of that particular hazard.

Where the hazard associated with a substance can be adequately indicated by a single figure, this is followed by a zero.

A hazard identification number prefixed by letter X indicates that the substance will react dangerously with water.

Table 23 below shows the meanings of hazard identification number combinations:

(*Water must not be used except by approval of experts)

Table 23 Hazard identification number meanings

Number	Meaning
20	Asphyxiant gas or gas with no subsidiary risk
22	Refrigerated liquefied gas, asphyxiant
223	Refrigerated liquefied gas, flammable
225	Refrigerated liquefied gas, oxidising (fire intensifying)
23	Flammable gas
238	Gas, flammable corrosive

Number	Meaning
239	Flammable gas, which can spontaneously lead to violent reaction
25	Oxidising (fire-intensifying) gas
26	Toxic gas
263	Toxic gas, flammable
265	Toxic gas, oxidising (fire-intensifying)
268	Toxic gas, corrosive
28	Gas, corrosive
285	Gas, corrosive, oxidising Flammable liquid that reacts with water, emitting 30flammable gases
30	Flammable liquid (flash-point between 23°C and 60°C inclusive) or flammable liquid or solid in the molten state with a flash point above 60°C, heated to a temperature equal to or above its flash point, or self-heating liquid
323	Flammable liquid that reacts with water, emitting flammable gases
X323	Flammable liquid that reacts dangerously with water, emitting flammable gases
33	Highly flammable liquid (flash point below 23°C)
333	Pyrophoric liquid
X333	Pyrophoric liquid, which reacts dangerously with water*
336	Highly flammable liquid, toxic
338	Highly flammable liquid, corrosive
X338	Highly flammable liquid, corrosive, which reacts dangerously with water*
339	Highly flammable liquid that can spontaneously lead to violent reaction

Number	Meaning
36	Flammable liquid (flash point between 23°C and 60°C inclusive), slightly toxic or self-heating liquid toxic
362	Flammable liquid, toxic, which reacts with water, emitting flammable gases
X362	Flammable liquid, toxic, which reacts dangerously with water, emitting flammable gases*
368	Flammable liquid, toxic, corrosive
38	Flammable liquid (flash point between 23°C and 60°C inclusive), slightly corrosive or self-heating liquid, corrosive
382	Flammable liquid, corrosive, which reacts with water, emitting flammable gases
X382	Flammable liquid, corrosive, which reacts dangerously with water, emitting flammable gases*
39	Flammable liquid, which can spontaneously lead to violent reaction
40	Flammable solid, or self-reactive substance, or self-heating substance
423	Solid that reacts with water, emitting flammable gas, or flammable solid which reacts with water, emitting flammable gases or self-heating solid which reacts with water, emitting flammable gases*
X423	Solid that reacts dangerously with water, emitting flammable gases, or flammable solid that reacts dangerously with water, emitting flammable gases, or self-heating solid that reacts dangerously with water, emitting flammable gas Flammable solid, in the molten state at an elevated temperatures*
43	Spontaneously flammable (pyrophoric) solid
X432	Spontaneously flammable (pyrophoric) solid that reacts dangerously with water, emitting flammable gases*
44	Flammable solid, in the molten state at an elevated temperature
446	Flammable solid, toxic in the molten state, at an elevated temperature

Number	Meaning
46	Flammable or self-heating solid, toxic
462	Toxic solid that reacts with water, emitting flammable gases
X462	Solid that reacts dangerously with water, emitting toxic gases*
48	Flammable or self-heating solid, corrosive
482	Corrosive solid that reacts with water, emitting corrosive gases
X482	Solid that reacts dangerously with water, emitting corrosive gases*
50	Oxidising (fire-intensifying) substance
539	Flammable organic peroxide
55	Strongly oxidising (fire-intensifying) substance
556	Strongly oxidising (fire-intensifying) substance, toxic
558	Strongly oxidising (fire-intensifying) substance, corrosive
559	Strongly oxidising (fire-intensifying) substance, which can spontaneously lead to violent reaction
56	Oxidising substance (fire-intensifying), toxic
568	Oxidising substance (fire-intensifying), toxic, corrosive
58	Oxidising substance (fire-intensifying), corrosive
59	Oxidising substance (fire-intensifying) that can spontaneously lead to violent reaction
60	Toxic or slightly toxic substance
606	Infectious substance
623	Toxic liquid, which reacts with water, emitting flammable gases
63	Toxic substance, flammable (flash point between 23°C and 60°C inclusive)

Number	Meaning
638	Toxic substance, flammable (flash point between 23°C and 60°C inclusive), corrosive
639	Toxic substance, flammable (flash point not above 60°C inclusive), which can spontaneously lead to violent reaction
64	Toxic solid, flammable or self-heating
642	Toxic solid, which reacts with water, emitting flammable gases
65	Toxic substance, oxidising (fire-intensifying)
66	Highly toxic substance
663	Highly toxic substance, flammable (flash-point not above 60°C inclusive)
664	Highly toxic substance, flammable or self-heating
665	Highly toxic substance, oxidising (fire-intensifying)
668	Highly toxic substance, corrosive
669	Highly toxic substance that can spontaneously lead to a violent reaction
68	Toxic substance, corrosive
69	Toxic or slightly toxic substance, which can spontaneously lead to a violent reaction
70	Radioactive material
78	Radioactive material, corrosive
80	Corrosive or slightly corrosive substance
X80	Corrosive or slightly corrosive substance, which reacts dangerously with water*
823	Corrosive liquid which reacts with water, emitting flammable gases

Number	Meaning
83	Corrosive or slightly corrosive substance, flammable (flash point between 23°C and 60°C inclusive)
X83	Corrosive or slightly corrosive substance, flammable (flash point between 23°C and 60°C inclusive), which reacts dangerously with water*
839	Corrosive or slightly corrosive substance, flammable (flash point between 23°C and 60°C inclusive), which can spontaneously lead to violent reaction
X839	Corrosive or slightly corrosive substance, flammable (flash point between 23°C and 60°C inclusive), which can spontaneously lead to violent reaction and which reacts dangerously with water*
84	Corrosive solid, flammable or self-heating
842	Corrosive solid which reacts with water, emitting flammable gases
85	Corrosive or slightly corrosive substance, oxidising (fire-intensifying)
856	Corrosive or slightly corrosive substance, oxidising (fire-intensifying) and toxic
86	Corrosive or slightly corrosive substance, toxic
88	Highly-corrosive substance
X88	Highly-corrosive substance, which reacts dangerously with water*
883	Highly-corrosive substance, flammable (flash-point between 23°C and 60°C inclusive)
884	Highly-corrosive solid, flammable or self-heating
885	Highly-corrosive substance, oxidising (fire-intensifying)
886	Highly-corrosive substance, toxic
X886	Highly-corrosive substance, toxic, which reacts dangerously with water*
89	Corrosive or slightly-corrosive substance, which can spontaneously lead to a violent reaction

Number	Meaning
90	Environmentally hazardous substance; miscellaneous dangerous substances
99	Miscellaneous dangerous substance carried at an elevated temperature

UK bulk vehicle placarding

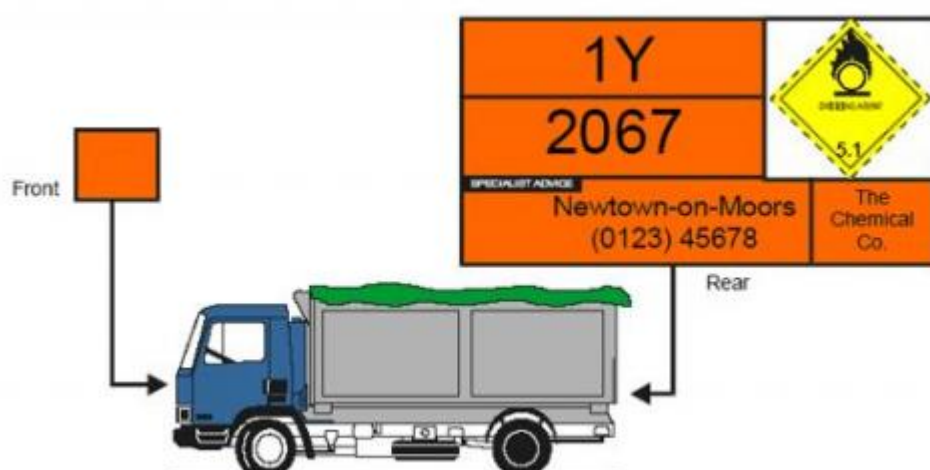


Image 19 UK Hazchem hazard warning panel - single bulk load

Single bulk load

Image 19 above shows the signage for a bulk single load (in excess of three cubic metres). The detailed signage will be on the sides and rear of the vehicle.

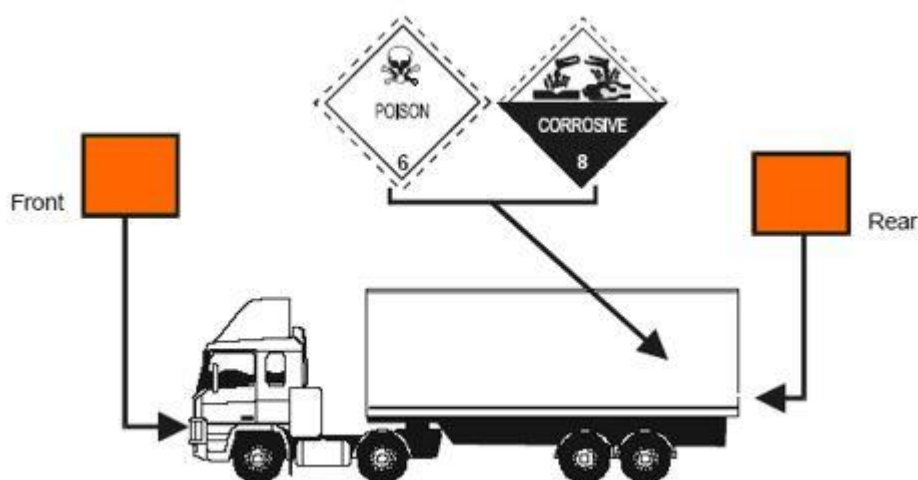


Image 20 Single load in packages in a freight container

Image 20 above shows signage for a vehicle carrying dangerous goods in packages in a

demountable freight container. In addition to orange panels on the front and rear of the vehicle, all sides of the container will have the standard warning symbols, according to the hazards posed by the load.

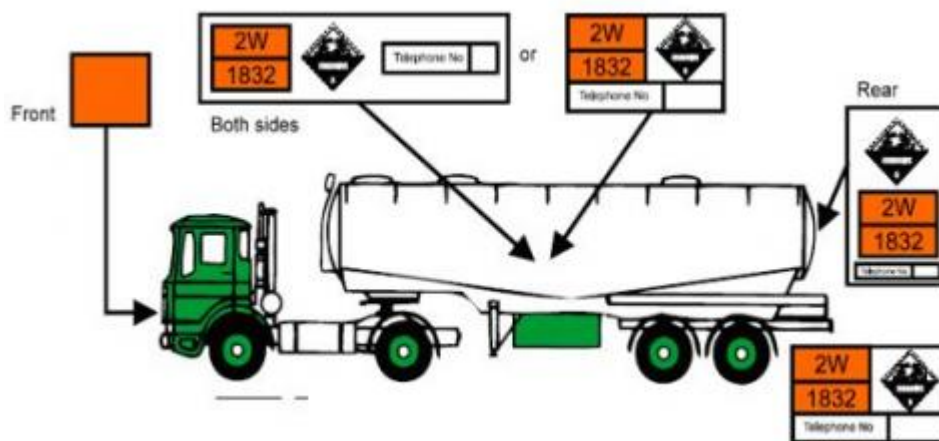


Image 21 Single load tanker

The image above shows a single load tanker. Note the variations in showing the key information.

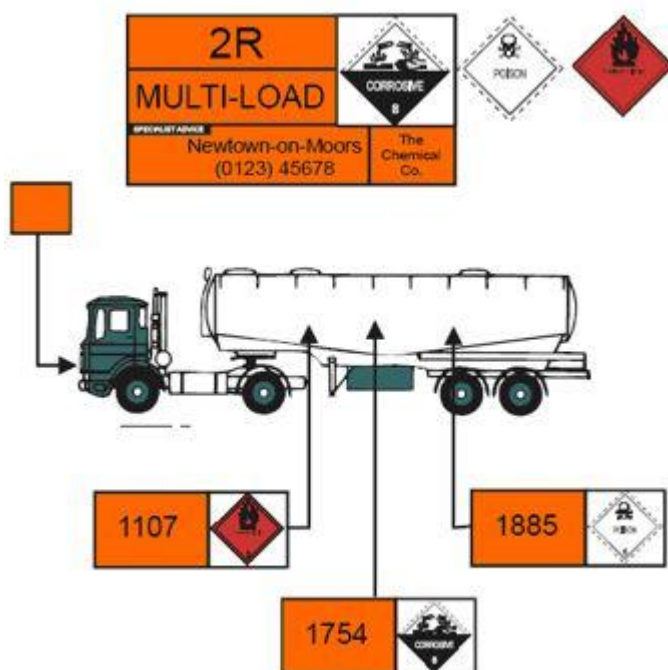


Image 22 Multi load tanker

Image 22 above shows the signage for a multi load tanker. The main placard will state multi-load but the hazard symbol(s) will show the hazard(s) of the load. Each individual compartment of the tanker will have its own sign giving the UN number for the substance and the hazard symbol denoting its specific hazard.



European ADR tanker or tank placarding

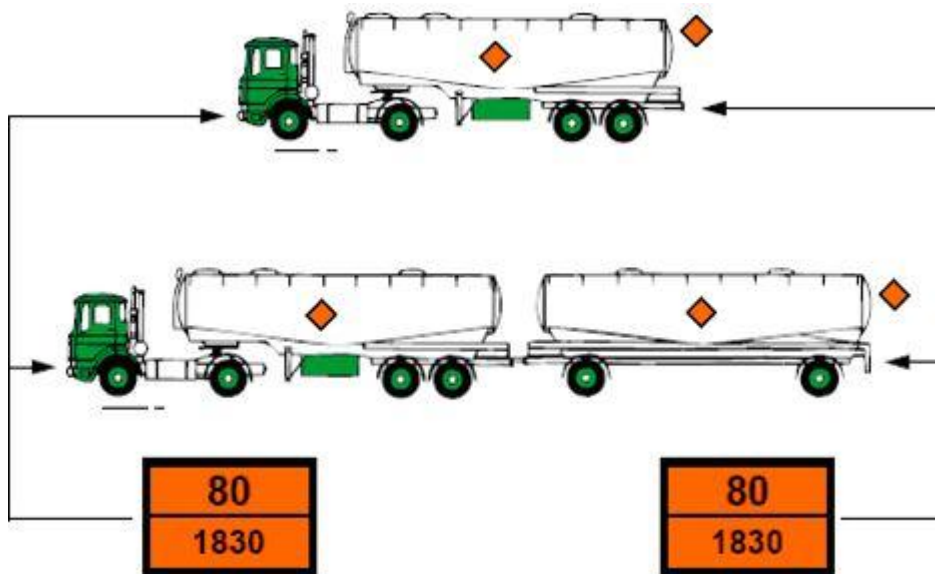


Image 24 Single load tanker showing ADR markings

Single load tanker

For tank vehicles carrying only one substance, as shown above, the identification numbers can be shown on the orange plates at the front and rear of the vehicle. Hazard warning symbols are located on each side of the vehicle and at the rear (as indicated).

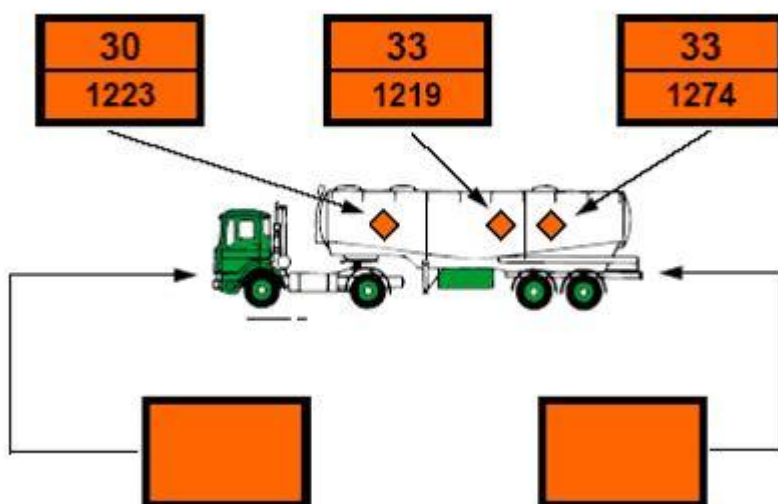


Image 25 Bulk load tanker

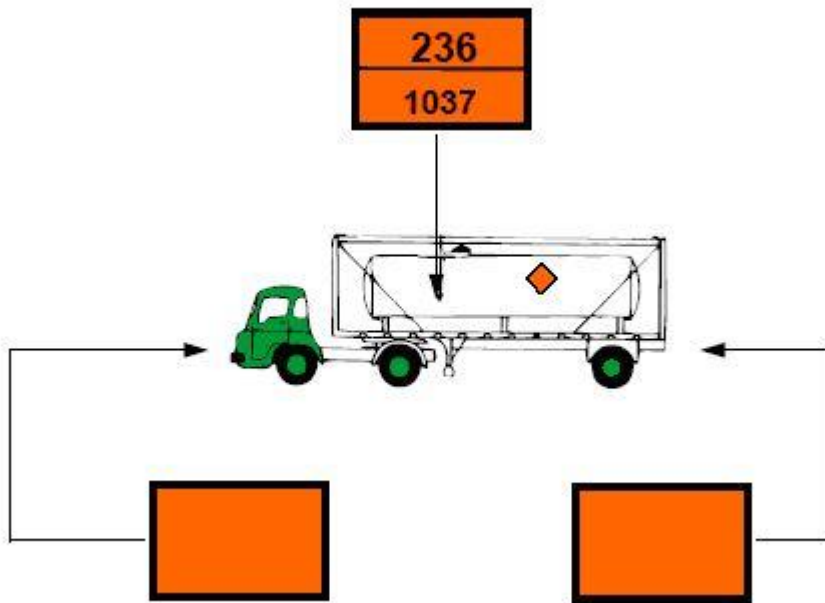


Image 26 Tank vehicle carrying a multi load will display signage as shown above

Tank container

Vehicles carrying tank containers must display orange plates on each side of the tank, or tank compartments, giving hazard and substance identification numbers. A blank plate is displayed at the front and rear. Hazard warning symbols are located on each side of the compartment adjacent to each ADR placard.

Tank containers must have the identification numbers on the tank itself to remain in sight when the tank is offloaded from the vehicle.

Elevated temperature marking

Tank vehicles, tank containers, portable tanks, special vehicles or containers or specially-equipped vehicles or containers carrying elevated temperature substances are required under ADR to display an elevated temperature mark on both sides and at the rear for vehicles, and on both sides and at each end for containers, tank-containers and portable tanks. Image 27 below shows the elevated temperature marking displayed according to ADR,



Image 27 Elevated temperature marking

Environmentally hazardous substances marking

When required to be displayed in accordance with the provisions of ADR, containers, tank-containers, portable tanks and vehicles containing certain environmentally hazardous substances are to be marked with the environmentally hazardous substance mark shown below.



Image 28 Environmentally hazardous substances marking



Switch-loading of petrol and distillate fuels

Switch-loading is the terminology used to describe the practice of loading a distillate fuel (e.g. diesel or gas oil), into a tank compartment that has previously contained petrol. Switch-loading can also be practiced between petrol and kerosene but this practice is normally discouraged because of the risk of residual petrol (liquid or vapour) lowering the flash point of the kerosene.

In the UK the practice of switch-loading road tankers is very common, undertaken by perhaps as many as 95% of petrol/distillate fuel tankers to minimise unnecessary journeys (e.g. by discharging one load and returning with another). Compartments of tankers that have been switch-loaded will not only contain the liquid distillate product but also an amount of petrol vapour remaining from the previous load or loads.

Road tankers that transport petrol are designed and constructed for bottom loading with vapour recovery and in addition to the compartment ullage spaces, petrol vapour will be retained in the associated vapour manifold and pipework, together with small amounts of petrol in other associated pieces of equipment.

Distillate fuels have a greater density than petrol and in many cases a nominal full load of distillate will require a tanker to run with an empty or partially filled compartment, to ensure that the vehicle does not exceed its maximum authorised mass on the road.

Large volumes of petrol vapour will be retained in the empty and/or partially-filled compartments of a tanker carrying distillates in which petrol has been previously loaded. Even in compartments not previously loaded with petrol there is a risk that vapour will be present. This is due to the inter-compartment connection afforded by the vapour manifold and the vapour transfer valves, all of which are open during the bottom loading process. It is possible that a tanker may arrive at a site with a full load of diesel and leave with a full load of petrol vapour.

Where a mixed load of liquid products comprises petrol, diesel, kerosene or aviation fuels the tanker will be marked with the UN number of the product with the greatest hazard i.e. the lowest

flashpoint. In the case of empty, uncleaned tanks, the tanker is marked as if it still contained the original product. However, there are no specific marking provisions where the transport of a single substance with the residual vapour of a product with a greater hazard (lower flashpoint) is undertaken, even though this may present a similar hazard to that of an empty uncleaned tanker.

Under the current regulations, a compartment that was previously filled with petrol and then refilled with diesel and subsequently emptied of the diesel would have to be marked UN 1202 (diesel) to reflect the last load in the uncleaned tank, but in fact could be filled with petrol vapour.

These hazards are recognised by the petroleum industry and as a result it has become widespread practice in the UK for road tanker operators to retain the petrol marking (UN 1203) on tankers for a number of full loads of diesel or gas oil (UN 1202) after carrying petrol, to reflect the presence of the retained petrol vapour and the greater danger this may pose.

Actions for fire and rescue services

Fire and rescue services should be aware that, when dealing with incidents involving petrol/distillate tankers, any of the tank compartments may contain mixtures of distillate and petrol vapour. Therefore, all the tanks should be treated as if they contained petrol vapour until information to the contrary is obtained.

This also means that tanks may contain diesel/gas oil as the main load but may still be marked as petrol to better reflect the greater danger from any residual petrol vapours.

The emergency action code (EAC) for all such tankers should therefore be taken to be 3YE (indicating a possible public safety hazard beyond the immediate area of the incident) even though the emergency action code for the distillates will be 3Y and some tankers may still be marked as such.

As there are no movements of petrol/distillate tankers to and from Europe this will not be an issue for non-UK registered tankers (i.e. those marked with ADR hazardous identification numbers).



Registration, evaluation, authorisation and restriction of chemicals (REACH) Regulations

Registration, evaluation, authorisation and restriction of chemicals (REACH) is a European Union regulatory framework for chemicals, which came into force on 1 June 2007. REACH has several aims and puts greater responsibility on industry to manage the risks from chemicals and to provide safety information that will be passed down the supply chain.

REACH will require some 30,000 chemical substances to be registered over a period of 11 years, excluding the following;

- Radioactive substances
- Substances under customs supervision
- The transport of substances
- Non-isolated intermediates
- Waste
- Some naturally occurring low-hazard substances

The registration process requires anyone manufacturing more than one tonne per year of these substances within the EU, or importing this amount into the EU, to generate data for all chemicals produced or imported, whether on their own or in one or more preparations. This information must be registered with the European Chemicals Agency. The registrants must also identify appropriate risk management measures and communicate them to the users.

In addition, REACH will allow the further evaluation of substances where there are grounds for concern and foresees an authorisation system for the use of substances of very high concern. This applies to substances that cause cancer, infertility, genetic mutations or birth defects, and to those that are persistent and accumulate in the environment. The authorisation system will require companies to switch progressively to safer alternatives where a suitable alternative exists. All applications for an authorisation need to include an analysis of alternatives and a substitution plan where a suitable alternative exists. Current use restrictions will remain under the REACH system.



Rail transportation

All classes of hazardous substances are carried on the UK rail network (except in Northern Ireland). The carriage of dangerous goods regulations apply to rail transport, with detailed guidance coming from the [Carriage of Dangerous Goods Manual \(HSE\)](#).

The only exceptions to the regulations are:

- Substances carried with the sole purpose of being used on, or by, the train (e.g. fuel)
- Radioactive materials; these have their own Regulations (Packaging Labelling and Carriage of Radioactive Material by Rail Regulations)

The regulations require that sufficient information is supplied with the load to ensure that all involved with the transportation process can:

- Identify what is being carried
- Be aware of the potential hazards

- In the case of the fire and rescue service, respond quickly and efficiently

The information is supplied to the train operator and the rail infrastructure controller, therefore if there is an incident and the information cannot be obtained from the train driver, it can be obtained from the operator.

The information given includes:

- Designation and classification of the dangerous goods
- UN number
- Packaging group
- Compatibility and division for explosives
- Consignor and consignee details
- Specialist advice
- Mass and volume of the:
 - Package
 - Tank, tank container, or tank wagon
 - Bulk load in container or wagon
 - Total consignment.

Containers, tank container, tank wagons and wagons must display relevant signage related to their contents, using the UK Hazchem system for UK-only journeys or the RID marking provisions for international journeys (these mirror those of ADR for road vehicles), as shown above.

Total operations processing system (TOPS)

The total operations processing system (TOPS) is a computerised system that enables Network Rail to keep a constant check on the position and availability of every rail vehicle on their system and provide specific information of the various loads that are being hauled.

It consists of a central computer system connected to regional control offices, marshalling yards and depots throughout the country. The system is based on a main computer, which is linked to input points at area freight offices throughout Network Rail.

From these control centres, details of all the wagon and freight details, whether they are loaded or unloaded, freight train movements and type of traffic conveyed are fed into the computer. On request by an incident commander via fire service control and Network Rail control office can obtain any specific information from the system, on any wagon or freight train and its cargo. Each wagon is clearly marked with an individual identification number on its side. This number will be recorded on the TOPS computer so that information on the load can be made readily available for operational staff in the event of an incident.

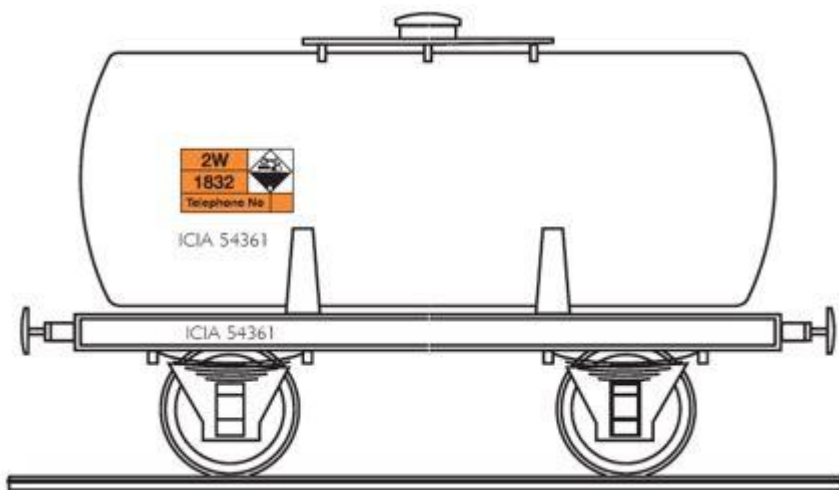


Image 29 Location of identification numbers and hazard warning plates on wagon

Additional tank wagon identification schemes

Tank wagons carrying certain classes of dangerous goods can be identified by specific colour schemes. For example, tank wagons carrying Liquefied petroleum gas (LPG) will have a white barrel with a horizontal orange stripe round the barrel at mid height. Tank wagons carrying flammable liquids are painted dove grey and the sole bars are painted signal red (sole bars are the two horizontal metal bars on which the bottom of the tank rests).

In addition, all wagons containing dangerous goods will have a Network Rail dangerous wagon label displayed on each side. This label indicates the class of substance being carried and the principal hazard that could be encountered. Containers that are hauled by rail are exempt from being labelled in this manner.

The emergency code for the label consists of a six digit number. The first four numbers are the substance identification number for the substance carried or the class, division and compatibility group in the case of explosives. The remaining two letters are referred to as the alpha code. This code has been allocated to firms and enables Network Rail to ascertain the telephone number that should be used to request specialist assistance in the event of an emergency.

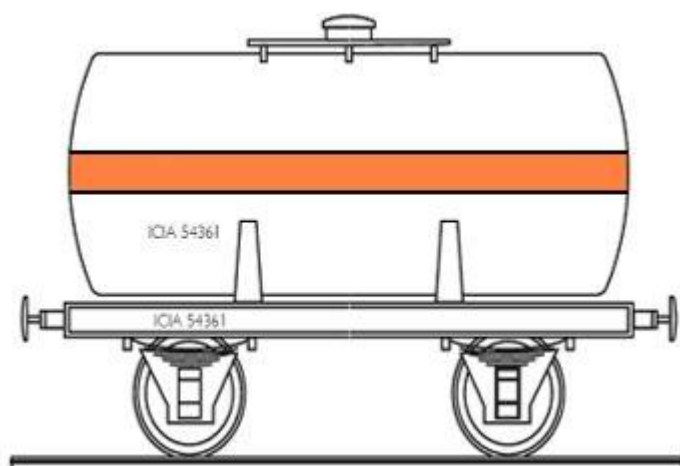


Image 30 Example of tank wagon designed to carry LPG

Information available from the rail vehicle crew

The rail vehicle crew holds information on the specific details of each wagon and the details of their individual loads. This is recorded on an information sheet known as the consist. It will contain the following information:

- Position of every wagon from front to rear
- Train identity number
- Locomotive identity number
- Wagon numbers
- Dangerous goods emergency codes
- UN number plus specialist advice contact code

It would be advisable for the incident commander to obtain the consist as it will provide immediate information on the type of loads being carried and give interim guidance on a course of action to follow until further information is secured either from TOPS or from a designated specialist adviser.

The [2018 Network Statement: Network Rail](#) gives further information on Exceptional Transports and Dangerous Goods.

Irradiated fuel flasks

If an incident involving an irradiated fuel flask occurs, NAIR will be activated immediately. However, some operational priorities need to be considered whilst the NAIR scheme is instigated. For further information see [National Operational Guidance: Health hazards](#).



Image 31 Irradiated fuel transport flask being loaded onto a train

Air transportation



Air transportation

Unlike road and rail transportation of hazardous materials, all air transport is classed as international and therefore is governed by international regulations and agreements.

The worldwide system used to control the transportation of dangerous goods by air is based on the same United Nation's Emergency Response Guidebook (ERG) requirements placed on all other modes of transport. International requirements for the safe air transportation of radioactive material also relate to UN standards. Because of the particular nature of air transportation, restrictions on the **type** and **quantities** of dangerous goods transported are strictly enforced.

Worldwide harmonisation

Worldwide harmonisation of the transportation of dangerous goods by air is overseen by an agency of the UN. The principles of the international requirements are contained in the International Civil Aviation Organisation (ICAO) technical instructions and include:

- Classification
- Identification (marking, labelling and documentation)
- Acceptability for air transport
- Packaging and packing
- Loading and stowage
- Information
- Training
- Reporting of incidents and accidents
- Inspection and investigation

International agreement

The Convention on International Civil Aviation (Chicago Convention) and its annexes set out the international standards and principles for air transportation throughout the world. Annex 18 to the Convention contains the principles applied to dangerous goods. They require that:

- States ensure compliance with the technical instructions
- There must be inspection surveillance and enforcement procedures
- Dangerous goods accidents and incidents must be reported
- Dangerous goods accidents and incidents must be investigated
- ICAO technical instructions and IATA dangerous goods regulations
- The ICAO technical instructions are produced in English and are the source of the legal rules.

The International Aviation Transportation Association (IATA), the aviation trade organisation, publishes a set of Dangerous Goods Regulations that incorporate the ICAO technical instructions. The only real difference between the two documents is the order of the information, although the IATA document is more restrictive than the technical instructions. The IATA document is a field document and is more commonly referred to in aviation circles.

UK law

The UK's legal obligations under the Chicago Convention are fulfilled by the following:

The Air Navigation Order 2016, which permits the making of regulations to control the carriage of dangerous goods by air.

The Air Navigation (Dangerous Goods) Regulations 2002 (As amended 2017) that contain detailed requirements and refer to the need for airlines to comply with the latest edition of the ICAO technical instructions.

The Air Navigation (Dangerous Goods) Regulations apply to:

- Shippers
- Freight agents
- Handling agents
- Couriers
- The Post Office
- Passengers
- Operators

The regulations require the above operators and users to comply with the technical instructions and to have permission to carry dangerous goods from the Civil Aviation Authority (CAA).

Cargo aircraft

These aircraft are designed or modified for the carriage of cargo only, both in the under-floor hold and on the main deck. Aircraft specifically designed to carry cargo may have nose-opening or tail-opening cargo doors to allow loading of large or specialist cargoes. Other cargo aircraft have large main-cabin freight doors, usually positioned aft of the nose area on the port side.

Dangerous goods can be carried on cargo aircraft either in the under-floor holds or on the main deck. Those in the under-floor holds will be in passenger aircraft quantities, whereas those on the main deck will usually be cargo aircraft only items.

Passenger aircraft with under-floor holds (only)

These aircraft (examples include the Boeing 737, 747 and Airbus 3 series) are designed primarily for carrying passengers. Cargo (and baggage) will be carried in holds that are below the main deck (under floor). The introduction of wide-bodied passenger-carrying aircraft means there is a great deal of capacity in the under-floor holds for carrying cargo. Dangerous goods may be carried in the under-floor holds in passenger aircraft in limited quantities.

Passenger aircraft with holds on the same deck as passengers (combi-aircraft)

These aircraft have also been designed primarily for carrying passengers. There are two types:

- The holds are on the same deck as the passengers

- The holds are on the same deck as the passengers and there are also under-floor holds

In aircraft with holds on the same deck as the passengers, the holds may be little more than areas of the cabin separated from the passengers by curtains. In others they may be surrounded by sealed bulkheads with access from outside the aircraft only or through doors in the cabin that are kept locked in flight. Aircraft with holds on the same deck as passengers have come to be known as combi-aircraft.

Dangerous goods in passenger aircraft quantities may be carried on combi-aircraft in under-floor holds and on the main deck holds. When dangerous goods are carried, the hold must be totally separated from passengers by a bulkhead. Some low-hazard dangerous goods (i.e. those that would not lead to a serious safety or health problem in the event of a leakage) may be carried in the main deck cargo hold on other types of combi-aircraft, with approval from the Civil Aviation Authority.

Convertible aircraft (quick change aircraft)

A number of aircraft are designed to be converted quickly so that during the day they can carry passengers and at night carry cargo; they are known as quick change (QC) aircraft. Dangerous goods can be carried on QC aircraft as permitted for passenger or cargo aircraft, depending on the configuration at the time

Principles of safe transportation of dangerous goods by air

According to the hazard posed by the substance, dangerous goods may be:

- Carried on passenger and or cargo aircraft
- Restricted to cargo aircraft only
- Forbidden on both passenger and cargo aircraft (but exemption to carry may be possible)
- Totally forbidden in all circumstances
- Packaged: no bulk transportation
- Carried in limited quantities per package for passengers and cargo

Dangerous goods integral to the aircraft

Many systems and items of equipment on board an aircraft are considered to be hazardous materials; these include:

- Aircraft equipment:
- Life rafts, aerosols
- Fire extinguishers
- Dry ice
- Batteries
- Alcohol
- Oxygen generators
- Perfumes and colognes
- Fuel, matches and lighters

- Passenger baggage

Packaging for transport by air

The requirements for packaging are similar to those required by ADR and the Chemicals (Hazard Information and Packaging for Supply) Regulations, except that packages must also take into account:

- Temperature variations
- Pressure differences
- Vibration

Packages are therefore required to undergo the following tests:

- Drop test
- Stacking test
- Leak-proof test (drums only)
- Hydraulic (pressure) test (drums only)

Marking and labelling

Packaged goods are marked and labelled in accordance with UN recommendations. Both primary and secondary hazard symbols are displayed if appropriate.

Where goods are designated as being excluded from passenger aircraft, an aircraft-specific CAO (cargo aircraft only) orange label **must** be displayed.



Image 32 Cargo aircraft-only label

Shipper's declaration

All dangerous goods must be accompanied by a shipper's declaration. The shipper's declaration for dangerous goods can be distinguished from other flight documents by the red and white hatching on each side of the document. The declaration should contain the following information:

- Proper shipping name

- UN number
- UN class, division and subsidiary risk(s)
- Packing group (if applicable)
- Packing instructions and type of packaging
- Net quantity and number of packages
- Radioactive materials must additionally carry the:
 - Name or symbol of radionuclide
 - Activity
 - Package category and transport index

The image below shows an example of the shipper's declaration, which is produced by the shipper. There should be one copy at the originating point with one other travelling with the dangerous goods.

DANGEROUS GOODS IN EXCEPTED QUANTITIES

This package contains dangerous goods in excepted small quantities and is in all respects in compliance with the applicable international and national government regulations and the IATA Dangerous Goods Regulations.

Signature of Shipper

Title

Date

Name and address of Shipper

This package contains substances in Class(es)
(check applicable copies)

Class	2	3	4	5	6	7	8	9
	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

and the applicable UN Numbers are

Image 33 Shipper's declaration

Notification to the commander (NOTOC)

A special load form must be given to the commander of the aircraft, identifying the dangerous goods that have been placed on board in the cargo and where they have been loaded. This form is known as a notification to the commander (NOTOC) and must be on the aircraft in the possession of the commander. There should also be a copy of the NOTOC at the loading airport although, unlike the commanders copy, this is not a legal requirement.

Loading of dangerous goods

- Packaged dangerous goods could be loaded into aircraft:
- As individual packages

- On pallets
- Within transport loading units (known as unit load devices (ULD))

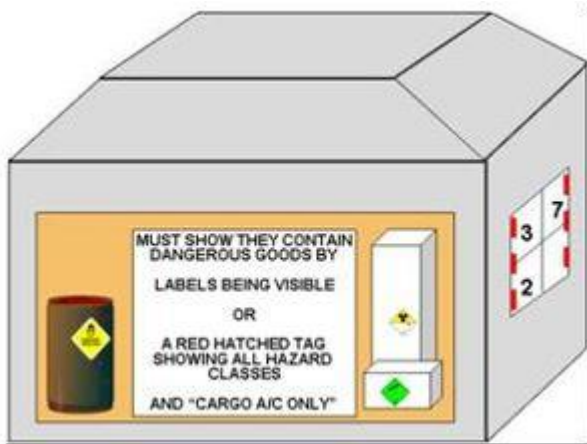


Image 34 Example of an air transport unit load device

Image 34 above illustrates a typical unit load device (ULD). This refers to any type of container with an integral pallet, or an aircraft pallet, whether or not owned by an IATA member, and whether or not considered to be aircraft-equipped. These units interface directly with an aircraft loading and restraint system. Such units become an integral part of the aircraft structure when loaded.

If the labels on packages are not visible when they are on pallets or in ULDs, a red hatched tag showing the hazard classes present must be displayed on the outside of the pallet or ULD. The cargo aircraft only (CAO) label must also be displayed or be visible where appropriate.

Loading restrictions

Packaged dangerous goods:

- Must not be stowed in the passenger cabin or on the flight deck
- Must not be on passenger aircraft if labelled 'cargo aircraft only' (CAO)
- Cargo aircraft only (CAO) packages must be accessible in flight
- Packages of liquids with orientation arrows must be upright
- Packages must be secured to prevent movement
- Damaged packages must not be loaded
- Incompatible dangerous goods must not be stowed to allow interaction
- Most explosives must be segregated from other dangerous goods
- Some types of radioactive materials must be separated from persons
- Magnetized material must be loaded so that the compass cannot be affected.

Incidents

Incidents can be categorized into those:

- On the ground
- Occurring during flight

If an incident involving dangerous goods occurs during the flight, the aircraft's commander will refer to Emergency Response Guidance for Aircraft Incidents Involving Dangerous Goods. This publication is produced by ICAO and provides emergency response details including an in-flight checklist for each dangerous substance category hazard. For incidents on the ground, the airport fire service will usually deal with the incident, supported by the airport's local fire and rescue service.

As a requirement of Annex 18 to the Chicago Convention, all incidents must be investigated.

See National Operational Guidance: [Transport](#).



Maritime transportation

Much of the cargo transported by sea may be classed as dangerous. Incidents involving dangerous substances at sea can be divided into two main areas:

- Incidents off-shore
- Incidents in harbour

The main difference between these two types of incident is that for an incident located in a harbour, the hazardous materials adviser (HMA) must liaise with the harbour master when advising on the operational plan.

Vessels carrying dangerous goods will display a red warning flag between sunrise and sunset. Between sunset and sunrise (and during the day in restricted visibility) vessels will display an all-round, uniform and unbroken red light visible for at least two nautical miles in good night time conditions when moored or anchored.

International Maritime Dangerous Goods Code (IMDG) code

Transporting dangerous goods by sea is an international industry and is governed by an international standard; the International Maritime Dangerous Goods Code (IMDG).

The Code is used by all areas of the shipping industry that carries dangerous goods, and covers all aspects of their transportation, from the construction of the vessels to limiting quantities of substances carried.

IMDG has three volumes:

- Volume 1 includes general provisions such as definitions, training requirements, etc.
- Volume 2 includes the dangerous goods list and limited quantities exceptions

- The supplement contains the emergency schedules and medical first aid guidance; it also contains two sections that are of specific interest to the hazardous materials adviser (HMA)

Marine pollutants

A number of dangerous substances are also identified as substances harmful to the marine environment; these are known as marine pollutants. Substances classified as marine pollutants are carried in packages or transport containers identified with a marine pollutant symbol. Amendment 23 of the IMDG introduced a new marine pollutant symbol of a dead fish and a tree, which replaced the previous triangle containing a dead fish and crossed lines.

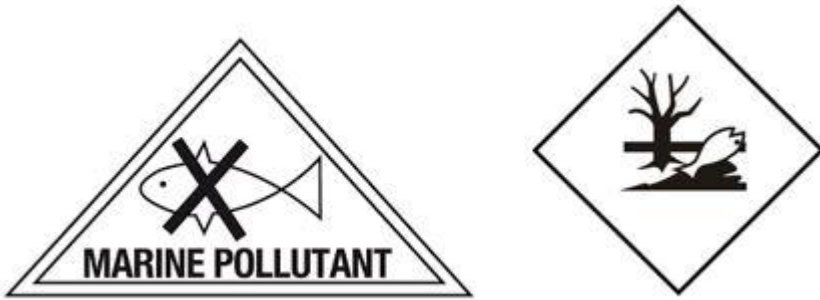


Image 35 New (right) and previously used (left) marine pollutant symbols

Emergency schedule (EMS)

This is the emergency schedule for dealing with incidents involving dangerous goods that are on fire or have been spilled.

Fire

A series of generic tables with the prefix F give guidance on the specific hazards of a substance when involved in fire and the firefighting tactics that should be employed in various locations on the ship.

Spillage

A series of generic tables with the prefix S give guidance on the hazards associated with various spills, personal protection and tactics for different sized packages and spills in various locations on the ship.

Medical first aid guidance (MFAG)

This section contains a flow chart to assist in the initial assessment of a casualty and refers the reader to generic numbered tables for specific conditions. In each case, casualty signs and symptoms are described and detailed treatments given. In many cases the treatments are significantly more involved than for normal first aid and are designed to preserve life whilst at sea, using the vessel's on board medical facilities. This information can prove to be of considerable value when attempting to assess whether the casualty has been exposed to a particular substance.

However, the guidance given under EMS and MFAG is designed for use when the vessel is at sea

and to assist the survival of the ship and casualties whilst awaiting help. As a result, some of the tactics and procedures outlined, such as ditching the material overboard, may not be appropriate when the ship is in port.

The EMS is reproduced as a section in Chemdata. When accessing Chemdata for incidents involving ships, the user should ensure they refer to the sections on emergency schedules. This information is not only essential when formulating a plan but also will give an understanding of the actions that may have been taken by the ship's crew prior to the arrival of the fire and rescue service.

Bulk storage of hazardous substances

The bulk storage of hazardous substances presents fire and rescue service personnel with specific problems, which are:

- Quantities of substances stored
- Variety of substances being stored
- Variety of storage media
- Proximity of other bulk storage of hazardous substances (for example, at Buncefield there were approximately 29 bulk storage tanks and three pipelines)
- Size of the consequence area in terms of the plume, firefighting media run off, potential proximity of residential areas, etc.

The Health and Safety Executive has issued regulations and approved codes of practice for aspects of the storage of hazardous substances. The regulations and approved codes of practice require that the owner/occupier carry out a detailed risk assessment on the premises storing hazardous materials, and subsequent safety systems be implemented. It is recommended that the hazardous materials adviser refers to these documents for details on safety systems.

The safety systems are based on the assessment of the risks from:

- Release of dangerous substances
- Ignition sources
- Separation of product
- Elimination or reduction of risks from dangerous substances through:
 - Ventilation
 - Control of ignition
 - Separation of product
 - Fire resistance of the storage media
 - Fire reaction



Bulk storage of hazardous

substances

The bulk storage of hazardous substances presents fire and rescue service personnel with specific problems, which are:

- Quantities of substances stored
- Variety of substances being stored
- Variety of storage media
- Proximity of other bulk storage of hazardous substances (for example, at Buncefield there were approximately 29 bulk storage tanks and three pipelines)
- Size of the consequence area in terms of the plume, firefighting media run off, potential proximity of residential areas, etc.

The Health and Safety Executive has issued regulations and approved codes of practice for aspects of the storage of hazardous substances. The regulations and approved codes of practice require that the owner/occupier carry out a detailed risk assessment on the premises storing hazardous materials, and subsequent safety systems be implemented. It is recommended that the hazardous materials adviser refers to these documents for details on safety systems.

The safety systems are based on the assessment of the risks from:

- Release of dangerous substances
- Ignition sources
- Separation of product
- Elimination or reduction of risks from dangerous substances through:
 - Ventilation
 - Control of ignition
 - Separation of product
 - Fire resistance of the storage media
 - Fire reaction



Packaging

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.

All hazardous materials containers have a number of design features. The cause of most hazardous

materials incidents is a failure of one or more of the requirements; for example, a container in fire is unable to withstand additional external temperature and internal pressure, leading to a breach.

Design features:

- Compatibility – must not react with its contents
- Suitability for the physical form (solid, liquid, gas) of the hazardous material for the temperatures and pressures the container may be subjected to
- Ability to withstand reasonably expected external stressors such as knocks or being dropped during transport
- Have access to add and/or remove the hazardous materials
- Meet certain legal requirements
- Meet regular testing, inspection and maintenance or replacement requirements

If the correct container has been used and it is intact, the substance is in a 'controlled' state and no risk is posed to people, infrastructure or the environment. Incidents involving hazardous materials are fundamentally driven by containment failure and the way in which failure occurs. This leads to the hazardous materials becoming 'uncontrolled' and introduces risk.

Containment failure can only occur following a 'stressor' being applied to the container. There are a limited number of stressors that can affect containment:

- Thermal
- Chemical/biochemical/photochemical
- Mechanical
- Human or animal

Once containment failure has become inevitable, the manner in which containment fails can also have significant effect on the outcome and scale of the incident. Again, a container can breach in a limited number of ways; these will lead to a specific type of release that will affect the scale and hazards:

Type of breach	Potential release
Disintegration	Detonation
Runaway cracking	Violent rupture
Attachments opening up	Rapid release
Punctures	Leak
Splits or tears	Spill

A useful mnemonic to help in the gathering of hazardous materials information is SEDITION:

- Stressor – What is causing or threatening to cause the containment to fail?

- Escapes – Where are the breaches in the containment system?
- Dispersal – Where is the substance going, or potentially going to go?
- Impingement – What is the substance going to come into contact with?
- Troubles – What are the potential negative effects?
- reactIOn - What reactions could take place?

Pressure receptacles

Pressure receptacles and their closures should be designed, calculated, manufactured, tested and equipped to withstand all conditions, including fatigue, to which they will be subjected during their normal use and during normal conditions of carriage.

Intermediate bulk containers

An intermediate bulk container (IBC) is a container constructed of moulded plastic, fibreglass, steel or plywood with steel reinforcing and is used for storage and transportation of goods. IBCs may range in size but are generally between 700 mm and 2000 mm in height. The length and width of an IBC usually depends on the country's standard pallet dimension. They may have pallet-like bases so that they can be easily lifted using forklift trucks. IBCs can contain powdered or liquid chemicals.



Image 36 Examples of IBCs

Drums

A drum is a flat-ended or convex-ended cylindrical packaging made from metal, fibreboard, plastics, plywood or other suitable materials. This also includes packaging of other shapes (e.g. round, taper-necked or pail-shaped). Wooden barrels and portable cans are not covered by this definition.



Image 37 Example of metal drum used for transporting hazardous materials

Bags

Hazardous substances typically found in bags include agrochemicals of a quantity of up to 1 tonne.



Portable tanks, multi-element gas containers (ISO tanks)

A portable tank is a multimodal tank used for the carriage of explosives (UN class 1) and other dangerous goods in UN classes 3 to 9. The portable tank includes a shell fitted with service equipment and structural equipment necessary for the carriage of dangerous substances. The portable tank can be filled and discharged without removing its structural equipment. It has stabilising members external to the shell, and can be lifted when full. It is designed primarily to be loaded onto a transport vehicle or ship and is equipped with skids, mountings or accessories to allow mechanical handling. Tank-vehicles, tank-wagons, non-metallic tanks and IBCs are not considered to fall within the definition for portable tanks.

Examples of portable tanks (ISO tanks)



Image 38 Non-pressure transit tankers

Non-pressure tankers are used for transporting liquids and gases that do not need to be stored under pressure. There are various models, ranging from single-load tankers to multi-load tankers. Tankers will not show any warning signage when empty.



Image 39 Non-pressure tank – nitric acid

Image 39 above shows a non-pressure tank containing Nitric Acid >70 per cent. Note the added protection to prevent accidental damage to the structure of the tank, which is a good indication that the tanker carries a high-consequence load.



Image 40 Example of a non-pressure, stainless steel, multi-compartment tanker

Image 40 above shows a 30,000-litre, non-pressure, stainless steel, multi-compartment tanker that can carry a variety of substances at different times, but only compatible loads during any single journey.



Image 41 Example of an ADR tank designed for the transportation of gas oil or black oil

Image 41 above shows a 33,000-litre insulated ADR tank designed for the transportation of gas oil or black oil. It has a top-fill loading system via a gantry and side access ladder with handrail. This container has fibreglass insulation with aluminium panels.

Vacuum-operated waste tanks



Vacuum-operated waste tanks

Image 42 above shows a vacuum-operated tank; note the external strengthening ribs that prevent the tank collapsing when the vacuum is applied. Details of the specifications regarding vacuum operated waste tanks can be found in Chapter 6.10 of ADR Volume II

Pressure tanks



Image 43 Example of a pressure tank designed for carrying liquefied petroleum gas

Image 43 above shows a typical pressure tank designed for carrying liquefied petroleum gas.

Cryogenic liquid tanks

A cryogenic receptacle is a transportable, thermally-insulated pressure receptacle for refrigerated liquefied gases.



A cryogenics tanker



Valve groupings, note the frosting indicating recent use



Emergency stop button



Safety kit located in cab of vehicle: note the thermal protective gloves

Image 44 Examples of cryogenic liquid tanks and associated equipment

Bulk containers

Typically this term applies to containers designed for use on road vehicles and in shipping, such as ISO-containers. The term container does not cover conventional packaging, IBCs, tank-containers or vehicles.



Image 45 Examples of stacked shipping containers

Image 45 above shows a shipping container stacked on the dockside. Containers could be used to transport dangerous goods that are not declared on the manifest, so care should be taken when opening containers.

An example of non-UN approved packaging used to transport dangerous goods are the oak barrels used to transport whisky.

Bulk tanks

The various tanks in use are designed to store different types of substances. The following list shows the design criteria for hydrocarbon oils:

Floating roof tanks, containing:

- Class A (flash point below 228°C) hydrocarbon fuels
- Class B (flash point between 228 and 656°C)

Non-pressure tanks, containing:

- Class A (flash point below 228°C)
- Class B (flash point between 228 and 656°C)
- Class C (flash point above 656°C)

Fixed roof tanks, containing:

- Class A (flash point below 228°C)
- Class B (flash point between 228 and 656°C)
- Class C (flash point above 656°C)

Pressure fixed roof tank:

- Class A (flash point below 228°C) hydrocarbon fuels

Spherical pressurised tank:

- Liquefied petroleum gas (LPG), liquid nitrogen gas (LNG)

Horizontal pressure tank:

- LPG, LNG

Refrigerated storage tank:

- LPG, ethylene, LNG, similar hydrocarbons, and ammonia



Image 46 Overview of a tank farm



Labelling and signage

Storage facilities for hazardous materials must apply signage to the premises in accordance with the Notification and Marking of Sites Regulations 1990 (NAMOS).



Pipelines

On-shore and off-shore pipelines are an economic way of transporting large volumes of hazardous and non-hazardous substances across, into and out of the United Kingdom. Pipelines have long been used to transport crude oil to refineries and to shipping terminals, and petroleum and its derivatives are still the main fluids moved by pipeline. Pipelines are increasingly used for transporting various industrial materials and products, in particular those of the chemical industry. Progress has also been made with transporting solid materials as slurries in water or other fluids.

The advantages of pipeline transport include reduced costs, easing congestion on roads, maintaining delivery round the clock irrespective of season or weather conditions, eliminating contamination during transport, removing dangerous fuel cargoes from the

roads and reducing stocks held in crowded areas. Pipelines are classified as cross-country or local; in law a cross-country pipeline is one whose length exceeds 16km.

Safety considerations

The safety of pipelines is overseen by the Gas and Pipelines Unit, part of the Health and Safety Executive (HSE). The unit is the enforcing authority for:

- Upstream natural gas transmission and distribution networks
- Gas storage facilities
- On-shore major hazard pipelines
- Offshore pipelines
- Other associated high-risk sites

The HSE has issued guidance on the safety of pipelines in the form of L82 'A Guide to the Pipelines Regulations'. These regulations cover all pipelines but of particular interest to fire and rescue services are major accident hazard pipelines.

A major accident hazard pipeline is defined as a pipeline that conveys a dangerous fluid with the potential to cause a major accident.

The regulations and guidance notes give best practice advice on:

- The requirement for emergency shutdown valves
- The major accident prevention document
- Arrangements for emergency plans

Marking of pipelines

Details of the types of markers used to indicate the location of pipelines can be found on the [linewatch website](#).

Operational considerations for pipeline incidents

The Health and Safety Executive has issued a document that includes information on:

- Hazards and effects of pipeline failures
- Fire and explosion
- Toxic effects
- Blast effects and projectiles
- Cryogenic effects
- Asphyxiation
- Noise

The incident commander and hazardous materials adviser will consider these as part of the risk assessment process.



Personal protective equipment

This section provides fire and rescue services with information on selecting and using personal protective equipment (PPE) at hazardous materials incidents. It is underpinned by the current, relevant PPE European standards that are prepared under a mandate given to the European Committee for Standardisation (CEN) by the Commission of the European Communities and the European Free Trade association. These standards support the requirements of the European Personal Protective Equipment Directive.

The field of chemical protective clothing (CPC) is one of constant development and change, with new materials and processes becoming available all the time. It is therefore important to understand that the information provided in this foundation material should not be regarded as definitive, but as the best available at the time.

In line with the concept of the hierarchy of controls in risk management, PPE forms the last line of defence for an individual working within a hazardous environment.

The importance of the effective selection and use of appropriate respiratory protective equipment (RPE) and chemical protective clothing at an incident involving hazardous materials can not be overstated. Making a correct selection can only be achieved by understanding the performance standards and level of protection afforded by PPE ensembles and identifying any additional measures that may be required to deal safely with the hazards presented. These could include:

- Physical properties of the substance
- Form (solid, liquid, gas)
- Toxicity/infectivity
- Concentration
- Quantity (amount of spill)
- Likelihood of direct contact (contamination and possible exposure)
- Fire or potential involvement in fire
- Nature and extent of proposed action or task to be performed
- Environment (e.g. open air or enclosed compartment/structure)
- Prevailing weather conditions (e.g. wind direction/strength)
- Potential decontamination strategy
- Balancing the benefits of CPC against negative aspects for the intended application at a particular incident (e.g. donning time scale, heat stress, etc.).

This list is not exhaustive, and must be considered with the operational circumstances, legal obligations, standard operating procedures, manufacturer's guidance, suggested levels of protection information data bases, Emergency Action Codes, Additional Personal Protection codes

(APP) and scientific advice.

Legislation

The Personal Protective Equipment at Work Regulations require that personal protective equipment (PPE) be supplied and used whenever there are risks to health and safety that cannot be controlled in other ways.

The regulations also require that PPE:

- Be properly assessed before use to ensure its suitability: this can only be achieved after a full analysis of the hazards presented at an incident, such as working proximity or weather conditions, and the task to be performed. Selecting the most appropriate level of personal protective equipment, including RPE, at a hazardous materials incident will require understanding of the specifications and performance standards against the chemical or identified hazard of the various options available. This is necessary to interpret the protection that might be afforded to the wearer and for how long. Additional information such as APP codes will also determine any additional PPE requirements. These include thermal protection and briefing of wearers on potential limitations of protection and aspects of the task in hand to maximise their safety.
- Be maintained and stored properly: correct testing, maintenance and storage regimes are not only essential to ensure that chemical protective clothing remains in a state of operational readiness and is fit for purpose, it can also significantly extend the life of a suit.
- Be provided with instructions on how to use it safely: wearers should be provided with instructions on how a chemical protection suit is to be checked prior to wearing, the donning/disrobing procedure, the requirement for additional protection (such as headgear), and the arrangements for distress procedures.
- Be used correctly: the use of CPC must always be evaluated against the nature of the task being undertaken to ensure any benefits of wearing the suit are not outweighed by other hazards. An example of this might be the operation of hydraulic cutting equipment at a road traffic incident balanced against the wearer's impeded vision, mobility, hand dexterity and the potential for manual handling injuries.

Respiratory protective equipment

For further information see [National Operational Guidance: Operations – RPE](#)

Chemical protective clothing

As the field of chemical protective clothing (CPC) is one of constant development and change, with new materials and processes becoming available all the time, it is important to understand that the information provided in this foundation material should not be regarded as definitive but as the best available at the time.

Hazardous material incidents involve a wide range of conditions and uncertainty with a potentially extensive range of known and unknown substances involved. Consequently, the performance requirements for CPC contained in the European standards for use by fire and rescue services are

high, reflecting their special needs.

If CPC is to provide satisfactory protection for hazardous materials incidents, a number of complex issues must be considered in both selection and use. It is therefore essential that this foundation material be considered in conjunction with the latest relevant British and European standards together with information available from the manufacturers and/or suppliers of CPC.



Standards and markings for protective clothing

Harmonised European standards for personal protective equipment (PPE) have been developed as the preferred means of demonstrating equipment conformity with the basic health and safety requirements (BHSRs) of the EC Personal Protective Equipment Directive (89/686/EEC). Only equipment that meets these BHSRs is entitled to carry the CE mark and to be sold for use in the EU.

The alternative route to obtaining the CE mark involves the manufacturer producing a technical file for the equipment that also demonstrates that it satisfies the BHSRs. In such cases, the equipment will carry the CE mark but may not display any standard number. The manufacturer's information will contain the performance specification.

Increasingly, European standards (prefixed EN – European Norm) are being superseded or subsumed by international standards (prefixed ISO). Where these are adopted in the UK, they will also be issued as British standards and be prefixed BS.

The British versions of standards (BS EN, BS ISO or BS EN ISO) may have minor differences from the original versions of the standard, usually in the form of a national foreword or national annex. This accounts for legislative or technical variations specific to the UK.

The following tables 24 – 27 list the current standards applicable to the various areas of chemical protective clothing.

Table 24 Standard applicable to hand protection

Standards applicable to CPC - hand protection	
Number and title	
BS EN 659:2003+A1:2008 - Protective gloves for firefighters	(Suitable for EACs 'S', 'T', 'Y', and 'Z')

Standards applicable to CPC - hand protection	
BS EN 16523-1:2015 Protective gloves against chemicals and micro-organisms: Resistance to permeation by chemicals	Required by DCOL 2/1996
BS EN ISO 374-1:2016 - Protective gloves against chemicals and micro-organisms	
EN 455-1:2000 – Medical gloves for single use – Part 1: Requirements and testing for freedom from holes	
BS EN 455-2:2009+A2:2013 – Medical gloves for single use – Part 2: Requirements and testing for physical properties	
BS EN 455-3:2015 – Medical gloves for single use – Part 3: Requirements and testing for biological evaluation	
BS EN 374-2:2014 Protective gloves against chemicals and micro-organisms: Determination of resistance to penetration	

Table 25 Standards applicable to foot protection

Standards applicable to CPC - foot protection	
Number and title	Comments
EN 13832-1:2006 Footwear protecting against chemicals – Part 1:Terminology and test methods	
EN 13832-2:2006 - Footwear protecting against chemicals – Part 2: Requirements for footwear resistant to chemicals under laboratory conditions	
EN 13832-3:2006 - Footwear protecting against chemicals – Part 3: Requirements for footwear highly resistant to chemicals under laboratory conditions	

Standards applicable to CPC - foot protection	
BS EN 15090:2012 Footwear for firefighters	F3 – Hazmat and structural firefighting - (Suitable for EACs 'S', 'T', 'Y', and 'Z') (CH – marking for chemical resistance)
Home Office Specification A 29 and A30	Suitable for EACs 'S', 'T', 'Y', and 'Z', however, A30 Leather boots may not provide adequate chemical resistance and therefore caution should exercised.

Table 26 Standards applicable to eye protection

Standards applicable to CPC - eye protection	
Number and title	
EN 166:2002 - Personal eye protection - specifications	<p>Markings:</p> <p>3 - resistant to liquid droplets (goggles), or liquid splashes (faceshields, but not mesh)</p> <p>4 - resistant to coarse dust particles</p> <p>5 - resistant to gas and fine dust particles</p> <p>9 - resistant to molten metals and hot solids</p> <p>G - resistant to radiant heat (EN 1731 faceshields only)</p> <p>S - increased robustness (oculars only)</p> <p>F - high speed particles, low energy impact (any type)</p> <p>B - high speed particles, medium energy impact (goggles and faceshields only)</p> <p>A - high speed particles, high energy impact (faceshields only)</p>

Standards applicable to CPC - eye protection	
EN 14458:2004 – Faceshields and visors for firefighters, ambulance and emergency services	EN 14458:2004 – Faceshields and visors for firefighters, ambulance and emergency services

Table 27 Standards applicable to body protection

Standards applicable to CPC – body protection (in addition to EN340: 2003 – general requirements for protective clothing)	
Number and title	Comments
BS 8467:2006 – Protective clothing – Personal protective ensembles for use against chemical, biological, radiological and nuclear (CBRN) agents – Categorization, performance requirements and test methods (see note1 below this table)	Category of clothing: A – gas-tight with breathable air supply. B1 – high levels of vapour challenge. B2 – high levels of mainly liquid challenge. C – low levels without vapour hazard. D – very low levels or risk of contact contamination.
**EN 943-2:2002 - Protective clothing against liquid chemicals. 'Gas-tight' (Type 1) chemical protective suits for emergency teams (ET) (<i>N.B. this was developed with the emergency services in mind and has an increased range of chemical resistance</i>). ** see note2 below this table	Suitable for APP codes 'A' and 'B'. Type 1a-ET: 'gas-tight' chemical protective clothing (CPC) for use by emergency teams with a breathable air supply independent of the ambient atmosphere, e.g. a self-contained, open-circuit, compressed air breathing apparatus (BA) worn inside the clothing. Type 1b-ET: 'gas-tight' chemical protective clothing for use by emergency teams with a breathable air supply, e.g. a self-contained, open-circuit, compressed air breathing apparatus (BA) worn outside the clothing. Limited use or reusable.
BS EN ISO 17491-3:2008 Protective clothing - Protection against liquid chemicals: Test method.	Determination of resistance to penetration by a jet of liquid (jet test).
EN 464:1994 Protective clothing against liquid and gaseous chemicals, including aerosols and solid particles: Test method.	Determination of leak tightness of gas-tight suits (internal pressure test).
BS EN ISO 17491-4:2008+A1:2016 Protective clothing against liquid chemicals. Test method.	Determination of resistance to penetration by spray (spray test).

Standards applicable to CPC – body protection (in addition to EN340: 2003 – general requirements for protective clothing)	
<p>**BS 8428:2004 - Protective clothing against liquid chemicals. Chemical protective suits with liquid-tight connections between different parts of the clothing for emergency teams (type 3-ET equipment).</p> <p>**see note2 below this table</p>	<p>Suitable when the 2nd character of EAC = 'P', 'R', 'W' or 'X'</p> <p>plus either 'limited use' or 'reusable'.</p>
<p>BS EN 14605:2005+A1:2009- Protective clothing against liquid chemicals. Performance requirements for chemical protective clothing (CPC) with liquid-tight (Type 3) or spray-tight (Type 4) connections, including items providing protection to parts of the body only (Types PB[3] and PB[4]).</p>	<p>Suitable when the 2nd character of EAC = 'P', 'R', 'W' or 'X' (Type 3 only).</p> <p>Type 3 – liquid-tight connections for whole body.</p> <p>Type 4 – spray-tight connections for whole body.</p> <p>Type PB[3] – liquid-tight partial body protection.</p> <p>Type PB[4] – spray-tight partial body protection</p>
<p>BS EN 943-1:2015- Protective clothing against liquid chemicals. Ventilated and non-ventilated 'gas-tight' (Type 1) and 'non-gas-tight' (Type 2) chemical protective suits that retain positive pressure to prevent ingress of dusts liquids and vapours</p>	<p>Type 1a – gas-tight with BA inside.</p> <p>Type 1b – gas-tight with BA outside.</p> <p>Type 1c – gas-tight air fed suit.</p> <p>Type 2 – non-gas-tight air fed suit.</p>
<p>BS EN 13034:2005+A1:2009 - Protective clothing against liquid chemicals. Chemical protective clothing offering limited protection against liquid chemicals (type 6 and type PB [6] equipment).</p>	<p>Type 6 – full body.</p> <p>Type PB[6] – partial body.</p>
<p>BS EN ISO 13982-1:2004+A1:2010 - Protective clothing for use against solid particulates - Part 1: Performance requirements for chemical protective clothing providing protection to the full body against airborne solid particulates (type 5 clothing).</p>	
<p>BS EN 14126:2003 - Protective clothing. Performance requirements and tests methods for protective clothing against infective agents.</p>	
<p>BS EN 469:2005 - Protective clothing for firefighters. Performance requirements for protective clothing for firefighting (Superseded EN 469:1995).</p>	<p>Suitable for EACs 'S', 'T', 'Y', and 'Z' with self-contained breathing apparatus (SCBA).</p> <p>Additional requirements may be met for penetration by liquid chemicals.</p>
<p>BS EN 1073-1:1998 - Protective clothing against particulate radioactive contamination - Ventilated suits.</p>	
<p>BS EN 1073-2:2002 - Protective clothing against particulate radioactive contamination - non-ventilated suits</p>	

Standards applicable to CPC – body protection (in addition to EN340: 2003 – general requirements for protective clothing)	
BS EN ISO 6529:2001 Protective clothing - Protection against liquid chemicals: Test method.	Resistance of materials to permeation by liquids.
BS EN ISO 6530:2005 Protective clothing - Protection against liquid chemicals: Test method.	Resistance of materials to penetration by liquids.
BS 7184:2001 Selection, use and maintenance of chemical protective clothing. Guidance.	
BS EN ISO 13982-2:2004 Protective clothing for use against solid particulates.	Test method of determination of inward leakage of aerosols of fine particles into suits.
BS ISO 13994:1998 Clothing for protection against liquid chemicals. Determination of the resistance of protective clothing materials to penetration by liquids under pressure.	
BS EN 14325:2004 Protective clothing against chemicals. Test methods and performance classification of chemical protective clothing materials, seams, joins and assemblages.	
BS EN 14786:2006 Protective clothing - Determination of resistance to penetration by sprayed liquid chemicals, emulsions and dispersions - Atomizer test.	
PD CEN/TR 15419:2006 Protective clothing - Guidelines for selection, use, care and maintenance of chemical protective clothing.	

*Note 1: BS 8467 specifies performance requirements for personal protective ensembles intended to be used during rescue, evacuation, escape, hazard containment, decontamination and similar associated activities by first responders, fire, ambulance, police and associated agencies and workers, for protection during CBRN(E) events.

This standard has been prepared using, wherever possible, existing British and European standards as a base for easy availability of testing facilities and the CE marking process.

The standard covers a variety of ensembles intended to provide varying levels of protection from chemical warfare agents, toxic industrial chemicals, selected biological warfare agents and contamination by radioactive particles. It is assumed that an equivalent amount of protection from radioactive particles will be provided as a result of the protection from chemical agents.

The standard does not cover ensembles intended to provide protection from ionising radiation

(beta and gamma radiation) and for which no currently available chemical protective clothing will offer protection. Ensembles conforming to this standard might be suitable for use in situations other than those involving the specific CBRN(E) agents identified in the standard. Information supplied by the ensemble suppliers or individual component manufacturers will indicate the additional possible performance applications.

Some typical anticipated environments and activities for which the various categories of ensemble could be used are also provided.

The standard identifies categories of ensembles, their associated performance requirements and test methods so that ensembles can be categorised including both material specific requirements and whole ensemble testing.

The categories of ensemble have been selected based on the anticipated activities expected to be undertaken by personnel, and the associated physiological demands together with the knowledge of ensembles currently available.

British Standard BS 8428:2004 'Protective clothing - Protection against liquid chemicals - Performance requirements for chemical protective suits with liquid-tight connections between different parts of the clothing for emergency teams (type 3-ET equipment)' may be considered complementary to BS EN 943-2:2002 which is for gas-tight, type 1 chemical protective suits for emergency teams.

However it should be recognised that unlike BS EN 943-2, BS 8428 is purely a British Standard, the European work on such a standard having been discontinued through lack of support. Hence BS 8428 does not carry the presumption of conformity that comes with European harmonised standards whereby meeting the standard brings with it conformity with the Personal Protective Equipment (PPE) Directive and the ability by the manufacturer to affix the CE mark.

Fire and rescue services should therefore be aware that any manufacturer wishing to use BS 8428 to gain CE certification will have to incorporate the standard into their technical file for submission to their notified body for the CE mark to be awarded. Fire and rescue services that wish to procure either gas-tight or liquid-tight suits are urged to consider the adoption of BS EN 943-2 or BS 8428 respectively into their own performance specifications.

BSi Pictograms (markings which may be found on CPC)

 XYZ	Chemical Protection	 ABC	Cold Protection
 ?	Low Chemical Resistance	 X	Radioactive Contamination
 ABCD	Mechanical Protection	 ABCDEF	Heat Protection
 B	Micro-Organisms	 A	Ionizing Radiation

Types of chemical protective clothing

Table 28 Types of chemical protective clothing (CPC) and associated BS and EN standards

Description	Types, standards and comments
Gas-tight.	<p>BS EN 943-1:2015 Protective clothing against liquid and gaseous chemicals, aerosols and solid particles.</p> <p>BS EN 464:1994, internal pressure test</p> <p>Type 1 – suits that are intrinsically sealed against the environment.</p> <p>Type 1a & 1aET – suits with breathable air supply independent of the ambient atmosphere, e.g. a self-contained, open-circuit, compressed air breathing apparatus (BA) worn inside suit (ET stands for emergency team and relates to firefighters).</p> <p>Type 1b & 1bET– suits with breathable air supplies e.g. self-contained, open-circuit, compressed air breathing apparatus (BA), worn outside the suit.</p> <p>Type 1c – suits with breathable air providing positive pressure (e.g. airlines).</p> <p>BS EN 943:part 2 CPC (1aET and 1bET) satisfy APP codes 'A' and 'B'</p>

Description	Types, standards and comments
Non-gas-tight.	<p>BS EN 943: 2002 Protective clothing against liquid and gaseous chemicals, aerosols and solid particles.</p> <p>Suits that retain positive pressure to prevent ingress of dusts liquids and vapours.</p> <p>Type 2 – chemical protective suit with breathable air providing positive pressure.</p>
Liquid-tight protective clothing against liquid chemicals.	<p>BS 8428: 2004.</p> <p>BS EN 14605: 2005 – type 3.</p> <p>BS EN ISO 17491-3:2008 – ‘Jet Test’ – determination of resistance to penetration by a jet of liquid.</p> <p>Type 3 - liquid-tight connections, including items providing protection to parts of the body only Type PB (3).</p> <p>BS 8428 and BS EN 14605 Type 3 CPC satisfies the EACs ‘P’, ‘R’, ‘W’ or ‘X’.</p>
Spray tight protective clothing against liquid chemicals.	<p>BS EN 14605: 2005 – type 4.</p> <p>BS EN ISO 17491-4:2008+A1:2016 – ‘Spray Test’ – determination of resistance to penetration by spray.</p> <p>Type 4 – spray-tight connections, including items providing protection to parts of the body only Type PB (4).</p>
Protective clothing for use against solid particulates.	<p>BS EN ISO 13982-1 & 2: 2004.</p> <p>Type 5 - chemical protective clothing (CPC) providing protection to the full body against airborne solid particulates</p>
Protective clothing offering limited protective performance against liquid chemicals	<p>BS EN 13034: 2005 / +A1 2009.</p> <p>Type 6.</p> <p>Type PB 6 (part body).</p>



Materials of construction

Selecting materials and construction methods for chemical protective clothing is a complex process. The three most important performance criteria for materials are:

- Protective performance (e.g. chemical resistance: the ability to resist penetration and permeation by hazardous substances)
- Wearability (all aspects of fit, mobility, comfort)
- Mechanical integrity (resistance to abrasion, puncture, etc. to ensure safe working conditions and flexibility allowing the material to be assembled into a usable garment)



Performance standards

Abrasion resistance: ensures that CPC material in a particular class has a degree of abrasion resistance, depending on the intended use. Due to the arduous nature of CPC use in fire and rescue services, the highest performance level is required.

Stability to heat: indicates whether the CPC material tends to stick to itself when subjected to heat. CPC for fire and rescue service use should not stick to itself when heated. It is important that this test is not confused with resistance to ignition.

Flex cracking: designed to reproduce the effect of the folding and creasing action of the suit when bending down, moving arms, etc. In addition, there is a requirement to pass a leak-tightness test.

Flex cracking at low temperatures: a similar requirement to that for flex cracking, but in this case at temperatures of -30C and -60C. A leak-tightness test is carried out after the flex cracking test.

Trapezoidal tear resistance: the ability of the material to resist tearing, and is dependant on its structure and bonding.

Burst resistance: the ability of a material to resist a stretching force.

Puncture resistance: the ability of a material to resist the penetration of a sharp object. If the suit is in use and has cuts in the material, any chemical travelling through such cuts or essential openings

is said to have penetrated the suit.

Resistance to ignition: this indicates the material's resistance to ignition, for example, if caught in a flash fire situation. For fire and rescue service use, the material is exposed to a flame for either five seconds or one second, depending on the performance level to be achieved. The flame should not burn for longer than five seconds, or it should be self extinguishing. This should be followed by a leak-tightness test.

Penetration – a physical process

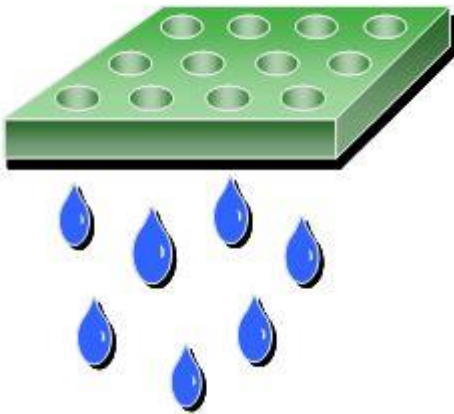


Image 47 Penetration

Penetration is a process whereby liquid, gaseous or solid substances penetrate a fabric by passing through pores or holes.

The test for penetration by liquids (EN 6530/EN 368) involves the material under test having a test sample of 10ml of chemical applied to it for an exposure time of ten minutes. This test rates the resistance of a fabric to permeation by a specified chemical in liquid form.

Permeation – a chemical process

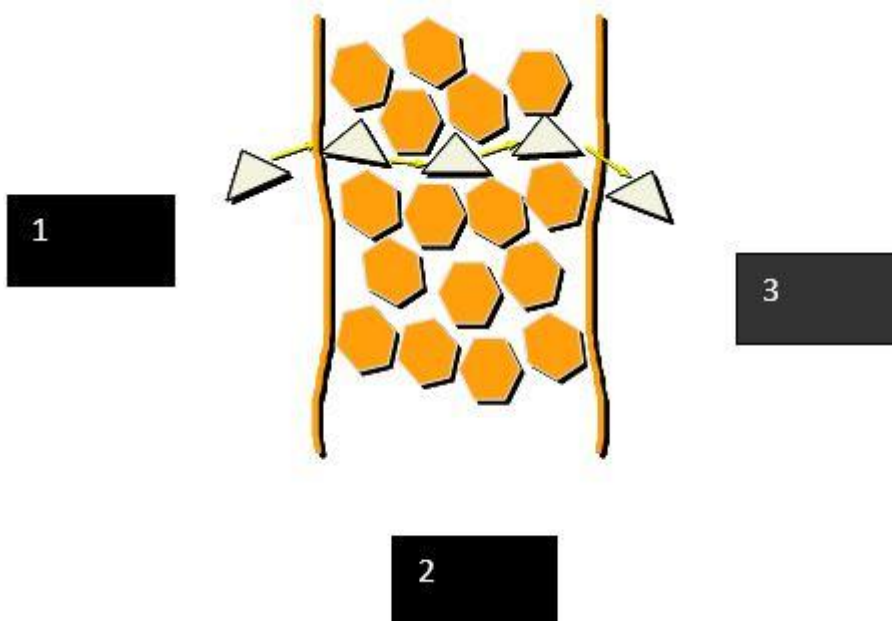


Image 48 Permeation

Image 48 illustrates molecules of a hazardous material passing through a fabric; 1 - absorption of molecules of liquid on to contact surface, 2 - diffusion of the absorbed molecules through material and 3 - desorption from the opposite surface.

Further details on the permeation test can be found by reference to EN ISO 6529/EN 369/EN 374-3.

Categories of material

The two most common categories of materials available are:

- Laminates/film composites: made up of a plastic film that is laminated on to a substrate (backing material).

Elastomeric: made up of rubber-based materials, such as butyl, neoprene, viton, hyperlon, and a combination of these coated on to a woven fabric.

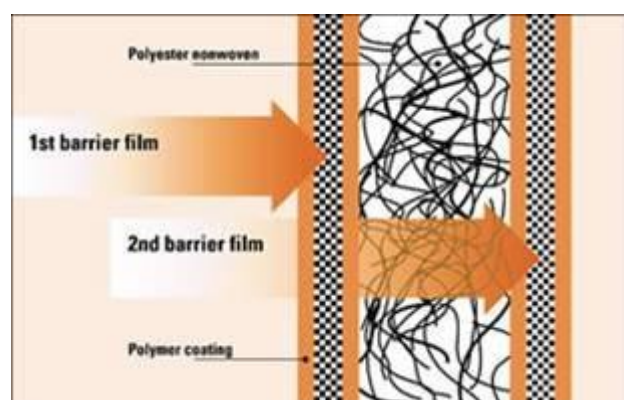


Image 49 Laminated construction of Tychem TK



Types of usage of chemical protective clothing (CPC)

Reusable CPC: generally of elastomeric construction, reuse depends on the type of chemical or chemicals to which the CPC has previously been exposed, the effectiveness of any decontamination process and any possible subsequent degradation of the suit.

Limited-life CPC: generally of laminated construction, provides protection for limited wear life, which is usually determined either by the requirement for repeated hygienic cleaning or because

chemical contamination has occurred.

As the name suggests limited-life suits have a shelf life advised by the manufacturer, beyond which they should normally be replaced. In certain circumstances the life of suits may be extended in consultation with the manufacturer, providing appropriate conditions for storage, transportation, and periodic testing are met. The procedures outlined for extending the shelf life of Tychem TK Limited Life Suits in Fire Service Circular 25-2004 are an example.



Selection of chemical protective clothing (CPC)

Only CPC that has the CE mark should be selected. When selecting clothing the user should have an awareness of the Personal Protective Clothing (PPE) Regulations, the relevant European or draft European standards.

Two main categories of CPC are currently in use in fire and rescue services:

- Gas-tight
- Liquid-tight

For both categories of CPC, it is recommended that a coverall design be used as this provides maximum protection for both the user and their breathing apparatus (BA). In addition, the process of decontamination is usually carried out more effectively on coverall design.

It is further recommended that the performance requirements for the materials of liquid-tight CPC are the same as for gas-tight CPC.

CPC is available in a choice of reusable or limited use clothing in both gas-tight and liquid-tight design.

Gloves: gloves should meet the requirements of BS EN 374-3 and selection made according to the hazard encountered. A dual glove system may afford the best protection. This normally consists of a laminated inner glove with good chemical resistance and an outer elastomeric glove affording protection against mechanical abuse as well as having some degree of chemical resistance.

Ideally the gloves or combination of gloves should afford the same chemical and physical protection as the CPC material.

Where gloves are permanently joined to the suit (not interchangeable), assurance of their performance data (physical and chemical barrier properties), should be sought from the CPC manufacturer or supplier.

For exchangeable gloves, similar performance data on physical and chemical barrier properties should be obtained from the glove manufacturer.

Visors: visors should be permanently fitted to the CPC and should be large enough to afford a satisfactory field of vision. Potentially, the visor represents the weakest part of the CPC from the point of view of chemical resistance, and unnecessarily large visors should therefore be avoided. The visor should be tested in accordance with BS EN 146.6-7.

Pass-thru: a pass-thru should be fitted to gas-tight or liquid-tight coverall CPC. Breathing apparatus connections require a certificate of conformity from the manufacturer. Reference should be made to BS EN 270. If CPC is selected without a pass-thru, risk assessments and standard operating procedures must be in place to address situations where wearers would need a pass-thru (e.g. low air whilst awaiting decontamination).

Attachment point: where an attachment point for a personal line is required, the attachment point should withstand a pulling force of 1000N (Newtons). Any additional exterior attachment points should withstand a pulling force of 250N.

Many additional considerations need to be taken into account when selecting CPC. These lists are not intended to be comprehensive and fire and rescue services should consider other matters as necessary during their risk assessment of the suitability of CPC depending on the intended application.

Practical aspects of CPC evaluation – questions to consider

- Is the CPC a moderate or severe inducer of heat stress?
- Is the CPC material flexible?
- Does the flexibility change with temperature?
- Can the CPC accommodate different size wearers?
- Is the CPC easy to handle?
- How well is visibility afforded?
- Can the CPC accommodate a helmet or hard hat?
- How easy is donning and doffing?
- Does the wearer feel secure and mobile within the CPC?

Questions to ask the supplier:

- From which materials is the CPC constructed?
- Are boots attached to the CPC or can different size boots be worn?
- To what European standard is the CPC manufactured?
- Are manufacturers' claims supported by data from independent test houses?
- How much does the CPC weigh?
- Does the manufacturer provide technical support?
- Is the manufacturer willing to repair/decontaminate damaged CPC?
- Will the manufacturer guarantee the integrity of the CPC after repair and decontamination?
- Is the manufacturer able to provide comprehensive data on chemical permeation?
- What is the recommended storage time for the CPC – how should it be stored?

- How often are pressure tests/visual tests required?
- How does the material perform in specific risks or an incident involving complex mixtures of chemicals, for example pesticides?
- What are the methods of seaming (elastomeric materials usually require seaming by adhesives, stitching or curing)? What tape material is used?
- How are exchangeable gloves, boots fitted? How easy is the operation of exchange?
- Does the garment provide uniform protection?
- Are the areas of potential mechanical failure minimised (i.e. seams, joints and interfaces)?
- Does the garment afford maximum comfort, fit and function to the user?
- What special equipment/tooling is required to make the CPC functional? What type and amount of labour is needed?
- What are the quality control practices of the manufacturer?
- Does the CPC require any type of over covers (and why)?
- Can the manufacturer supply contactable references within emergency services?
- Does the manufacturer supply an after-sales service?
- Will the material/CPC be of long-term availability?
- How is the type of closure fitted?
- How easily are replacement parts available?
- What are the limitations in the manufacturers' instructions for use?
- Where was the CE mark obtained?
- Does the manufacturer provide a 24-hour emergency response service?
- What are the visual signs of degradation or fatigue of materials or component parts?

When you have asked all these questions and received satisfactory answers, you should be able to make direct comparison between different products.

Risk assessment

In establishing a policy of operational risk assessment, the following questions may be considered:

- How long is a CPC to be worn? What is the maximum/minimum duration?
- Is gas-tight or liquid-tight protection required? Gas-tight equipment can be a substitute for liquid-tight equipment, but not the other way round.
- What type of training is necessary?
- As opposed to proper decontamination, what cleaning facilities are available?
- Are decontamination and after-decontamination test facilities available?
- What storage/maintenance facilities are available?
- Is the CPC intended for first-response or lengthy clean-up procedures?
- What chemical emergency risk assessments have been made?
- What limitations of use can be expected? What are the limited mechanical properties and limited chemical resistance properties?
- What fitments/equipment have to be obtained by the user (e.g. pass-thru connections, pressure test kit, gloves, boots, additional over garments, anti-mist/cleaning products, etc.)?
- Are there site-specific risks?

Selecting CPC at emergency HazMat incidents

Personal protective equipment (PPE) should only be used as a last line of protection to control the exposure of personnel to hazardous materials.

Generally, six basic factors will determine the level and type of protection required by responding crews:

- Toxicity: via inhalation, ingestion or the dermal route
- Corrosiveness: from high concentrations of acids or alkalis
- Oxidation: where there is a reaction with organic compounds producing heat and/or oxygen
- Temperature: where the substance is at an extreme of temperature hot or cold
- Biohazards: from pathogens and open cultures
- Radiation (ionising): whether involving an unsealed source or not

The choice of level of protection may be influenced by reference to the emergency action code (EAC); by use of the PRPS Hot Zone Decision Tool or by direct access to Chemdata or other similar database.

Before making the final selection, an assessment of the incident presented should be made adopting a risk-assessed approach and considering the following aspects:

- What is the nature of the task to be undertaken?
- Is it to be undertaken in the open or a confined space (e.g. inside a building)?
- Does the substance meet the criteria of being a single substance at normal temperature and pressure (this is the basis on which levels of protection are quoted.)?
- Is the benefit of wearing CPC outweighed by additional hazards presented (i.e., fire, working at height, operating hydraulic tools, etc.)?
- Is the likelihood of contamination by direct contact with the substance and areas of the wearer most likely to be affected?
- Is an immediate life saving action an option, and would the time taken to rig in CPC affect the potential success of that action?

Note that wearing more layers of protection does not always equate to a higher level of safety, and could be detrimental in some circumstances.

It should also be borne in mind that whilst wearing CPC incorporating a respirator such as the Powered Respirator Protective Suit (PRPS), constant monitoring for oxygen deficiency in an enclosed working environment should be undertaken.



Using chemical protective clothing at hazardous materials incidents

Using CPC at an incident must be carefully monitored as wearing the suit can create hazards. CPC

crew members have been known to suffer from heat, physical, and psychological stress. The potential for heat stress is increased in personnel who:

- Have suffered a recent illness (especially vomiting or diarrhoea)
- Are suffering from sunburn
- Have taken medication that could affect their fluid balance
- Are suffering from the after-effects of alcohol consumption

To avoid excessive heat stress in CPC, a maximum working period of 20 minutes should be considered. This may be extended by the agreement of the incident commander and the wearer. If a wearer displays any symptoms of heat stress such as dizziness, nausea, abdominal discomfort, burning sensation to the skin, dilation of the pupils or possible disorientation, they should be withdrawn immediately. For further information regarding heat, physical and psychological stress see National Operational Guidance: Operations and A Foundation for Breathing Apparatus.

Dressing/disrobing procedure

It is important that correct dressing and disrobing procedures be adopted to ensure the appropriate level of protection and combined safety and welfare of the wearer.

Examples of dressing/disrobing procedures are outlined in the National Resilience Assurance Team (NRAT) guidance issued for CPC and provided for fire and rescue service contribution to national resilience.

Clothing under CPC

Head protection in the form of a fire helmet or bump hat should always be considered. The level of clothing worn beneath a chemical protection suit should be determined following a risk assessment which considers the hazards presented by the substance and environment, the task to be undertaken, extremes of temperature (hot or cold) and the potential for heat stress.



Wearing CPC in flammable or explosive atmospheres

The rubbing action of synthetic materials used in CPC against skin or under garments will cause an electrostatic charge to build up on the fabric. The dissipation of this charge via a spark has the potential to ignite a flammable atmosphere or cause an explosion. In circumstances where the relative humidity is below 25% the likelihood is increased.

For this reason, manufacturers of some CPC state that their fabric does not have an anti-static treatment, and should not be used in potentially flammable or explosive environments. Fire and rescue services should be aware of any such limitations imposed by the manufacturers of their

selected CPC. In exceptional circumstances (i.e. imminent loss of life), where CPC has to be worn in flammable or explosive environments, wetting the suit before entry will promote conduction of any electrical charge to ground and reduce electrostatic build up.



Other types of CPC

In a potential or identified CBRN(E) or mass decontamination incident, additional forms of CPC might be encountered which could include the following:

Powered respirator protective suit (PRPS)

These suits are for use within the warm zone at mass decontamination incidents and are designed to address some of the limitations of gas-tight suits, such as the working duration of a breathing apparatus set and physiological effects. The police now use PRPS (along with the SR3 quick don suit described below) having previously used the CR1 Chemical Protective Suit.



Image 50 Powered respirator protective suit (PRPS)

A full description of PRPS, operational procedures and storage arrangements can be found in the

Swift Responder 3 suit



Image 51 SR3 Quick Don chemical protective suit

The Swift Responder 3 quick don suit has evolved as a result of a requirement to have personal protective equipment that can be donned in under five minutes.

It is a single layer suit manufactured from a high performance lightweight material developed by Du Pont and WL Gore. It is designed to protect against a wide range of toxic industrial chemicals used as weapons of mass destruction contaminants¹; it is coupled with the Avon respirator to form the complete ensemble.



Contamination and decontamination

Definitions

It is important that all fire and rescue services adopt common terminology and definitions to improve inter-operability and safety at all hazardous materials incidents whether they are conventional or CBRN (E).

Exposure

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

Exposure does not automatically mean contamination.

Contamination

Contamination occurs when a substance adheres or is deposited on people, equipment or the environment, creating a risk of exposure and possible injury or harm.

Contamination does not automatically lead to exposure but may do. Alpha, beta and gamma emissions in themselves cannot cause contamination, although the actual source materials may, depending on their physical properties and their containment.

Cross-contamination

Cross-contamination occurs when a person who is already contaminated makes contact with a person or object that is not contaminated.

Concepts of contamination

The process of decontamination involves the physical and/or chemical reduction, stabilisation or neutralisation of contaminants from personnel and equipment. The process is vital to reduce the potential of transferring contaminants beyond the hazard zone and exposing people to harm from the hazardous materials.

The four basic concepts in contamination are:

- Avoid contamination, prevent exposure
- Surface contamination versus permeation contamination
- Direct contamination versus cross-contamination
- Types of contaminants



Avoid contamination, prevent exposure

A firefighter who has been contaminated when wearing appropriate personal protective equipment (PPE) will not have been exposed. For example, breathing apparatus (BA) wearers can be contaminated with asbestos particulates on the outside of their PPE without having their respiratory system exposed to the contaminant. For exposure, they must breathe in the particulates through a breach or failure of their BA. Even if a contaminant makes direct contact with a firefighter inside their PPE, it still does not necessarily mean they will be harmed by the contaminant. Harm depends on the dose, route of exposure and the hazards and properties of the

contaminant. Although exposure can occur through a breach or failure of PPE the most common cause is poor decontamination. Decontamination is a critical control measure at hazardous materials incidents. Fire and rescue services should place great emphasis on developing and implementing a well-planned, structured and disciplined approach to decontamination operations. This should be supported by an appropriate training and auditing programme. If contact with the contaminant is controlled, the risk of exposure is reduced and the need for decontamination can be minimised.

To avoid contamination, these basic principles should be considered:

- Stay up wind and up-hill/slope where possible
- Do not allow eating or smoking on site and strictly control hygiene where drinking/ hydration is provided
- Cover any open wounds
- Ensure personnel refrain from bringing their hands into contact with their face/mouth whilst on site
- Emphasise work practices that minimise contact with hazardous materials
- Avoid direct contact with hazardous materials wherever possible
- Do not walk through areas of obvious contamination and stay out of areas that potentially contain hazardous materials.
- Take special care to avoid slips, trips and falls into contaminants
- Do not kneel in contaminants
- If contact is made with a contaminant, move contaminated staff to the decontamination holding area and remove/reduce the contaminant as soon as possible; generally, the longer hazardous materials are in contact with PPE/staff/equipment the more harm can be done
- Keep the wearers' respiratory protective equipment on for as long as possible during the decontamination process
- Use limited use or disposable chemical protective clothing as this can significantly reduce the decontamination requirements and mitigate permeation or matrix contamination
- Use a planned and systematic approach to decontamination



Surface contamination versus permeation contamination

Contaminants can present risks in any physical state (i.e. gas, liquid or solid). There are two general types of contamination:

Surface contaminants are found on the outer layer of a material but have not been absorbed into the material. Surface contaminants are usually easy to detect and remove to a reasonably achievable and safe level using firefighter decontamination procedures (dusts, powders, fibres etc).

Permeation contaminants are absorbed into a material at the molecular level. Permeated contaminants are often difficult or impossible to detect and remove. If the contaminants are not removed they may continue to permeate through the material. Permeation through chemical protective clothing could cause exposure inside the suit. Permeation can occur with any porous material not just personal protective equipment. Factors that influence permeation include:

- Contact time: the longer a contaminant is in contact with an object, the greater the probability and extent of permeation
- Concentration: molecules of the contaminant with flow from areas of high concentration to areas of low concentration; generally, the greater the concentration, the greater the potential for permeation
- Temperature: increased temperatures generally increase the rate of permeation; conversely lower temperatures will generally slow down the rate of permeation
- Physical state: generally, gases, vapours and low-viscosity liquids tend to permeate more readily than high viscosity liquids or solids.

A single contaminant can present both a surface and a permeation threat; this is especially the case with liquids



Direct contamination versus cross-contamination

Direct contamination occurs when a person comes into direct physical contact with a contaminant or when a person comes into contact with any object that has the contaminant on it. Direct contamination usually occurs when working in the hot zone but can occur during the decontamination process. Gloves and boots are the most common areas to be contaminated.

Cross-, or secondary contamination occurs when a person who is already contaminated makes contact with a person or object that is not contaminated. This is typically the result of poor site management and cordon control, inadequate decontamination and site safety procedures or a failure to follow safety procedures. Cross-contamination is a greater risk when dealing with liquids and solids; it can go on and on, spreading from one person to the next as they touch. This is why it is so important to confine contaminated people and separate the dirty from the clean.



Types of contaminants

The more that is known about the contaminant the faster and more focused the decontamination operation can be. The types of contaminants can be divided into categories based on their primary hazards. These include the following:

- Highly acute toxicity contaminants that can cause damage to the human body as a result of a single or short duration exposure. These can be found in solid, liquid or gas forms and will present risks to firefighters from any route of exposure (chlorine, potassium cyanide etc).
- Moderate to highly chronic toxicity contaminants; repeated exposure over time to these substances can cause damage to target internal organs, or the onset of debilitating injuries. These can be found in solid, liquid or gas forms and will present risks to firefighters from any route of exposure (asbestos, certain heavy metals, mercury, benzene etc).
- Teratogens or embryotoxic contaminants; these are substances that can act during pregnancy to cause adverse effects on the foetus. The period of greatest susceptibility is the first eight to 12 weeks of pregnancy. This includes the period when women firefighters may not know they are pregnant; special precautions must therefore be taken at all times (lead compounds, ethylene oxide, formamide, etc).
- Allergenic contaminants, which are substances that produce skin and respiratory hypersensitivity. Firefighters are at risk from allergens from both inhalation and direct skin contact. Two people exposed to the same allergen at the same level may react differently (chromium, formaldehyde, isocyanates, etc).
- Flammable contaminants, which are substances that readily ignite or burn in air and are persistent (they hang around and can stick to personal protective equipment). Although most are liquids some flammable solids and gases will also present hazards, especially when confined. Always expect flammables to present more than one contamination problem (examples include petrol, acetone, benzene, ethanol)
- Highly reactive or explosive contaminants, which can react with the oxygen present; others are heat, shock and friction sensitive. The concentration of these contaminants plays an important role in determining the risk involved in decontamination. It is also important to recognise that evaporation and distillation of these materials can cause high risk scenarios. Metal tools such as spatulas and shovels should not be used to clean up peroxides contaminants because metal contamination can lead to explosive decomposition. Firefighters should avoid friction, grinding and other forms of impact.
- Water-reactive contaminants that react on contact with water or moisture. In many cases, where the amount of the substance deposited on firefighters' PPE is minimal, decontamination with copious amounts of water will still be an effective method.
- Etiologic or biological contaminants are micro-organisms such as viruses, fungi and bacteria. They can cause illness, disease and death. They can enter the body through inhalation, ingestion and direct contact. They are not always labelled clearly and on-site detection techniques and equipment may be limited. Fortunately, most biological contaminants are relatively easy to kill using a wide variety of commercially available decontamination solutions. However, to achieve a dose sufficient to kill these organisms, an appropriate contact time will be necessary. These decontamination solutions are divided into disinfectants and antiseptics.
- Radioactive contaminants include some isotopes and radioactive nuclides in the form of a dust or powder, liquid or gas. Radioactive contamination can only occur if the radioactive

material is or has become unsealed. These materials pose significant hazards to responders if they enter the body and expose tissues and organs to irradiation. The physical form of the radioactive material will dictate the type of chemical protective clothing required. Generally, water should not be used to decontaminate wearers as it will spread the contamination and may also make it more difficult for radiation detection and monitoring equipment to detect areas of contamination. The exception to this is mass decontamination because of the large numbers of people involved. For mass decontamination, the risk assessment may dictate that full disrobing and wet shower decontamination is most appropriate for the circumstances. Sealed sources may present an exposure risk to responders (irradiation) but they cannot cause contamination. Cordon control and monitoring using radiation survey meters is essential but decontamination will not be necessary unless there is a risk of damage to the source's form of containment.

Beware of contaminants that have multiple hazards.



Decontamination methods

No universal decontamination method will work for every hazardous materials incident. Different decontamination methods will be required for chemical, radioactive and biological contamination. Chemical decontamination may, for instance, involve mass dilution, whereas minimal quantities of water should generally be used for biological and radioactive contamination. However, procedures for firefighter decontamination should not be too varied. It is vital that operational staff are completely familiar with their set-ups and procedures. These should be flexible enough to allow for variations in the methods and scale of decontamination.

Physical decontamination

Decontamination methods can be divided into two basic categories:

- Physical methods: generally involve physically removing the contaminant from the contaminated person or object or the safe removal of the protective clothing from the contaminated person without cross-contamination. Whilst these methods are often easier to perform and may dilute the contaminant's concentration, thereby reducing its harmful effects, the contaminant generally remains chemically unchanged.
- Chemical methods: generally involve removing and or reacting the contaminant by some type of chemical process.

Note that some methods may introduce other hazards into the process.

Decontamination of casualties

Initial actions

Initial operational response guidance focuses heavily on the initial actions to be undertaken by fire and rescue service staff at a CBRN(e) incident. It is generally accepted that such an event would require mass decontamination; however, these may not be the only incidents requiring this approach. Many industrial or commercial incidents could easily see a number of members of the public becoming contaminated and they would therefore benefit from the mass decontamination procedure.

The first step in the procedure is to remove the members of the public from the hot zone or the area of gross contamination.

Once away from the contaminant, members of the public should now be encouraged to remove their outer layer(s) of clothing. Testing has shown that clothing is an effective barrier against a contaminant in the short term, depending on the nature of the clothing and the amount of skin surface it covers. Materials such as waterproof fabrics will normally hold off a contaminant longer than materials that are absorbent, but none is likely to be chemical protection clothing unless it is being worn at a commercial or industrial premises and has been provided for that purpose. Rapidly removing the outer layers will remove the contaminant, however care should be taken when removing clothing to minimise the potential of any substances touching the skin; clothing which would normally be removed by pulling over the head should instead be cut off to avoid spreading the contaminant over the face (nose, mouth and eyes).

Once the clothing is removed, decontamination can commence. This will be either improvised, interim or full mass decontamination but often will be a combination of all three.

Mass decontamination

Mass decontamination is the planned and structured procedure delivered by fire and rescue services using purpose-designed decontamination equipment and where there are large numbers of contaminated casualties.

The responsibility for decontaminating members of public lies with the Department of Health. The decision on whether or not to decontaminate people will be taken by the ambulance service in consultation with the fire and rescue and police services.

Full, specific guidance on mass decontamination is outside the scope of this document. For further information see:

Strategic National Guidance - The decontamination of people exposed to chemical, biological, radiological or nuclear (CBRN) substances or materials, 2nd edition in May 2004, published by the Home office

Fire and rescue services Circular 58-2006 – Memorandum of Understanding on Mass

Decontamination, published by CLG

Tactical Guidance Document - Fire and Rescue Service Response to CBRN(E) Events, CLG 2008

Fire and Rescue Service Response to CBRN(E) Events – Operational Guidance Document, CLG 2012

National Resilience IRU and Mass Decontamination Manual V3.0



Image 68 Mass decontamination area - set up



Image 69 Mass decontamination area

Improvised decontamination

Improvised decontamination is the use of an immediately available method of decontaminating members of the public before using specialist resources.

Generally, in the very early stages of an incident and depending on the symptoms and needs of contaminated people, improvised decontamination may be initiated by emergency service personnel, witnesses to the incident, passers by or even the contaminated people themselves.

The need to commence improvised decontamination depends on the type of contamination, the availability of a means of decontaminating and the symptoms displayed by the contaminated people.

Improvised decontamination may take many forms, including removing contaminated clothing, wiping down, washing, rinsing, etc. It can have a positive effect on the contaminated people (for example, removing contaminated clothing reduces personal levels of contamination). Following research by Public Health (England) into the best way of removing a contaminant from the skin, in most cases a contaminant will be a material that can be lifted from the skin using an absorbent material, such as tissue. Improvised decontamination should therefore focus heavily on a dry decontamination procedure rather than wet, although wet decontamination will be necessary in certain circumstances such as when corrosive materials are involved.

The ambulance and police services may initiate improvised decontamination in the early stages of a CBRN (E) event, depending on the symptoms and needs of contaminated people.



Image 70 Improvised decontamination of public

The fire and rescue service incident commander should also consider improvised decontamination. In cases where the contaminant is corrosive then the member of the public is likely to complain of a burning sensation on the skin or of irritation. In these cases the skin will need to be washed and a wet decontamination method employed; this is still considered improvised decontamination even though the water may be provided from a firefighting pumping appliance.

Wet decontamination may also be necessary if members of the public have contaminant in their hair. The risk from this can increase if the person has a lot of hair, and dry decontamination may not remove the contamination.

Contaminated people who are subject to improvised decontamination should also subsequently be assessed by ambulance service personnel who will consider further decontamination requirements.

Interim decontamination

Interim decontamination is the use of standard equipment to provide a planned and structured decontamination process for large numbers of the public before purpose-designed decontamination equipment is available.

In the early stages of an incident and depending on the symptoms and needs of contaminated people, the fire and rescue service incident commander may decide to establish interim decontamination systems. This decision should be taken in consultation with ambulance service and police service incident commanders where they are present. In their absence, the fire and rescue service incident commander may need to make the decision unilaterally.

The benefits of establishing interim decontamination should be considered along with the risks; depending on the method used, there may be issues around maintaining systems for long periods, disrobe provision, re-robe provision, ability to use warm water, enclosures, ability to capture water run off, limited personal protective equipment (PPE) for fire and rescue service personnel, contamination of appliances and equipment, etc.

Where interim decontamination is established and used, fire and rescue service disrobe packs (if available) should be deployed if necessary before and after interim decontamination.

There is no national standard for interim decontamination; each fire and rescue service has established its own individual methods. However, interim decontamination has the advantage of being a more structured and controlled method than improvised decontamination.

The following example details how standard pumping appliances can be used to provide interim decontamination. Methods such as this may prove invaluable where incident response units carrying mass decontamination assets have long travel and set-up times.

Position the appliances

Position two appliances approximately 1.5 to 2 metres apart, with the near side of both vehicles parallel to each other. Ensure the exhausts face outwards and the bodies of the vehicles are in line with each other so the rear locker on one vehicle is opposite the front locker of the other vehicle.



Image 71 Interim decontamination

Set up the shower frame

Separate a short-extension ladder and place the widest extension up against one appliance in line with the middle locker; this can be used to gain access to position the ladder on the appliance roof. At no time should operational personnel mount the roof of an appliance. Position other ladder extensions to bridge the gap between the vehicles, ensuring the ladder pawls are against the roof of the vehicle.



Image 72 Interim decontamination, shower frame set up

Set up the shower units

Using both hose reels from each vehicle, lock each branch open and set to wide spray on maximum flow. Hang the branches over rounds nearest to the vehicle and position the branch to spray inwards. Ensure all windows and doors are shut and lockers closed as far as possible.

Set in to the nearest hydrant or other water supply and charge hose reels to 10-20 bar. Adjust nozzles to ensure a good mist effect is achieved.



Image 73 Interim decontamination, shower unit set up

This set-up is an example only. Fire and rescue services should fully risk assess this, or any other, method, before adopting it into their standard operating procedures.

Clinical decontamination

Clinical decontamination is the process where contaminated casualties are treated individually by trained healthcare professionals using purpose-designed decontamination equipment.

The ambulance service defines and prioritises casualties:

Priority 1 (P1) casualties: patients with a high priority for either immediate emergency medical care or immediate, emergency life-saving decontamination, or both

Priority 2 (P2) casualties: less severely affected patients who need either emergency medical care or early decontamination to prevent further intoxication

Priority 3 (P3) casualties: patients with slight to moderate intoxication and without contamination at a level that requires immediate action. A percentage of P3 casualties will leave the scene and self-present to local hospitals and clinics.

Clinical decontamination is the responsibility of the ambulance service and is a structured and thorough decontamination process their personnel will carry out for contaminated P1 or P2 casualties who by definition are unable to proceed unaided through the process.

The ambulance service considers all contaminated people to be casualties; however, P3 casualties will proceed without physical assistance to the decontamination structures and will then proceed through the fire and rescue service ambulant decontamination structures again without the need for physical assistance. P1 and P2 casualties will normally be rescued by fire and rescue personnel and will be taken to the ambulance service decontamination structures for clinical decontamination undertaken by ambulance service personnel. A more in-depth casualty assessment will be conducted by ambulance service personnel as soon as time and resources permit.

It is assumed that a large number of people within the inner cordon will require precautionary decontamination. These people will proceed to the decontamination structures and will then proceed through the fire and rescue service ambulant decontamination structures without the need for physical assistance.

Clinical intervention within the inner cordon may also be possible. The ambulance service has introduced response teams (Hazardous Area Response Teams) in England, Wales and Northern Ireland and Special Operations Response Team (SORT) in Scotland) to provide a hazardous area response.

Safe undressing procedures

Gas-tight chemical protective clothing safe undressing procedures

The following is an aid for crews carrying out firefighter full decontamination using national resilience gas-tight chemical protective clothing.

Procedure

Operative: Provide prepared decontamination bag and place adjacent to veranda ready to receive the wearer

Wearer: Step into decontamination bag

Operative: Disarm distress signal unit on BA set (for example, insert spare key)

Wearer: Withdraw arms into suit, disconnect GTCPS umbilical from breathing apparatus set and unfasten GTCPS waist belt

Wearer: Don the pair of nitrile*/medical gloves and cross arms on chest

Operative: Open zip flap and mop zip area from top to bottom with paper towel, place used paper towel in bag

Operative: Unzip suit, fold back zip carefully and peel down to boot level ensuring the outside of the suit (including the zip) does not touch the wearer

Wearer: If necessary, use gloved hands to lean on operatives for support

Wearer: Step out of suit, remove nitrile/medical gloves and place in bag, walk to the edge of salvage sheet and don personal issue footwear**

Operative: Secure bag by placing hands under roll over and pull up to the closed position, secure with a cable tie

Wearer: Go to disrobing area, remove BA facemask and report to entry control operative, collect tally and complete suit log sheet

Operative: Avoid kneeling down, and carry out the safe undressing procedure at arms length to prevent unnecessary contact with the wearer. Ensure the outside of the suit does not touch the wearer during disrobe. If any obvious cross-contamination is observed seek scientific advice immediately.

* These are to be given to the wearer prior to entry and carried within the suit until required in the safe undressing procedure (SUP)

** The Home Office Project 'Mass Decontamination and Undressing Procedures' report ECM/2008/01 recommends a safer path for the Wearers to don their shoes and exit the area. The report recommends either a clean path, alternative temporary footwear or a narrow salvage sheet folded back on itself lengthways.

Showering times when using the MD4 unit

The showering times used should be decided by hazard assessment. The following times were used in trials whilst developing the safe undressing procedures (SUP) and may be an appropriate system to use:

- Three minutes of self washing with brushes including washing the brush handles themselves

- Two minutes of rinsing each other
- Two minutes where wearer 1 washes wearer 2 with brush, ending at zip under Velcro flap
- Two minutes where wearer 2 washes wearer 1 with brush, ending at zip under Velcro flap
- Two minutes of rinsing each other



Image 74 CPC safe undressing procedure

The safe undressing procedure takes place off the MD4 unit's veranda because of difficulties experienced by operatives in removing the gas tight chemical protective clothing when carried out on the higher level of the veranda.



Image 75 CPC safe undressing procedure - nitrile / medical gloves

Wearers are passed clean nitrile/medical gloves from the clean area as an additional control. These are discarded at the end of the undressing procedure.



Image 76 CPC safe undressing procedure - minimise risk of contact

The wearer in nitrile/medical gloves crosses arms to minimise any possible contact with the outside of the CPC or decontamination operatives.



Image 77 CPC safe undressing procedure - wearer assistance

The wearer is assisted into the clean area by the decontamination assistant who is wearing breathing apparatus as an additional precaution and for emergency situations.

Powered respirator protective suit safe undressing procedures

The following is an aide memoir for crews carrying out firefighter full decontamination using the national resilience powered respirator protective suit (PRPS). This procedure should be used after undergoing MD4 showering procedures.

Procedure:

1. Operative: Provide prepared bag and place in front of veranda ready to receive wearer
2. Wearer: Step into bag, with the operative's assistance if required
3. Wearer: Stretch arms out to sides
4. Operative: Open zip flap and mop entire zip area, place used paper towel in bag
5. Operative: Unzip suit, fold back zip edge, hold the wearer's gloves to allow the wearer to pull their arms from the sleeves
6. Wearer: If wearing helmet, undo securing strap then cross arms across chest.
7. Operative: Hold hood to allow the wearer to duck down out of hood
8. Wearer: Duck out of suit hood
9. Operative: Fold hood to the rear of the wearer and roll the suit down away from the wearer to waist level
10. Wearer: Release support belt and disconnect hydration tube
11. Operative: Fold suit down to top of boots
12. Wearer: Step out of boots, steadying on the operative if necessary, walk to edge of disrobe area and don personal issue footwear, report to the entry control operative to collect tally and complete log book
13. Operative: Switch off the respirator power pack
14. Operative: Secure bag by placing hands under roll over and pull up to the closed goose neck position, secure with cable tie and complete details on label and bag
15. Operative: Bagged suits are to be stored adjacent to inner cordon to await further advice



Physical methods

- Adsorption/absorption is the process of soaking up a liquid hazardous material to prevent enlargement of a contaminated area. It is primarily used in decontamination for wiping off personal protective equipment (PPE), respiratory protective equipment (RPE), chemical protective clothing (CPC) and other equipment using sponges, absorbent pads, towels, disposable cloths or specialist material such as activated carbon or fuller's earth etc. With some materials, this procedure can generate heat.
- Brushing or scraping to remove a contaminant can be used for decontaminating PPE, RPE, CPC and other equipment in both dry decontamination and wet decontamination operations using liquid decontamination solutions. The aim should be to remove as much of the gross contamination as possible before moving on to further decontamination processes or safe undressing
- Diluting/washing is using cold or warm water or soap/degreaser and water solutions to flush the hazardous materials from protective clothing and equipment. Using detergent/soap/degreaser takes advantage of the surfactant properties and works well on

oils, greases, solvents, dirt, grime, powders etc. Diluting/washing using detergents is the most commonly used method for decontaminating firefighters. Tests have shown that this method can be more effective if the soap/degreaser is applied to the contaminant in neat concentration and then agitated to form an emulsion prior to rinsing with water.

- Freezing has limited use at emergency incidents but is used to solidify runny or sticky liquids into a solid so that it can be scraped or flaked off
- Heating usually involves using high temperature steam in conjunction with high pressure water jets to heat up and blast away the contaminant. It is primarily used for decontaminating vehicles, structures and equipment. Heating techniques are unlikely to be appropriate to decontaminate CPC or people.
- Isolation and dispersal is a form of dry decontamination and is a two-step process that does not involve the use of any water or decontamination solution. Firstly, contaminated articles are removed and isolated in a designated area where they are then bagged and tagged. Secondly the bags are packaged in a suitable transportation container and taken to an approved hazardous waste facility. Note that any form of dry decontamination may carry the increased risk of cross-contamination when the decontamination operatives assist wearers with removing CPC.
- Pressurised air may be used to blow dusts and liquids from hard-to reach places in equipment and structures. It should never be used for firefighter decontamination because pressurised air on skin may result in fatal embolisms. A secondary hazard of this method is the potential to create hazardous aerosols.
- Vacuuming is primarily used to decontaminate structures and equipment and can be used on a range of contaminants including asbestos, hazardous dusts, fine powders, etc. The vacuum must be designed and approved for the specific application. High-efficiency particulate air vacuums should be used for personal decontamination of hazardous dusts and fibres such as asbestos. High-efficiency particulate air filters physically capture the contaminant but must be replaced frequently. Using high-efficiency particulate air vacuums in fire-related incidents may not be effective due to the amount of wet PPE, RPE and CPC.
- Evaporation allows a contaminant to evaporate or gas-off. Its effectiveness can be limited when dealing with porous surfaces and large quantities of materials.



Chemical methods

- Chemical degradation is the process of altering the chemical structure of the contaminant using a second chemical or material. Commonly used degradation agents include calcium hypochlorite bleach, sodium hypochlorite bleach, sodium hydroxide (household drain cleaner), sodium carbonate slurry (washing soda) and calcium hydroxide oxide slurry (lime). Chemical degradation is primarily used to decontaminate structures, vehicles and equipment and should not normally be used on CPC without specialist advice. These agents should never

be applied directly to the skin. Technical advice must be obtained from product specialists to ensure that the solution used does not react with the contaminant.

- Neutralisation is the process used on corrosives to bring the pH of the final solution to somewhere within the range of pH 5 to pH 9. The neutralisation process uses an acid to neutralise alkalis or vice versa. Preferably, the less harmful by-product produced is a neutral or biodegradable salt. It is primarily used to decontaminate structures, vehicles and equipment that are contaminated with a corrosive material.
- Solidification is a process by which a contaminant physically or chemically bonds to another object or is encapsulated by it. This method is primarily used to decontaminate equipment and vehicles. Commercially available solidification products can be used for the clean-up of spills.
- Disinfection is the process used to inactivate virtually all recognised pathogenic micro-organisms. Proper disinfection results in a reduction in the number of viable organisms to some acceptable level. It does not completely destroy the micro-organism; consequently, it is important that firefighters obtain technical advice about disinfection techniques prior to their use. There are two major categories of disinfectants:
 - Chemical disinfectants, the most practical for on-site operations
 - Antiseptic disinfectants, designed primarily for direct application to the skin
- Sterilisation is the process of destroying all micro-organisms in or on an object. Because of the size of the equipment needed to carry out this form of decontamination it has limited emergency use and cannot be used on operational staff. Emergency response equipment may be sterilised through autoclaving, but the ability for the item to withstand this process must be confirmed by the manufacturer.

In 1995 the Home Office Fire and Research and Development Group carried out research into the effectiveness of various methods of decontamination used by fire and rescue services. The research was in three trials using the three following types of chemical protective clothing:

- Non-coverall (breathing apparatus outside) chemical protection suit made of poly vinyl chloride (PVC)
- Coverall suit made of neoprene
- Gas-tight suit made of hyperlon/neoprene.

Table 29 below displays a shortened summary of the effectiveness of various decontamination methods. The shower system tested in these trials was of the mass dilution type.

Table 29 Effectiveness of decontamination methods

Method summary	Overall average reduction (1-8)
Strong detergent scrub and shower	5.6
hot detergent scrub and shower	5.0
Scrub with detergent then hose reel	4.7

Method summary	Overall average reduction (1-8)
Scrub with detergent then shower - not rubbing	4.4
Hose reel only - rubbing	4.2
Car wash brush with detergent	3.8
Car wash brush - no detergent	3.3
Shower - rubbing - no detergent	3.1
Shower - no rubbing, no detergent	2.7

A score of eight represents the complete removal of containment. All methods cleaned the suits well enough to remove the wearers from them.

It was found that:

- None of the decontamination methods used were completely successful in removing all the contaminant but some methods were found to be more successful than others
- Generally, methods that used some form of scrubbing with detergent gave a greater degree of decontamination
- Methods that used hose reels or main jet/spray branches out-performed the portable shower units, when used alone
- Vacuum cleaners appeared to be relatively ineffective against dry powder contaminants.

The trials recommended that after primary decontamination (firefighter decontamination on-site), fire and rescue services should consider whether any further action is necessary before a used suit is returned to operational service. This will depend on the chemical encountered and the degree of contamination. Appropriate records, including the nature of contaminants, should be kept. For further information see DCOL 8/1995 Item D and CFBAC Research Report No. 63.



Firefighter decontamination

Firefighter decontamination is the use of equipment in a planned and structured manner on the incident ground to minimise the risk of further harm occurring and keep cross-contamination to a level as low as reasonably practicable (ALARP). However, at some incidents the nature or the extent of the contamination may be such that adequate decontamination is beyond the resources of the fire and rescue service and requires specialist treatment.

Fire and rescue service firefighter decontamination procedures should aim to:

- Minimise the risk of people being exposed to contaminants
- Enable responders to remove contaminated clothing, personal protective equipment and respiratory protective equipment without being exposed to hazardous materials
- Stop hazardous materials being spread beyond the decontamination area



Selection of the level of decontamination

Firefighter decontamination (primary decontamination) is divided into two levels:

- Initial decontamination is the decontamination of firefighters using equipment immediately available on a pumping appliance. It should be used in all cases where unforeseen contamination of firefighters has occurred, where there is an immediate life risk or where, at a minor incident, the hazards posed by the substance can be adequately controlled by the procedures. In all cases the incident commander should carry out a risk assessment and remember that initial decontamination is intended as a first-aid measure and not a substitute for the provision of full decontamination.
- Full decontamination is the decontamination of firefighters on site using decontamination equipment, structured procedures and personnel who have been trained fully in its use

Both levels of firefighter decontamination usually involve two processes:

1. Contamination reduction or contamination stabilisation
2. Safe undressing

The level of decontamination chosen will be based on the:

- Nature of the contamination
- Degree of contamination
- Type of protective clothing worn
- Method of decontamination
- Life risk and urgency to intervene



Positioning of the

decontamination area

The factors that will influence the positioning of the decontamination area (DA) are the:

- Operational circumstances and risk assessment
- Level and method of decontamination
- Weather conditions
- Wind direction (see photos of improvised wind socks below)
- Slope of the ground
- Location of drains, watercourses, etc. (or their absence)
- Position of the inner cordon and hot zone
- Location of breathing apparatus (BA) entry control
- Location of a pumping appliance
- Welfare of staff



Image 52 Decontamination area - wind direction



Image 53 Decontamination area - wind direction



Decontamination system

The following is a generic fire and rescue service decontamination system; this good practice model should be considered at every hazardous materials incident, irrespective of the level of decontamination selected. Some elements may not be necessary depending on the operational circumstances.

Table 39 Generic decontamination system

Generic decontamination system			
No.	Stages	Considerations for 'initial' decontamination	Contamination for 'full' decontamination
1	Position the decontamination area	See Positioning the decontamination area	See Positioning the decontamination area

Generic decontamination system			
2	Brief wearers (and operatives if applicable)	Be aware of hazards Avoid contamination Minimise contact & note areas of contact Ensure a safe path to the DA Make sure personnel know how to employ the chosen decontamination method Remove personal items from pockets	
3	Set out the decontamination are	See photos below	See Full decontamination procedure below
4	Drop tools	Designate an area Brief wearers	Position a suitable sealable container or bags Brief and instruct wearers

Generic decontamination system			
5	Remove or reduce contamination (from external surfaces or layers of PPE)	<p>Before starting, check for breaches of PPE and personal exposure</p> <p>Remember this is likely to be a single stage (e.g. hose reel spray) and likely to be a self- or 'buddy'-operated procedure</p>	<p>Before starting, check for breaches of PPE and personal exposure</p> <p>Consider assisting wearers by the use of decontamination operators</p> <p>Remove gross contamination using methods/steps as appropriate, for example:</p> <ul style="list-style-type: none"> Remove boots & gloves Rinse Wash Scrub Rinse Wipe CPC zips, PPE joins and RPE seals
6	Undress safely (Remove external layers of PPE or CPC depending on degree of contamination)	<p>Use standard procedure</p> <p>Peel CPC back on itself</p> <p>Ensure wearers don medical gloves when working gloves are removed</p> <p>Remove BA last</p> <p>Remember weather protection</p>	<p>As for 'initial,' but noting that though safe undressing procedures for gas-tight CPC have been developed for mass decontamination, they may be used at conventional incidents</p>
7	Check for risk of exposure	<p>Check for gaps in PPE</p> <p>Check for visible contamination</p>	As for 'initial'
8	Wash hands, face and any areas of contamination	<p>Consider general hygiene requirements</p> <p>Use soap and water</p>	As for 'initial'

Generic decontamination system			
9	Re-robe and welfare	Make sure of personal hydration Use national resilience re-robe packs	As for 'initial' Designate a welfare area
10	Record any exposure	Ensure medical surveillance	As for 'initial'
11	Manage contaminated PPE and equipment	Ensure it is assessed by a competent person (e.g. hazardous materials adviser)	Ensure it is assessed by a competent person (e.g. hazardous materials adviser) seeks specialist advice from manufacturers etc.)
12	Secondary decontamination	See Secondary decontamination	See Secondary decontamination



Initial decontamination procedure

The first or initial level of firefighter decontamination uses equipment carried on pumping appliances. The equipment may range from hose reels to primary shower units. This level of procedure may suffice at many minor incidents, but there will be some at which full decontamination procedures will be required.

The decontamination method adopted depends on the type of contaminant, amount of contaminant and information from sources such as Chemdata. But generally under this level, decontamination will be a simple wet method using hose reels, brushes and/or sponges followed by a safe undressing procedure.

Broadly, fire and rescue services use two ways of carrying out wet decontamination:

- Decontamination of the wearers by operatives using a hose reel, brush and containment dam
- Self-decontamination or buddy-decontamination by the wearers using a shower system or

using a hose reel, brush and containment dam

Again, normally under initial firefighter decontamination the latter type will be used.



Image 54 Salvage sheets overlapped and with suction hose positioned beneath



Image 55 Initial decontamination example layout

Images 54 and 55 above show an example layout of Initial firefighter decontamination using salvage sheets and hard suction hose to mark the decontamination area and separate clean from

dirty areas. Note also that the dirty area has been clearly divided into a contamination reduction area (with improvised dam) and a safe undressing area (with undressing bags and tripod to assist with breathing apparatus set removal). The clean area contains a bucket for hand washing and re-robe clothing.

The following images (56 - 64)illustrate an example of a safe undressing procedure for wearers in BA and chemical gauntlets.



Image 56 - Stand in decontamination bag and remove helmet



Image 57 - Wipe or sponge down face mask seal area and any areas known to have been contaminated



Image 58 - Remove BA set from body but keep mask on



Image 59 - Wipe or sponge PPE fastenings and any area where contamination could have gathered unnoticed



Image 60 - Remove chemical gauntlets or firefighting gloves, place in bag. Don surgical / disposable gloves.



Image 61 - Remove tunic / fire coat and place in bag

Carefully peel-back fire trousers keeping hands inside PPE as far as possible to avoid touching potentially contaminated areas of PPE



Image 62 - Slide fire/flash hood over BA demand valve hose and remove BA facemask



Image 63 - Step into clean area. Remove surgical/disposable gloves and drop into decontamination or waste bag in dirty area.





Full decontamination procedure

Full firefighter decontamination is the decontamination of firefighters on-site using decontamination equipment, structured procedures and staff who have been trained fully in its use. Full decontamination should be supported by a decontamination team.



Decontamination team

Most fire and rescue services will mobilise a decontamination unit and team if it is likely that the resources required are greater than those available from the initial decontamination structure. Alternatively the incident commander should immediately arrange for decontamination resources if it is anticipated that they may be needed. The team should be supported by a hazardous materials adviser or scientific adviser with regard to technical advice and information.

Depending on the decontamination method(s), the decontamination team will consist of:

- A decontamination officer (or sector commander), who is responsible for:
 - Taking charge of decontamination procedures
 - Supervising the decontamination area
 - Instructing operatives
 - Safeguarding contaminated staff
 - Taking direction from the incident commander (who will be advised by the hazardous materials adviser) on the decontamination method(s)
 - Wearing structural firefighting PPE and remaining outside the decontamination area
- A decontamination assistant, who should:
 - Wear BA and chemical resistant gloves (this may need to be varied through risk assessment)
 - Act on the directions of the decontamination officer
 - Work between the clean and dirty areas (cold and warm zones)

- Assist the wearers with safe transition to the clean area
- Decontamination operatives, who should:
 - Wear RPE and chemical resistant gloves (this may need to be varied through risk assessment)
 - Remain within the dirty area (warm zone)
 - Act on the direction of the decontamination officer
 - Decontaminate the wearers' CPC sufficiently, assist safe undressing and transition to the clean area



Decontamination equipment

A typical list of equipment for use by a decontamination team may include:

- Chemical protective clothing
- Self-contained breathing apparatus
- Powered respirator protective suits
- Airline breathing apparatus equipment
- Plastic bags (possibly water soluble) with ties and labels
- Barrier tape, cones, poles, signs
- Soda ash, detergent, bleach, disinfectant
- Flexible brush with water control
- Shower system
- Water containment system and pump
- Portable dam
- Fire and rescue service national resilience MD4 firefighters' decontamination unit
- Salvage sheets
- Appropriate tabards and loud hailer
- Clean overalls and footwear
- National Resilience disrobe and re-robe packs
- Radiation survey and contamination meters
- Dry encapsulation material (Fullers Earth).
- Vacuum cleaner (approved type only, see note below)

Only CE-marked vacuum cleaners (e.g. class H for asbestos) with true or absolute high-efficiency particulate arrestor (HEPA) filters should be used. It is now generally regarded that dry decontamination using a vacuum cleaner is not in its own right a complete decontamination process; it should be followed by wet decontamination or a risk-assessed alternative. Also, vacuum cleaners are best suited to dry, still-air conditions, and these are rarely encountered at operational incidents. Fire and rescue services should ensure that other methods of decontamination are always available.



Decontamination good practice

Note any areas that come into contact with the hazardous materials and ensure these are focused on during decontamination (e.g. feet and hands).

When reducing contaminants from wearers, start at the top (head or helmet) and work down.

When wiping, scrubbing, brushing or spraying wearers, focus on the areas of likely contamination and areas where substances could build up (creases, folds and joins in CPC, under webbing or straps etc.). Beware of forcing contaminants beneath the layer of personal protective equipment.

Safe undressing procedures (SUP) for mass decontamination crews carrying out firefighter full decontamination have been developed through the fire and rescue service national resilience project.

Respiratory protective equipment should generally be the last item removed when carrying out the safe undressing procedure.

When using wet decontamination methods ensure that:

- Zips and other joins in PPE and CPC are sponged before they are opened to avoid water entering the wearers' under-clothing
- Dissolvable bags are of the hot wash type (not cold) to prevent premature degradation

Following unforeseen circumstances or immediate life saving rescues, wearers may need to carry out emergency dis-robing (stripping away of contaminated, or potentially contaminated, PPE and clothing in the dirty area prior to contamination reduction actions). If so, consider using the national resilience disrobe packs (see Emergency decontamination)

All procedures should be set out clearly, on water resistant boards to assist the decontamination team and wearers who may experience difficulty in communications.

Recording should be carried out away from the decontamination area, including the clean area. Any exposure of staff to hazardous materials must be recorded. The following details may be needed:

- Names, addresses and contact numbers
- Hazardous materials involved
- Role at the incident
- How exposure occurred
- Period of exposure
- Areas of the body exposed

- Decontamination and medical treatment.

This information must be available immediately after the incident in case of delayed physical or medical reactions to the exposure.

The following images show an example of full firefighter decontamination that could be used with the generic decontamination system

Fire and rescue services should tailor their specific procedures and equipment to their local circumstances and risk assessments, which should be informed by their risk management plans. Many fire and rescue services are incorporating the MD4 firefighter decontamination unit, provided through the fire and rescue service national resilience programme, into their hazardous materials standard operating procedures.



Image 66 Firefighter using 'tool drop' bin



Image 67 MD4 Firefighter decontamination shower incorporated into an example of a full decontamination set-up



Emergency decontamination

Fire and rescue services should also have an emergency decontamination procedure as an additional control measure for exceptional circumstances such as a breakdown of PPE (e.g. ripped CPC, BA malfunction, injured wearer, etc.). The decontamination procedures to be adopted in such circumstances should be adapted from the principles and procedures detailed above.

Emergency decontamination will be necessary include occasions where fire and rescue service personnel have:

- Inadequate protection
- Sustained damage to their CPC (including boots)
- Sustained injury
- Suffered a BA set failure or are low on air
- Suffered wearer distress

Emergency decontamination may also be necessary where there are members of the public or site staff who are not protected or who have inadequate protection.

Where responders are wearing CPC and require emergency decontamination, every effort should be made to remove the suit whilst ensuring that contamination does not contact the skin of the wearer. A peel-back or dry-peel procedure should be used.

If they have suffered skin contamination, either via a damaged suit or because of inadequate or no protection, contaminated clothing should be removed and affected skin washed with warm soapy water. Details of the extent and type of contamination should be recorded and communicated to medical teams.

It should be noted that the removal of outer layers of clothing in a controlled way will, in most cases, remove up to 80% of the contaminant.



Secondary decontamination

Chemicals that adhere to the surface of the CPC (surface contamination) are fairly easy to remove; this means that until the CPC has been decontaminated the surface contamination presents the most significant risk to unprotected staff handling it or to the wearer during disrobing. This is the reason CPC is decontaminated at the site, to remove the surface contamination before undressing. Primary decontamination may or may not remove any chemicals that have been absorbed or permeated into the CPC material (permeation or matrix contamination).

Accurate assessment of the degree of any remaining contamination of CPC can only be made by specialists, which may involve a destructive test, thereby making reuse of a test suit impossible.

Chemicals that have been absorbed into the matrix of the CPC material may, in some cases, continue to diffuse through the material during storage, presenting a possible risk of contamination to those who next wear or handle it.

The practice of firefighter or primary decontamination of CPC on site is intended for cleaning the suit and reducing any contamination to assist safer undressing procedures. This should generally be considered as only part of a decontamination process.

Further off-site assessment and decontamination (i.e. secondary decontamination), which may involve washing, scrubbing, thermal treatment and airing, will generally be needed. Fire and rescue services should have systems to assess CPC, RPE, equipment and other kit. This should take place as soon as possible after the incident and should be carried out by a competent person who has access to specialist advice. The assessment and its findings should be recorded.

Just because CPC appears clean on visual inspection, the complete removal of the contaminant is not necessarily certain, depending on the nature of the material.

Consideration of whether reuse is possible should be based on this assessment of the hazardous materials involved and the circumstances of the particular incident. Care should be taken in the reuse of CPC; advice regarding whether it can continue to be used safely may need to be sought from the CPC manufacturer/supplier or other competent person/agency.

General degradation of CPC may lessen the standard of chemical protection afforded. Degradation may be due to:

- Exposure to chemicals
- Mechanical damage
- Any combination of the above
- Ageing



Decontamination of casualties

Initial actions

Initial operational response guidance focuses heavily on the initial actions to be undertaken by fire and rescue service staff at a CBRN(e) incident. It is generally accepted that such an event would require mass decontamination; however, these may not be the only incidents requiring this approach. Many industrial or commercial incidents could easily see a number of members of the public becoming contaminated and they would therefore benefit from the mass decontamination procedure.

The first step in the procedure is to remove the members of the public from the hot zone or the area of gross contamination.

Once away from the contaminant, members of the public should now be encouraged to remove their outer layer(s) of clothing. Testing has shown that clothing is an effective barrier against a contaminant in the short term, depending on the nature of the clothing and the amount of skin surface it covers. Materials such as waterproof fabrics will normally hold off a contaminant longer than materials that are absorbent, but none is likely to be chemical protection clothing unless it is being worn at a commercial or industrial premises and has been provided for that purpose. Rapidly removing the outer layers will remove the contaminant, however care should be taken when removing clothing to minimise the potential of any substances touching the skin; clothing which would normally be removed by pulling over the head should instead be cut off to avoid spreading the contaminant over the face (nose, mouth and eyes).

Once the clothing is removed, decontamination can commence. This will be either improvised,

interim or full mass decontamination but often will be a combination of all three.



Mass decontamination

Mass decontamination is the planned and structured procedure delivered by fire and rescue services using purpose-designed decontamination equipment and where there are large numbers of contaminated casualties.

The responsibility for decontaminating members of public lies with the Department of Health. The decision on whether or not to decontaminate people will be taken by the ambulance service in consultation with the fire and rescue and police services.

Full, specific guidance on mass decontamination is outside the scope of this document. For further information see:

Strategic National Guidance - The decontamination of people exposed to chemical, biological, radiological or nuclear (CBRN) substances or materials, 2nd edition in May 2004, published by the Home office

Fire and rescue services Circular 58-2006 – Memorandum of Understanding on Mass Decontamination, published by CLG

Tactical Guidance Document - Fire and Rescue Service Response to CBRN(E) Events, CLG 2008

Fire and Rescue Service Response to CBRN(E) Events – Operational Guidance Document, CLG 2012

National Resilience IRU and Mass Decontamination Manual V3.0



Image 68 Mass decontamination area - set up



Image 69 Mass decontamination area



Improvised decontamination

Improvised decontamination is the use of an immediately available method of decontaminating members of the public before using specialist resources.

Generally, in the very early stages of an incident and depending on the symptoms and needs of contaminated people, improvised decontamination may be initiated by emergency service personnel, witnesses to the incident, passers by or even the contaminated people themselves.

The need to commence improvised decontamination depends on the type of contamination, the availability of a means of decontaminating and the symptoms displayed by the contaminated

people.

Improvised decontamination may take many forms, including removing contaminated clothing, wiping down, washing, rinsing, etc. It can have a positive effect on the contaminated people (for example, removing contaminated clothing reduces personal levels of contamination). Following research by Public Health (England) into the best way of removing a contaminant from the skin, in most cases a contaminant will be a material that can be lifted from the skin using an absorbent material, such as tissue. Improvised decontamination should therefore focus heavily on a dry decontamination procedure rather than wet, although wet decontamination will be necessary in certain circumstances such as when corrosive materials are involved.

The ambulance and police services may initiate improvised decontamination in the early stages of a CBRN (E) event, depending on the symptoms and needs of contaminated people.



Image 70 Improvised decontamination of public

The fire and rescue service incident commander should also consider improvised decontamination. In cases where the contaminant is corrosive then the member of the public is likely to complain of a burning sensation on the skin or of irritation. In these cases the skin will need to be washed and a wet decontamination method employed; this is still considered improvised decontamination even though the water may be provided from a firefighting pumping appliance.

Wet decontamination may also be necessary if members of the public have contaminant in their hair. The risk from this can increase if the person has a lot of hair, and dry decontamination may not remove the contamination.

Contaminated people who are subject to improvised decontamination should also subsequently be assessed by ambulance service personnel who will consider further decontamination requirements.



Interim decontamination

Interim decontamination is the use of standard equipment to provide a planned and structured decontamination process for large numbers of the public before purpose-designed decontamination equipment is available.

In the early stages of an incident and depending on the symptoms and needs of contaminated people, the fire and rescue service incident commander may decide to establish interim decontamination systems. This decision should be taken in consultation with ambulance service and police service incident commanders where they are present. In their absence, the fire and rescue service incident commander may need to make the decision unilaterally.

The benefits of establishing interim decontamination should be considered along with the risks; depending on the method used, there may be issues around maintaining systems for long periods, disrobe provision, re-robe provision, ability to use warm water, enclosures, ability to capture water run off, limited personal protective equipment (PPE) for fire and rescue service personnel, contamination of appliances and equipment, etc.

Where interim decontamination is established and used, fire and rescue service disrobe packs (if available) should be deployed if necessary before and after interim decontamination.

There is no national standard for interim decontamination; each fire and rescue service has established its own individual methods. However, interim decontamination has the advantage of being a more structured and controlled method than improvised decontamination.

The following example details how standard pumping appliances can be used to provide interim decontamination. Methods such as this may prove invaluable where incident response units carrying mass decontamination assets have long travel and set-up times.

Position the appliances

Position two appliances approximately 1.5 to 2 metres apart, with the near side of both vehicles parallel to each other. Ensure the exhausts face outwards and the bodies of the vehicles are in line with each other so the rear locker on one vehicle is opposite the front locker of the other vehicle.



Image 71 Interim decontamination

Set up the shower frame

Separate a short-extension ladder and place the widest extension up against one appliance in line with the middle locker; this can be used to gain access to position the ladder on the appliance roof. At no time should operational personnel mount the roof of an appliance. Position other ladder extensions to bridge the gap between the vehicles, ensuring the ladder pawls are against the roof of the vehicle.



Image 72 Interim decontamination, shower frame set up

Set up the shower units

Using both hose reels from each vehicle, lock each branch open and set to wide spray on maximum flow. Hang the branches over rounds nearest to the vehicle and position the branch to spray inwards. Ensure all windows and doors are shut and lockers closed as far as possible.

Set in to the nearest hydrant or other water supply and charge hose reels to 10-20 bar. Adjust nozzles to ensure a good mist effect is achieved.



Image 73 Interim decontamination, shower unit set up

This set-up is an example only. Fire and rescue services should fully risk assess this, or any other, method, before adopting it into their standard operating procedures.



Clinical decontamination

Clinical decontamination is the process where contaminated casualties are treated individually by trained healthcare professionals using purpose-designed decontamination equipment.

The ambulance service defines and prioritises casualties:

Priority 1 (P1) casualties: patients with a high priority for either immediate emergency medical care or immediate, emergency life-saving decontamination, or both

Priority 2 (P2) casualties: less severely affected patients who need either emergency medical care or early decontamination to prevent further intoxication

Priority 3 (P3) casualties: patients with slight to moderate intoxication and without contamination at a level that requires immediate action. A percentage of P3 casualties will leave the scene and self-present to local hospitals and clinics.

Clinical decontamination is the responsibility of the ambulance service and is a structured and thorough decontamination process their personnel will carry out for contaminated P1 or P2 casualties who by definition are unable to proceed unaided through the process.

The ambulance service considers all contaminated people to be casualties; however, P3 casualties will proceed without physical assistance to the decontamination structures and will then proceed through the fire and rescue service ambulant decontamination structures again without the need for physical assistance. P1 and P2 casualties will normally be rescued by fire and rescue personnel and will be taken to the ambulance service decontamination structures for clinical decontamination undertaken by ambulance service personnel. A more in-depth casualty assessment will be conducted by ambulance service personnel as soon as time and resources permit.

It is assumed that a large number of people within the inner cordon will require precautionary decontamination. These people will proceed to the decontamination structures and will then proceed through the fire and rescue service ambulant decontamination structures without the need for physical assistance.

Clinical intervention within the inner cordon may also be possible. The ambulance service has introduced response teams (Hazardous Area Response Teams) in England, Wales and Northern Ireland and Special Operations Response Team (SORT) in Scotland) to provide a hazardous area response.

Safe undressing procedures

Gas-tight chemical protective clothing safe undressing procedures

The following is an aid for crews carrying out firefighter full decontamination using national resilience gas-tight chemical protective clothing.

Procedure

Operative: Provide prepared decontamination bag and place adjacent to veranda ready to receive the wearer

Wearer: Step into decontamination bag

Operative: Disarm distress signal unit on BA set (for example, insert spare key)

Wearer: Withdraw arms into suit, disconnect GTCPS umbilical from breathing apparatus set and unfasten GTCPS waist belt

Wearer: Don the pair of nitrile*/medical gloves and cross arms on chest

Operative: Open zip flap and mop zip area from top to bottom with paper towel, place used paper towel in bag

Operative: Unzip suit, fold back zip carefully and peel down to boot level ensuring the outside of the suit (including the zip) does not touch the wearer

Wearer: If necessary, use gloved hands to lean on operatives for support

Wearer: Step out of suit, remove nitrile/medical gloves and place in bag, walk to the edge of salvage sheet and don personal issue footwear**

Operative: Secure bag by placing hands under roll over and pull up to the closed position, secure with a cable tie

Wearer: Go to disrobing area, remove BA facemask and report to entry control operative, collect tally and complete suit log sheet

Operative: Avoid kneeling down, and carry out the safe undressing procedure at arms length to prevent unnecessary contact with the wearer. Ensure the outside of the suit does not touch the wearer during disrobe. If any obvious cross-contamination is observed seek scientific advice immediately.

* These are to be given to the wearer prior to entry and carried within the suit until required in the safe undressing procedure (SUP)

** The Home Office Project 'Mass Decontamination and Undressing Procedures' report ECM/2008/01 recommends a safer path for the Wearers to don their shoes and exit the area. The report recommends either a clean path, alternative temporary footwear or a narrow salvage sheet folded back on itself lengthways.

Showering times when using the MD4 unit

The showering times used should be decided by hazard assessment. The following times were used in trials whilst developing the safe undressing procedures (SUP) and may be an appropriate system to use:

- Three minutes of self washing with brushes including washing the brush handles themselves
- Two minutes of rinsing each other
- Two minutes where wearer 1 washes wearer 2 with brush, ending at zip under Velcro flap
- Two minutes where wearer 2 washes wearer 1 with brush, ending at zip under Velcro flap
- Two minutes of rinsing each other



Image 74 CPC safe undressing procedure

The safe undressing procedure takes place off the MD4 unit's veranda because of difficulties

experienced by operatives in removing the gas tight chemical protective clothing when carried out on the higher level of the veranda.



Image 75 CPC safe undressing procedure - nitrile / medical gloves

Wearers are passed clean nitrile/medical gloves from the clean area as an additional control. These are discarded at the end of the undressing procedure.

The wearer in nitrile/medical gloves crosses arms to minimise any possible contact with the outside of the CPC or decontamination operatives.



Image 77 CPC safe undressing procedure - wearer assistance

The wearer is assisted into the clean area by the decontamination assistant who is wearing breathing apparatus as an additional precaution and for emergency situations.



Powered respirator protective suit safe undressing procedures

The following is an aide memoir for crews carrying out firefighter full decontamination using the national resilience powered respirator protective suit (PRPS). This procedure should be used after undergoing MD4 showering procedures.

Procedure:

1. Operative: Provide prepared bag and place in front of veranda ready to receive wearer
2. Wearer: Step into bag, with the operative's assistance if required
3. Wearer: Stretch arms out to sides
4. Operative: Open zip flap and mop entire zip area, place used paper towel in bag
5. Operative: Unzip suit, fold back zip edge, hold the wearer's gloves to allow the wearer to pull their arms from the sleeves
6. Wearer: If wearing helmet, undo securing strap then cross arms across chest.
7. Operative: Hold hood to allow the wearer to duck down out of hood
8. Wearer: Duck out of suit hood
9. Operative: Fold hood to the rear of the wearer and roll the suit down away from the wearer to waist level
10. Wearer: Release support belt and disconnect hydration tube
11. Operative: Fold suit down to top of boots
12. Wearer: Step out of boots, steadying on the operative if necessary, walk to edge of disrobe area and don personal issue footwear, report to the entry control operative to collect tally and complete log book
13. Operative: Switch off the respirator power pack
14. Operative: Secure bag by placing hands under roll over and pull up to the closed goose neck position, secure with cable tie and complete details on label and bag
15. Operative: Bagged suits are to be stored adjacent to inner cordon to await further advice



Section 3: Physical hazards



Explosive hazards

Explosives are generally categorised as those that:

- Deflagrate: a technical term describing subsonic combustion that usually spreads through thermal conductivity (hot burning material heats the next layer of cold material and ignites it). Deflagrations are usually less destructive than detonations, but still present a serious risk as they will generate an overpressure, which has the potential to harm individuals.
- Detonate: a process of supersonic reaction in which a shock wave is propelled forward due to energy release in a reaction zone behind it. In a detonation, the shock compresses the material, increasing the temperature to the point of ignition. The ignited material reacts behind the shock and propels the shock wave. Because detonations generate high pressures, they are very destructive.

Explosives, irrespective of whether they deflagrate or detonate, produce large quantities of hot gases and proceed without consuming oxygen from the surroundings. Ignited explosives can, for example, explode under water. Once initiated, the application of water will not extinguish a fire involving explosives.

The types of energy that can initiate explosives are:

- Impact/friction
- Fire/heat
- Fragment attack/overpressure
- Electrostatic discharge
- Electromagnetic radiation such as mobile phones, pagers etc (in the case of electro-explosive devices)
- Chemical reaction

For the purpose of transporting dangerous goods, explosives are defined as follows:

- Explosive substances: an explosive substance (or mixture) is a solid or liquid substance (or a mixture of substances) that is in itself capable by chemical reaction of producing gas at such a temperature and pressure and at such a speed to cause damage to surroundings. TNT and dynamite are known examples of explosive substances.
- Pyrotechnic substances: a substance (or a mixture of substances) designed to produce an effect by heat, light, sound, gas or smoke (or a combination of them) as a result of non-detonative self-sustaining exothermic chemical reactions. Pyrotechnic substances are commonly found in fireworks.
- Explosive articles: an article containing one or more explosive substances. For example, all

kinds of ammunition.

- Pyrotechnic articles: an article containing one or more pyrotechnic substances or mixtures
- Phlegmatised (de-sensitised): a substance (or 'phlegmatiser') has been added to an explosive to enhance its safety in handling and transport. The phlegmatiser renders the explosive insensitive, or less sensitive to heat, shock, impact, percussion or friction. Typical phlegmatising agents include wax, paper, water, polymers (such as chlorofluoropolymers), alcohol and oils (such as petroleum jelly and paraffin).

Hazards

Blast

Multi-level injury from blast (blast injury) may result in impairments to groups of body organs and systems. A phenomenon called blast overpressure forms from the compression of air in front of a blast wave, which heats and accelerates the movement of air molecules. This overpressure phenomenon is considered to be the positive phase of the blast wave. The negative phase of the blast wave occurs later, as a result of sub-atmospheric pressure/under-pressurisation. The amount of damage from the pressure wave depends on the peak pressure, duration and medium in which the explosion occurs (open air, confined space, or water) and distance from the explosion.

The type of explosive will affect the nature and severity of the resulting blast injury. Explosives are categorised as either high-order or low-order.

High-order explosives are chemicals with a high rate of reaction. They include nitroglycerine, dynamite, C-4 (a common commercial and military explosive) and a mixture of ammonium nitrate and fuel oil. When a high-order explosive detonates, the chemicals are converted into gas at a very high temperature and pressure. High-order explosives can generate a large volume of initial pressure and a blast wave that may expand outwards in all directions.

Low-order explosives are designed to burn and gradually release energy at a relatively slow rate. These types of explosive are referred to as propellants because they propel an object, such as a bullet, through a barrel. Low-order explosives do not create the shock waves generated by high-order explosives. The blast wind of low-order explosives is a pushing effect rather than the shattering effect found in the blast wave of high-order explosives.

The effects of blast injuries are broken down into three distinguishable areas, these are:

- Primary blast injuries caused by the direct action of a blast wave on the body. The two most common injuries are eardrum rupture and lung haemorrhage. Lung haemorrhage is in fact the most likely cause of death in cases where primary blast effects prove fatal.
- Secondary blast injuries are defined as those that occur as a direct consequence of blast damage to buildings and structures. These injuries include lacerations caused by flying glass, blunt trauma caused by crushing and impact of falling masonry and suffocation caused by asphyxiating dust. Secondary blast injuries can occur at significantly greater distances from an explosion than either primary or tertiary blast injuries, and experience shows that structural collapse is the dominant mode of death and injury from explosions in built-up areas. Secondary blast injuries are normally related to the degree of building damage.

- Tertiary blast injuries are defined as those resulting from body movement induced by the blast wave. Two modes may be distinguished: injuries caused by differential displacement of internal body organs following high acceleration and injuries caused by impact when the body is either blown over or picked up by the blast wave and thrown against an object.

The constituents of explosives, especially fireworks, vary significantly; compounds such as metals, metal salts, chlorine donors, hydrocarbon fuels, and binders are incorporated into compositions for colour or sound effects, etc. Some of the constituents of fireworks are toxic. Unfortunately, literature relating to fireworks manufacture does not tend to cover this aspect in much detail. For example, most fireworks contain potassium perchlorate which in itself is an irritant to the mucous membrane and can adversely affect blood and the thyroid gland.

Fireball

Severe burns may result even if no explosion takes place, as the ignition of some types of HD 1.3 and HD 1.4 explosives can result in a significant fireball. For example, the burst diameter of an aerial firework shell can be in excess of 100 metres. Lung damage may result if inhalation takes place.

Noise

Explosives generate considerable noise when they explode. This can cause hearing damage, usually a temporary loss of hearing, or ringing in the ears. Communication can be difficult especially if it happens over a protracted time with HD 1.4 fireworks, for example.

Structural collapse

There is a risk of entrapment following the collapse of a structure.

Quarries

The majority of locations holding civilian blasting explosives are quarries. Explosives are typically held in a steel store. For quarrying operations most explosives are mixed on-site from non-explosive ingredients.

COMAH sites

The Control of Major Accident Hazards Regulations 2015 (COMAH) apply mainly to the chemical manufacture and storage industry, but also to other industries where threshold quantities of dangerous substances identified in the Regulations are kept or used.

Explosives manufacturing

High explosives, or munitions using high explosives, are only manufactured at a few sites in the UK. Other sites and companies are engaged in manufacturing small arms ammunition, munitions, pyrotechnics, detonators and oil well explosives, amongst others. Explosives manufacturing of this nature is not a seasonal activity.

Fireworks

Most fireworks are sold and used during the peak firework season (October/November). However, professional firework displays take place at public and private events at other times of the year and a limited number of retailers sell fireworks all year round. Fire and rescue services could therefore encounter large stocks of fireworks at any time of the year.

Fireworks importation varies according to the time of the year and the special event for which the fireworks have been imported. For example, in 2006, approx. 1180 containers were brought through the port of Felixstowe, equating to 15,559 tonnes of fireworks (gross weight). Some 57% of these were received in August and September.

Fireworks display operators

Fireworks display operators are likely to be using HD1.1 and HD1.3 fireworks in addition to HD1.4. The main implications are:

- HD 1.1 presents a mass explosion hazard
- When fireworks of HD1.1 are present in a store together with HD 1.3 or HD 1.4 fireworks, the whole quantity will behave as if it is HD 1.1
- HD 1.3 articles do not present a mass explosion hazard; there is nevertheless a potential for them to explode and produce large fireballs

Note that while the UN HD definition states that HD 1.3 fireworks have no mass detonation, this is based on a test of the articles in the open within their correct transport or stowage packaging. Evidence from the Health and Safety Laboratory demonstrates that UN HD 1.3 fireworks will mass deflagrate (almost no perceptible difference to a detonation) when confined. In addition, containment presents a different reaction to that of confinement (e.g. ISO containers).

Retail premises

Shops and supermarkets usually only store small quantities of fireworks and then only during the peak firework season; these are kept either within the shop or in an ISO container in the goods yard. Typically this will be up to 250 kg of HD1.4, or smaller quantities of HD1.3, but may be more if separation distances permit. Fire and rescue services should also be mindful of transient locations where explosives may be encountered and ensure that operational crews are made aware of these. This may mean providing temporary mobilising information.

Improvised or home-made explosive devices

A concerning development in recent years is the increased manufacture and use of improvised or home-made explosives and explosive devices. These have many forms but the most common group are peroxide explosives (e.g. triacetone triperoxide (TATP), hexamethylene triperoxide diamine (HMTD) etc.).



Common explosives and their uses

Nitroglycerine

A very powerful and extremely sensitive liquid explosive that is usually mixed with other inert materials to form propellant, dynamites and blasting gelatines. The liquid is particularly sensitive to heat, flame, shock, oxygen or UV radiation and is not transported or used in its pure form as it is too dangerous to handle. Some types of explosives containing nitroglycerine such as dynamite, release nitroglycerine liquid when in contact with water. This can present particular dangers during firefighting or where the explosives are involved in flooding. Nitroglycerine is also transported and used either as a dilute solution in alcohol or as a mixture with a solid dilutant for pharmaceutical purposes. Nitroglycerine is highly toxic in both vapour and liquid form and is readily absorbed through the skin.

Trinitrotoluene (TNT)

A comparatively insensitive explosive mostly used for military purposes. It is a stable solid substance that is generally safe to handle. Small, unconfined quantities may burn quietly but larger quantities, particularly under confinement, are likely to burn to detonation. On decomposition, toxic fumes are given off. TNT is moderately toxic by ingestion and can be absorbed through the skin.

Nitrocellulose (guncotton, pyrocotton, nitrocotton)

Nitrocellulose is a white or cream coloured fibrous material produced in a range of forms. Its properties depend on the amount of nitrogen in it. Types with a nitrogen level above 12.6% are generally used in explosives manufacture. Those below that are used for other purposes. Nitrocellulose is sensitive to impact and friction and easy to ignite by flame when dry and is therefore normally transported either wetted with water or alcohol or it is plasticised. Explosives-grade nitrocellulose can present a fire or explosion hazard depending on its level of dryness and whether it is confined. Non-explosives-grade nitrocellulose will normally burn and is often classified as a class 4.1 flammable solid. Its principal uses are as an ingredient in propellant mixtures for ammunition and rocket motors, and in nitroglycerine explosives. Non-explosive grades of cellulose nitrate are used with other substances in the manufacture of paints and lacquers. Small arms propellant powders are usually made from nitrocellulose (single base) or nitro-cellulose with nitroglycerine (double base) and are usually in the form of a free-flowing granular material. For the most part, they burn fiercely but under confinement many types can burn to detonation. As a consequence, the hazard can be either a fireball or a mass explosion.

Primary explosives such as fulminates, azides and styphnates

These are initiating explosives that are highly sensitive and dangerous, particularly when they contain heavy metals such as lead, silver or mercury. They explode violently and are commonly used in initiators such as detonators and cap compositions. These types of explosive are infrequently transported and are only carried when wetted with water or other suitable liquid to minimise their sensitivity to impact and friction. Transport packages are carefully designed to minimise the risk of wetting agents leaking and the explosive consequently drying out. Some forms of these substances, such as styphnic acid or potassium azide, have low explosive properties. However, they can react with other substances such as copper or lead salts to become highly dangerous forms. This can be a serious problem where these substances have been spilled and allowed to get in contact with copper, lead or other reactive species. Because the sensitive forms tend not to dissolve in water, a hazard could rapidly develop.

Gunpowder/black powder/black blasting powder

These are generally made from a mixture of charcoal, sulphur and potassium nitrate and are frequently described as low explosives. They are very sensitive to ignition from sparks, heat and friction. They burn violently even when loose and uncompressed and when confined may explode. They also release volumes of smoke on burning or exploding. Black powder is used as a blasting explosive as well as an ingredient in some types of sporting cartridges, fireworks and pyrotechnics.

Oxidisers

These substances are not explosives in their own right but can explode in a fire under certain conditions. Two types commonly used in explosives are worthy of comment.

- Nitrates are used in explosives such as gunpowder, emulsion and slurry-blasting explosives and pyrotechnic substances. The most common are potassium, sodium, barium and ammonium nitrates. If mixed with a fuel these compounds can burn fiercely or explode. Wood, if impregnated with oxidisers, can burn fiercely, which can be a potential problem on vehicles with wooden floors or in wooden storage buildings where oxidisers have been transported or stored. Care must be taken in warehouses to ensure that oxidisers are segregated from other dangerous goods. Ammonium nitrate is used as a fertiliser and is commonly found in farming areas. It is usually supplied as a porous prill (pellet) that can readily absorb liquids. It forms the basis of ammonium nitrate and fuel oil (ANFO) explosives often used by terrorist organisations. It is possible that other fuels such as sawdust and metal powders could also form explosive mixtures with ammonium nitrate. There have been a small number of reports throughout the world of nitrates exploding without other chemicals being present, when confined or subject to severe heat. In recognition of this danger, the size of stack of ammonium nitrate in storage is normally carefully controlled
- Chlorates, mostly in the form of potassium chlorate, are mainly used in pyrotechnic compositions. As with nitrates, chlorates can decompose violently in a fire, particularly if mixed with fuels. As a general rule, chlorates are more aggressive and less stable in a fire than nitrates

Emulsion and slurry explosives

Emulsion and slurry explosives are relatively new types of explosives that are mixtures of nitrates

and other substances, often in a water-based system. They are now replacing nitroglycerine-based explosives for many uses, particularly in quarrying. A small proportion of emulsion and slurry explosives are produced as pre-packed, ready to use products. Most of this type of explosives, however, is manufactured at the scene (shot hole), immediately prior to use. This mixing is carried out on a specially designed mixer truck that carries the necessary ingredients for producing a fully active explosive.

• Peroxide explosives (improvised or home-made explosives)

Peroxide explosives are extremely dangerous. Only small quantities are needed to cause serious injury or explosions, the constituents are readily available from almost any high street and they are easy to make, with instructions for their manufacture easily available on the internet

Emergency services may encounter them at many routine incidents (e.g. domestic property fires)

The main constituents are:

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

It is important for fire and rescue service responders to know and remember these main constituents because identifying the possibility of home-made explosives being present in the early stages of an apparently routine incident can save lives.

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. Responders should not rely on physical appearance alone to identify this hazardous material. It is more important to recognise the raw constituents along with other indicators such as mixing jars and containers or a fridge or freezer to keep the substance cool.

Common types of peroxide explosives are:

- Triacetone triperoxide (TATP) is an explosive that has appeared as a terrorist weapon in the Middle East. TATP has been used by suicide bombers in [Israel](#), and was chosen as a detonator in 2001 by the thwarted shoe bomber Richard Reid. It is one of the most sensitive explosives known and is extremely sensitive to impact, temperature change and friction
- Hexamethylene triperoxide diamine (HMTD) is another peroxide-type explosive that is less sensitive than TATP but still dangerous



Transportation and packaging

In accordance with the UN Recommendations on the Transport of Dangerous Goods (commonly known as the orange book) explosives (in their packaging) are classified into hazard divisions (HD) for transportation. Licences issued under the Explosives Regulations refer to hazard types (HT)

With explosives that are packaged for transport, the hazard division and hazard type will be the same; however, in some cases (e.g. detonators), unpackaged explosives may present a higher hazard.

HD 1.1 or hazard type 1

Substances and articles that have a mass explosion hazard. This is an explosion that affects almost the entire load virtually instantaneously. If involved in fire, major structural damage can be expected (e.g. high-explosive shells, bombs, etc.).

HD 1.2 or hazard type 2

Substances and articles that have a projection hazard but not a mass explosion hazard (e.g. mortar bombs, rocket propelled grenades, etc.).

HD 1.3 or Hazard Type 3

Substances and articles that have a fire hazard and blast hazard or a minor projection hazard or both, but not a mass explosion hazard. On combustion, they will radiate considerable heat or each package will burn one after another, producing minor blast or projection effects or both (e.g. flares).

HD 1.4 or Hazard type 4

Substances and articles that present only a slight risk of explosion in the event of ignition, or initiation during carriage, storage or manufacture. The effects are local, largely confined to the package and no projection of fragments of appreciable size or range is to be expected. An external fire will not cause virtually instantaneous explosion of almost the entire contents of the package (e.g. small arms ammunition etc.).

HD 1.5

This division comprises substances with a mass explosion hazard but they are so insensitive that there is very little probability of initiation or transition from burning to detonation under conditions of normal transport (e.g. ammonium nitrate fuel and oil (ANFO), a preparation for blasting).

HD 1.6

Extremely insensitive substances and mixtures that do not have a mass explosion hazard. This division comprises articles that contain only extremely insensitive detonating substances that demonstrate a negligible probability of accidental initiation or propagation.

Both the UN scheme of classification and the Explosive Regulations 2014 recognise that many substances and articles classified as explosives do not present the same degree of hazard and subdivide them according to their potential for harm.

Throughout the rest of this document the term hazard division is used to mean all aspects of explosives, whether in manufacture, storage or transportation.

Certain explosives have to be segregated during storage and transport for safety. To allow this, each explosive is assigned to one of 13 compatibility groups. Explosives can be segregated into a group by compatibility according to well-established mixing rules, to avoid increasing the probability or magnitude of an accidental initiation.

Table 31 below lists the descriptions of the explosives that make up the various compatibility groups, and their subsequent classification codes.

Tables 31 Explosives, compability groups and classifications

Description of substance or article to be classified		
	Compatibility group	Classification code
Primary explosive substance.	A	1.1A
Article containing a primary explosive substance and not containing two or more protective features.	B	1.1B 1.2B 1.4B
Propellant explosive substance or other deflagrating explosive substance or article containing such an explosive substance.	C	1.1C 1.2C 1.3C 1.4C
Article containing a secondary detonating explosive substance without means of initiation, with propelling charge (other than one containing a flammable liquid or gel or hypergolic liquids).	E	1.1E 1.2E 1.4E

Description of substance or article to be classified		
Article containing a secondary detonating explosive substance with means of initiation, with a propelling charge (other than one containing a flammable liquid or gel or hypergolic liquids) or without a propelling charge.	F	1.1F 1.2F 1.3F 1.4F
Pyrotechnic substance or article containing a pyrotechnic substance, or article containing both an explosive substance and an illuminating, incendiary, tear or smoke producing substance (other than a water-activated article or one containing white phosphorous phosphides, a pyrophoric substance, a flammable liquid or gel, or hypergolic liquids). Article containing both an explosive substance and white phosphorous.	G H	1.1G 1.2G 1.3G 1.4G 1.2H 1.3H
Article containing both an explosive substance and a flammable liquid or gel.	J	1.1J 1.2J 1.3J
Article containing both an explosive substance and a toxic chemical agent.	K	1.2K 1.3K
Explosive substance or article containing an explosive substance and presenting a special risk (e.g. due to water activation or presence of hypergolic liquids, phosphides or a pyrophoric substance) and needing isolation of each type.	L	1.1L 1.2L 1.3L
Articles containing only extremely insensitive detonating substances.	N	1.6N

Description of substance or article to be classified		
Substance or article so packed or designed that any hazardous effects arising from accidental functioning are confined within the package unless the package has been degraded by fire, in which case all blast or projection effects are limited to the extent that they do not significantly hinder or prohibit firefighting or other emergency response efforts in the immediate vicinity of the package.	S	1.4S

Where explosives of different hazard divisions are stored together, they are treated as if they are all of the highest hazard division (e.g. 100 kg HD 1.3 and 1000 kg HD 1.4 is treated as 1,100 kg of HD 1.3). For transportation purposes, the same principle applies for substances from different hazard divisions carried together, and the vehicle should be placarded accordingly.



Road

ADR requires that, subject to some exceptions, vehicles carrying explosives should be marked with placards in accordance with the regulations.



Image 78 Warning placard for hazard division 1.1 to 1.3 and compatibility group

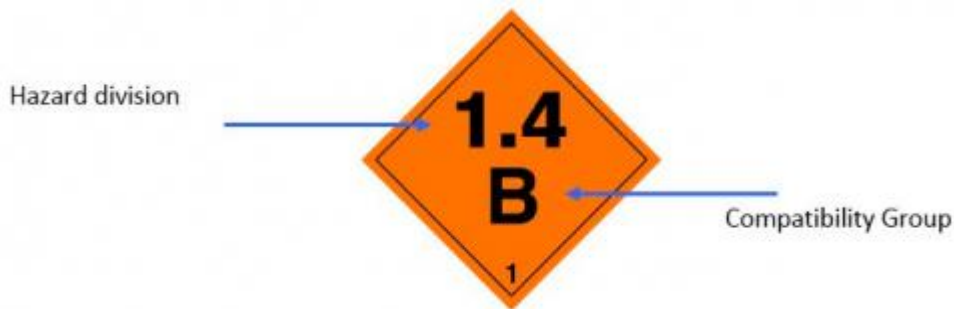


Image 79 Warning placard for division 1.4 to 1.6 and compatibility group (N.B. bomb burst pictogram not present)

Vehicles carrying larger quantities of fireworks and other hazards 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 non-placarded vehicles. Explosives could be carried illegally.

Vehicles carrying more than five tonnes of HD1.1 explosives must have a driver and attendant (if less than 5 tonnes or another HD is carried, then no attendant is required); both will have received specific training to the ADR standard that enables them to take measures for their own safety, that of the public and the environment. The vehicle crew should therefore always be consulted.

If the crew members are injured and cannot be consulted, instructions in writing should be found, in the drivers cab (if it is safe to retrieve them). These are prepared to a standard format and in a language that the driver understands, outlining the load and any special actions required.

All packages and the vehicle must be correctly identified as per the carriage regulations. The package labels and vehicle placards provide safety information for those involved in transportation and for the emergency services; placards must be displayed at all times.

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

Although small quantities of explosives maybe 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 item maybe carried on public transport, the items must remain with the person carrying them, be properly packaged and reasonable precautions must be 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 similar to those required for road transport are displayed on both sides of the wagon and on all four sides of containers.

Information in writing 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; if uninjured, crews should always be consulted.

The incident should be managed in a similar manner to a road transport incident but modified as necessary to ensure the safety of personnel working on the rail infrastructure.

Wagon labelling

The wagon label for explosives (both commercial and military) replaces the individual UN hazardous substance number with a set of four characters identifying the category of the explosive. A wagon label whose emergency code begins with the characters 1.1D would indicate an explosive of hazard division 1.1, compatibility group D, (i.e. an explosive presenting a mass explosion hazard).

Weight limitations

Only commercial explosives are covered by the Railway Group Standard GO/RT3422 (that identifies the requirements for the acceptance and carriage by rail of explosives on Network Rail); the total amount to be conveyed on any one train is limited to 36.25 tonnes.

Military explosives are covered by the Conveyance by Rail of Military Explosives Regulations 1977. The weight limits for military explosives and for mixed commercial and military loads are given in GO/RT3053.

To summarise, no more than 20 tonnes of explosives per wagon or container can be carried with a net amount of the same explosives. It is permissible to convey several groups of explosives on the same train, but subject to a separation distance of 80 metres and a limitation of 40 tonnes per group. This is applicable to groups within hazard division 1.1 and combined with 1.3 and/or 1.5. For groups within hazard divisions 1.3 and 1.5, whether carried separately or together, the separation distance reduces to 40 metres and the limit per group increases to 120 tonnes.

Tank wagons held in sidings

Railway wagons laden with explosives in transit are occasionally parked overnight in railway sidings; the working manual for rail personnel is quite specific in detailing their responsibilities where explosives are concerned. The manual places personal responsibility on the supervisor for ensuring that any wagon of explosives standing in the sidings, goods or marshalling yards is kept under surveillance by railway staff and for keeping a tally of each wagon with its location whilst in their

responsibility.

If through exceptional circumstances it becomes necessary to hold wagons containing explosives in unsupervised locations such as goods yards or sidings, on the Chief Operating Officer of Network Rail has made arrangements to ensure that Network Rail personnel responsible for the handling and conveyance of dangerous goods will inform the British Transport Police and the fire and rescue service.



Sea and inland waterways

Unless a licence has been granted, legislation prohibits, (with certain exceptions):

- Explosives being brought into or handled in a harbour
- The loading/unloading of explosives on a vessel when this occurs on any part of the coast or in the tidal waters or within the territorial waters of Great Britain

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 is to ensure that the vessel or vehicle is taken out of the harbour or harbour area as soon as is reasonably practicable unless the harbour master and, if berthed, the berth operator, agree.

The operator of any berth where explosives are being loaded/unloaded or stored shall ensure that their emergency plan is made available to the fire and rescue service.

Royal Navy vessels

All Royal Navy vessels have a liaison officer who will inform the fire and rescue service whenever the vessel is in port. Pre-arranged liaison and courtesy visits may be beneficial to any emergency planning process, especially if different types of vessels visit. On a warship, protection of the ships magazine will often be the top priority and the action taken to achieve this may appear to be contrary to fire and rescue service priorities.

Inland waterways

Fire and rescue services should contact the appropriate controlling authority for their area which is usually, but not always, the British Waterways Board for information on:

- Types of vessel (e.g. barges, small craft)

- Mooring
- Storage areas
- Emergency access points to canals and rivers

Visits should be made to the wharves and vessels for familiarisation and to liaise with the owners, masters, wharfing and berthing agents, etc. and a response plan drawn up. Although the UK has only adopted part of ADN (the European agreement concerning the international carriage of dangerous goods by inland waterways), vessels on inland waterways may well display warning signs similar to those for road and rail in line with British Waterways Board guidance. In addition, packages (unless carried for on inland waterways for their entire journey) must comply with the carriage regulations for any part of their journey by road or rail. On canals and many rivers it will often be possible to deal with the incident from the land and similar methods as those for dealing with road and rail transport can often be used.



Air

Civil aircraft; the International Air Transport Association (IATA) Dangerous Goods Regulations and International Civil Aviation Organisation (ICAO) technical instructions detail classifications that follow the UN system. Goods in HD 1.1, HD 1.2, HD 1.3 and HD 1.5 are normally forbidden.

In the event of an incident occurring (e.g. an aircraft overshooting the runway) the operator must inform the emergency services of any dangerous goods being carried. The airport fire service will usually be the first to be informed. In addition, the aircraft operator is required to ensure that a copy of the dangerous goods documentation, or the information contained in it that had been provided to the aircraft captain, is readily available at the points of departure and intended arrival.

Military aircraft: if military aircraft are involved in any incident, guidance should always be sought from the Ministry of Defence or armed services personnel, as the munitions carried will present a wide variety of hazards (e.g. high explosives, sub-munitions that arm on ejection, incendiaries and possible radiation hazards from depleted uranium ammunition).

For further information regarding transport related guidance see National Operational Guidance: [Transport](#)



International Standards

Organisation transport containers (ISO)

International standards organisation (ISO) containers are used for transporting fireworks from the port of origin to the port of disembarkation; they are also used for storing fireworks. They can be found in a number of locations, varying from designated container yards and private properties to derelict sites. A fire involving, or near an ISO container should be treated with extreme caution if information about its contents cannot be determined.

In certain conditions selected fireworks stored in ISO containers may be liable to simultaneous detonation. This could result in the fragmentation of the container. If there is a window of opportunity to prevent direct burning or thermal radiation affecting the container, every effort should be made to completely cool the container; if the container is at any risk of heating then firefighting actions should not be undertaken.

If complete cooling of ISO containers is not possible, a 600m minimum hazard zone should be put in place (this distance should be extended depending on the quantity stored on-site). This situation may arise when fireworks containing flash powder are stored. If only one of the large fireworks detonates, a shock wave could be produced that provides localised heating through the container with sufficient energy to detonate all or most of this grade of firework at the same time. This will generate high pressure that is likely to destroy the container.

Where only HD 1.4 fireworks are stored, the containers should be suitably marked but only when the container is in use. An example of such storage arrangements would be a supermarket prior to bonfire night.

Any fire involving an ISO container at any location, not just explosives sites, should be treated with caution until information on its contents is known.

At manufacturing and storage sites a large number of ISO containers may be found in close proximity (within 1m) of each other. In these circumstances it is possible for a fire involving one container to affect another.

Under no circumstances should the doors of an ISO container doors be opened, even if the fire appears to be out. The doors should not be opened for at least 24 hours and the container treated as a potential source of explosion until that time.



Storage of explosives

General storage

Where explosives are stored, it is the net explosive content (NEC) or net explosive quantity (NEQ) that is the licensable amount. The NEC is the amount of explosive in the article, not including the packaging. In the case of fireworks the NEC is assumed to be 25% of the weight of the firework but can be as high as 70%, so a store licensed for 2 tonnes NEC may actually contain 8 tonnes gross weight including packaging. Licences for storage of less than 2 tonnes NEC are issued by the appropriate licensing authority that, depending on the quantity stored and the location in the UK, can be the police service, metropolitan fire and rescue authority, local authority or, in harbour areas and mines, the Health and Safety Executive. Where lower quantities are stored then the appropriate licensing authority may issue a registration rather than a licence. For stores involving more than 2 tonnes the HSE will issue a licence.

Site recognition

Licensed sites and military establishments storing and using explosives should conform to UK legislation and regulation.



Image 80 Typical fire division signs for buildings and stacks

Licensing

A licence is required for most manufacturing or storage activities. Manufacturing includes processes where explosive articles or substances are made or assembled/ disassembled, repaired or modified. The Health and Safety Executive (HSE) is the licensing authority for all manufacturing. Depending on the quantity and type of explosives, the licensing authority for storage could be the local authority, metropolitan fire and rescue authority, police service or the HSE. There are a number of licensing exemptions for the storage of small quantities and for temporary storage; for example, there are allowances for storing limited quantities of shooters' powders, certain lower-risk pyrotechnics and articles such as flares, fog signals, car airbags and seatbelt pre-tensioners.

Unlicensed storage

During the fireworks season, fire and rescue services should be aware that they may encounter illegally-stored fireworks. Situations could include:

- Transport haulier depots
- Shops on short lets
- Warehouse or lockup storage

Planning

Identifying sites is a key element as it enables fire and rescue services to determine those sites that present the greatest potential hazard, in turn allowing fire and rescue services to prioritise each site for gathering information, pre-planning, response plans, etc.

The Manufacture and Storage of Explosives Regulations Approved Code of Practice requires that manufacturing and/or storage sites should contact the fire and rescue service, who may wish to undertake familiarisation visits to explosives sites. However, it is good practice for fire and rescue services to be proactive and not rely on the manufacture and or storage site contacting them.

The relevant licensing authority maintains a register of licensed sites and will be able to provide details.

It is estimated that there are between 20 and 30 thousand premises licensed to store explosives. The vast majority of these are shops and supermarkets are licensed for storing fireworks during the firework season. These premises are licensed either by the fire and rescue service (in the metropolitan counties and Cornwall) or by the local licensing authority.

In Scotland and Wales, for explosives not requiring an explosives certificate the enforcing authority is the local council. The fire authority may administer licensing on its behalf.

Sites storing the larger quantities of explosives are licensed by the HSE, who license about 230 sites in the UK. These sites range from manufacturers of blasting explosives and munitions through to firework importers and firework display operators.

Sites holding smaller quantities of high explosives are licensed by the police service (e.g. quarries). The police service also grants explosives certificates to private individuals holding black powder (gunpowder). This can be up to 5kg of black powder.

Fire and rescue services should contact the HSE and other licensing authorities with a view to identifying HSE-licensed sites in their areas, so that they can undertake visits to gather information. This will give them the information on the most hazardous sites in their area. A close and effective working relationship with the police service, HSE, Customs & Excise and the local authority planning and trading standards should be adopted to ensure that information about the movement, storage and use of explosives is made available to all partner organisations.

Sites owned and/or used by firework display operators store quantities of fireworks within ISO containers and as such should be treated as falling into the priority group for risk based visits/inspections. Fire and rescue services should also ensure that operational crews are reminded that explosives can be encountered at domestic homes and many retail businesses (e.g. flares stored at retail chandlers or RNLI property; shotgun cartridges in homes, etc.).

There should be effective systems for gathering information identifying the information fire and rescue services require and arrangements for updating that information at regular intervals.

Close liaison with the licensing/enforcing authority, ideally via joint site visits, will assist the fire and rescue services to:

- Establish the explosives and quantities that should be on site

- Identify the buildings, construction type and any potential and/or actual structural hazards, where they are processed or stored
- Determine that the buildings, etc. are correctly marked to identify their contents
- Determine any special conditions imposed by the site's licence
- Ensure all of the above conform with the site's licence
- Obtain other valuable information about the site (layout, water supplies, etc.)
- Obtain a copy of the site operator's emergency arrangements

Accurate, clear and up-to-date information is essential and should be gathered by the fire and rescue service through regular visits (in addition to any joint visits) supplemented by other sources, such as operational intelligence. The recommendations above represent the minimum that fire and rescue services should be considering as part of their operational tactical planning.



Ministry of Defence (MoD) sites

The safety of explosives at Ministry of Defence (MoD) sites or being transported is determined by the MoD, together with firefighting recommendations. Fire and rescue services should make themselves aware of these procedures through good liaison with the sites. Fire and rescue services may also wish to consider developing a memorandum of understanding (MoU) with MoD sites.



Response plans

Response plans should be in place for all locations where explosives may be found, including temporary arrangements (e.g. during loading/unloading of ships in harbours). The plans will be a mixture of those required by legislation and the fire and rescue service's tactical plan. The size and complexity of the plan should reflect the type of site; for example, sites categorised as top tier in the Control of Major Accident Hazard Regulations 2015 are required to have a safety case that will include an on-site plan with an integrated external emergency plan that must be prepared by the local authority.

When an incident occurs at smaller sites outside of normal working hours (e.g. retail storage of fireworks), their plan may not be readily available. Consideration should therefore be given to obtaining a copy as part of the risk based inspection/visit process.

For firefighting and search and rescue, fire and rescue services should consider:

- Safe access/egress routes within the establishment and boundary, particularly for aerial appliances and other specialised vehicles, giving consideration to available headroom, width, ground clearance, hard standing turning circles and load restrictions
- Travel distances from access points to various points in the building or around the grounds
- Details of fixed fire protection installations (ventilators, sprinklers, drenchers, fire shutters, any back-up installations, etc.)
- Safe areas where firefighting operations can be undertaken
- The locations in which to site command and control units, breathing apparatus control and special appliances to maximise the overall control of the incident
- Communication dead spots
- Water supplies, hydrants (open and tanked)
- Distances from water sources and pressure calculations
- Designated rendezvous points for initial attendance and whether these are emergency services as a whole or for fire and rescue service use only; consideration should be given to dependency on wind speed and direction and alternatives

For hazard zones, exclusion zones and evacuation distances, fire and rescue services should consider:

- Safe distances to establish notional hazard zones associated with the permitted quantity, HD, etc.
- Evacuation distances for when explosives are involved in fire

Once explosives are confirmed to be involved in a fire an exclusion zone should be set up

For further information regarding hazard zones and evacuation distances see National Operational Guidance: Physical hazards - Hazard - Explosive materials involved in fire.



Fire safety inspections

Fire and rescue services are responsible for the general fire precautions on all (except military) sites. The process of fire safety is the responsibility of the licensing authority. Therefore, due to this dual enforcement position, fire safety inspections should be joint inspections wherever possible (i.e. the fire and rescue service and the licensing authority). Under the Regulatory Reform (Fire Safety) Order, the licensing authority has a duty to consult with the fire and rescue service before a licence can be granted.

Information contained in the fire and rescue service fire safety file should therefore also be

considered when producing operational site specific plans. If, as a result of any on-site risk inspection visit, it is identified that a premises does not have a fire safety file, then the normal fire and rescue service process for information exchange should be followed.

Ministry of Defence (MOD) establishments

The Explosives, Storage and Transport Committee of the Ministry of Defence (MoD) determines the safety of explosives at any MoD site (or being transported) together with firefighting recommendations. Fire and rescue services should ensure that:

- Effective and regular liaison is maintained with MoD establishments
- They are fully aware of the emergency procedures for the establishment
- They make themselves aware of these procedures via good liaison with the sites to ensure that co-ordination with MoD personnel is arranged during pre-planning and before firefighting



Familiarisation and exercising

It is important that personnel required to attend specific explosives manufacturing and/or storage locations, are fully aware of the layout of the site and all facets of fire prevention. Personnel should undertake exercises with other emergency services responders and site personnel on a regular basis to ensure that response plans are fully understood. Training and exercising should not be constrained by time; safe and effective outcomes are the crucial factors meaning training and exercising should be as realistic as possible, with full consideration of the tasks to be undertaken and the levels of command that may be implemented. Consideration should be given to specialised equipment that may assist in an incident (e.g. high volume pumps could prove to be a valuable asset for drawing and delivering large quantities of open water).

These principles would apply to sites identified as being of high risk, but the level of detail needed will depend on the complexity of each site. Where a fire and rescue service has an arrangement in place with a neighbouring fire and rescue service, it is essential that that the service is also involved in any training and exercises that are relevant to the overall planning and response.

Technical training should also be undertaken by all personnel who may be expected to attend incidents at identified risk sites. This is particularly important for any operational/tactical managers who may have to take command at an incident. This should include an understanding of the hazards and risks associated with explosives and operational procedures.



Other hazards

Illegal fireworks

A proportion of fireworks in the UK may be stored or sold illegally such as:

- Selling door to door
- Unlicensed storage sites, which may be encountered at any time, but there is greater likelihood during the firework season
- ISO containers that have been used for storage at sites where it would not normally be expected to find fireworks
- Imported fireworks of a lower standard than legislation permits
- Importation of illegal fireworks in unexpected ways (e.g. in an ISO container whose paperwork or hazard warning placards indicates that the contents are not fireworks and 'legal')
- Theft from licensed premises

Unlawful activity at licensed sites

Although there is legislation on the manufacture, storage and transportation that requires the highest degree of care and precaution, there may be occasions when these have not been properly implemented, even at licensed sites:

- Storage areas may be incorrectly marked for the explosives held
- More explosives may be stored than the licence allows
- Explosives of a different, i.e. higher, hazard type may be stored than the licence allows
- Illegal explosives may be present, such as imported fireworks of a lower standard than legislation permits
- Separation distances may be inappropriate for the explosives held giving the potential for a quicker fire spread and mass explosion
- The on-site responsible person may provide inaccurate or misleading information about the site's contents, or they may not have the level of competency that would be expected

Fire and rescue services should be aware of these additional hazards:

- Large above- or below ground oil or gas pipelines serving the establishment, or supplying products for storage or process
- Compressed gases
- Electrical transformers, sub-stations, etc.
- Secondary blast injuries caused by projectiles from the explosion (walls, glass, etc.)

- Environmental consequences: watercourses, interceptors and plant drainage systems, etc.
- Equipment required to mitigate environmental impact

Fire and rescue services should obtain the following information from the duty holder:

- Details of the responsible person for the site and the contact details during working hours and out of hours
- Where they can get access to a current copy of the on-site plan
- Whether explosives are transported around the site and if so, how this is achieved
- Whether security regimes are employed by the duty holder (e.g. electrified fences, guard dogs, etc) that might have an impact on operational tactics
- Whether using mobile communication equipment would create a hazard
- Any technical data that gives general information on the properties and physical nature of substances

Planning arrangements should also include the development of contingency plans for a range of reasonably foreseeable events. The plans should also make provision for a pre-determined attendance (PDA) that reflects the access and facilities provided for the fire and rescue service and the type of incident likely to be encountered. They should also take into account the size of the building, the time required to gain access should this be necessary and the time required to assemble sufficient resources to undertake firefighting and search and rescue operations from the PDA and the effect that this will have on the anticipated mode of operations. The PDA should ensure that adequate resources of staff and equipment are provided to undertake initial assessment and safely effect an early response to the incident..



Ammonium nitrate based fertiliser

The chemical compound ammonium nitrate (AN), chemical formula NH_4NO_3 , is a white crystalline solid at room temperature and standard pressure. It is commonly used in agriculture as a high-nitrogen fertiliser, but it has also been used as an oxidising agent in explosives, including improvised explosive devices. It is the main component of ammonium nitrate fuel and oil mixtures (ANFO), which is a very powerful blasting explosive.

The type of ammonium nitrate fertiliser can be identified from information on the label or safety data sheets supplied with the product. The different types of ammonium nitrate fertiliser are:

- Straight ammonium nitrate fertiliser, which contains ammonium nitrate to provide the essential element nitrogen, although it may also contain fillers such as ground limestone, calcium sulphate, ground dolomite, magnesium sulphate or kieserite
- Compound fertiliser, which contains ammonium nitrate mixed with potash and/or phosphate

to supply the essential elements nitrogen, phosphorus and potassium; this is sometimes referred to as NPK fertiliser.

- Cigar burners, which can sustain a decomposition even when the fire has been extinguished. They are normally compound fertilisers that contain between 5% and 25% nitrogen from ammonium nitrate, up to 20% phosphate and chloride (which may only be present as a small percentage). However, a fertiliser that meets this description is not necessarily a cigar burner.

All fertilisers fall into one of three categories:

- Oxidisers belonging to Class 5.1, UN Number 2067
- NPK/NP/NK fertilisers capable of self-sustaining decomposition belonging to Class 9, UN Number 2071
- Non-hazardous

AN-based fertilisers are of two main types:

- Straight nitrogen fertilisers: these products contain only nitrogen (N) as the principal plant nutrient. Typical products are Ammonium Nitrate (AN) and Calcium Ammonium Nitrate (CAN), which are mixtures of AN and dolomite/limestone/calcium carbonate, and Ammonium Sulphate/Ammonium Nitrate (ASN) mixtures.
- Compound fertilisers: NPK/NP/NK. These products contain, in addition to nitrogen, at least one other nutrient such as phosphate (a source of P_2O_5) and/or potash (a source of K_2O).

The main methods of handling are:

- Packaged in intermediate bulk containers of 500-1500kg capacity
- 25 or 50kg bags
- On pallets with up to 1.5 tonne load
- Loose bulk.

Hazards

The three main potential hazards of relevance to ammonium nitrate (AN)-based fertilisers are:

Fire

Ammonium nitrate itself does not burn, but is an oxidising substance and as such can support combustion. Combustible material must therefore be present for a fire involving ammonium nitrate (AN).

In a fire, all types of ammonium nitrate may melt and decompose with the release of toxic fumes (mainly oxides of nitrogen) that may be white, yellow or brown. Most types do not continue to decompose once the fire has been extinguished. However, when some types of AN fertilisers (cigar burners) are heated they undergo a smouldering (self-sustaining) decomposition that can spread throughout the mass to give substantial toxic fumes, even when the initial heat source is removed. Anyone suffering the effects of inhalation of toxic fumes should be removed to a safe shaded area where they should be kept warm and rested, ideally lying down.

Decomposition

Ammonium nitrate melts at around 170°C and decomposes between 200 and 260°C. Ammonium nitrate (AN)-based fertilisers can chemically break down under the influence of heat. The presence of a combustible substance is not necessary for decomposition to take place. The decomposition hazard depends on the type of product, the temperature of the heat source, the duration of exposure to the heat source and the containment of the fertiliser.

When heated, AN decomposes into gases including oxygen (non-explosive reaction); however, AN can be induced to decompose explosively by detonation.

Large stockpiles of the material can be a major fire risk as they support oxidation and may also detonate.

AN decomposes in temperatures normally above 200°C. However the presence of impurities (organic and/or inorganic) will often reduce the temperature point when heat is being generated.

Once the AN has started to decompose a runaway reaction will normally occur as the heat of decomposition is very large. AN produces so much heat that this runaway reaction is not normally possible to stop. This is a well-known hazard with some types of NPK fertilisers.

Certain compositions of compound fertilisers (NPK/NP/NK) are capable of undergoing self-sustaining decomposition (i.e. once a hot source, such as a hot electric light bulb or hot welding material has initiated the decomposition, the reaction in the fertiliser is sufficiently thermally energetic to continue on its own without further heat input from any outside source). Such fertilisers are described as self-sustaining decomposition (SSD) type.

The decomposition hazard in straight nitrogen (N) fertilisers such as AN, CAN, ASN and in non-SSD type compound fertilisers (NPK, NP, NK) depends on contamination with sensitising materials such as chromates, chlorinated chemicals and various metals such as zinc and copper and their salts.

Decomposition is generally accompanied by the emission of toxic gases such as NO_x, ammonia, hydrogen chloride and nitric acid vapours.

Explosion

Ammonium nitrate (AN) will not explode due to the friction and impact found in normal handling, but it can be detonated under heat and confinement or severe shock. For example, in a fire, pools of molten AN may be formed and if the molten mass becomes confined (e.g. in drains, pipes, plant or machinery) it could explode, particularly if it becomes contaminated with combustible materials such as grease or oil.

Self-confinement (i.e. the weight of the material itself compressing and confining the material at the bottom of a pile or stack) of straight AN in large stacks can increase the risk of a detonation of the whole stack in a fire. For this reason regulations limit stacks of AN-based fertilisers (fertilisers with more than 28% nitrogen) to a maximum of 300 tonnes.

AN and AN-based fertilisers can only detonate under certain conditions, requiring a strong source

of initiation. Standard good quality fertiliser products have high resistance to denotation. However, this resistance can be adversely affected by a number of factors, such as:

- Substantially smaller particle size
- Higher porosity (hence a lower bulk density)
- High levels (above safe limits) of combustible, organic and other sensitising materials



Gases under pressure

Gases under pressure

Recognition and classification

UN Class 2 - classification



Image 81 Gases are recognised by their containers, warning symbols and their behaviour

In the system of hazard classification devised by the United Nations Sub-Committee of Experts on the Transport of Dangerous Goods (UNSCETDG) the following classes are directly associated with gases:

Class 2.1 – Flammable gases

Class 2.2 – Non-flammable, non-toxic gases

Class 2.3 – Toxic gases

For compressed gases, primary identification is by means of the shoulder label with the name and chemical formula, an example is shown in image 82 below.

CLASS 2 – Gases



Flammable gases

Non-flammable,
non-toxic gases



Toxic gases

Image 82 Class 2 gases

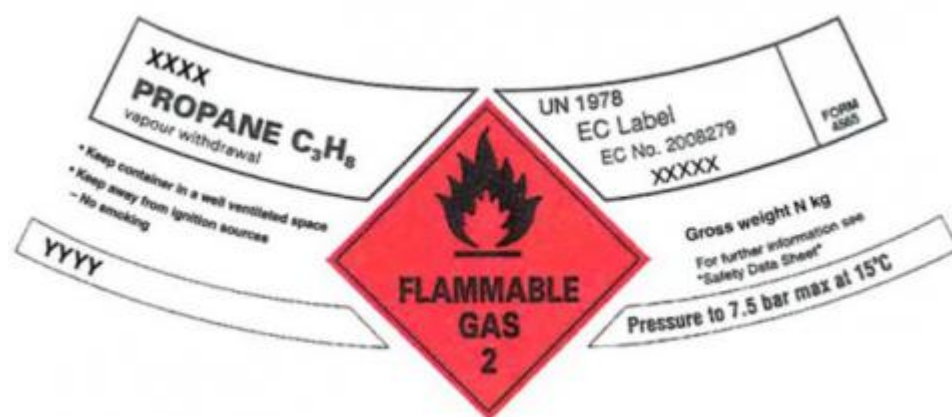






Image 83 Shoulder label for cylinders with the name and chemical formula


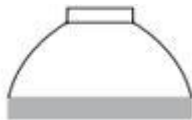

Secondary identification is by cylinder shoulder colour. Unless otherwise specified, gas and gas mixtures can be identified by a colour classification indicating gas properties in accordance with the risk diamond on the cylinder label, for example:





Table 32 Cylinder secondary identification - gas properties

Gas type	Colour	
Inert	Bright green	
Oxidising	Light blue	
Flammable	Red	
Toxic and/or corrosive	Yellow	

A number of the most common gases have been assigned a specific colour. The specific colours assigned to the common gases are shown below. The full scheme is contained in BS EN 1089-3: 1997, which although not mandatory is being adopted by the British Compressed Gas Association (BCGA) member companies. Fire and rescue service responders should be aware that body colours below the shoulder of a cylinder are not specified and may vary according to the gas company.

Table 33 Cylinder secondary identification – common gases

Gas type	Chemical symbol	Colour	
Acetylene	C_2H_2	Maroon	
Oxygen	O_2	White	
Nitrous oxide	N_2O	Blue	
Argon	Ar	Dark green	

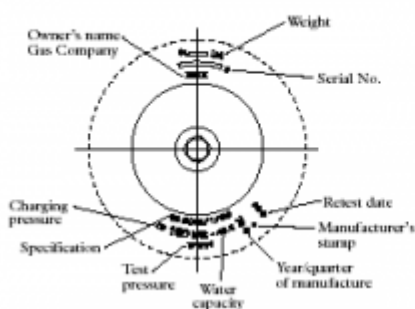
Gas type	Chemical symbol	Colour	
Nitrogen	N ₂	Black	
Carbon Dioxide	CO ₂	Grey	
Helium	He	Brown	
Air or synthetic air	O ₂ ≤ 23.5%	Bright green	



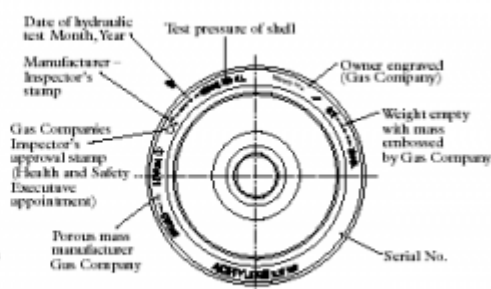
Cylinder identification marks

There are stamp markings on the cylinder shoulder, which may also help to identify the contents of a cylinder and the owner. Image 84 below shows typical markings on cylinder necks. The name of the industrial gas company will be stamped on the cylinder. This will allow fire and rescue services to identify the cylinder owner. For acetylene cylinders, the word acetylene is stamped onto the neck.

Common compressed gas cylinder markings



Acetylene cylinder markings



For guidance regarding gases under pressure see National Operational Guidance: Physical hazards
- Gases under pressure involved in fire (e.g. potential BLEVE).



Transportation and packaging

General

The transportation of gases at ordinary temperatures and pressures is not a practical or economically viable option due to the size of containers that would be required. Viable storage and transport options rely on cooling, applying pressure and dissolving gases. The favoured option is to use pressure to liquefy a gas but for every gas there is a critical temperature above which it can not be liquefied in this way.

Gases below their critical temperatures are called vapours and can be liquefied by applying pressure so they can be transported or stored as liquids at ambient temperature. When a pressurised liquid is warmed it will exert the critical pressure on its container at the critical temperature.

Table 34 Critical nature of common gases

Critical temperatures of common gases			
Name	Critical temperature (°C)	Critical pressure (bar)	Boiling point (°C)
Ammonia	132	112.8	-33
Butane	152	38	-1
Chlorine	144	77	-34
Propane	97	97	-42
Sulphur dioxide	158	79	-10
Argon	-122	49	-10

Critical temperatures of common gases			
Oxygen	-119	49.6	-183
Nitrogen	-147	34	-196
Hydrogen	-240	13	-252
Helium	-268	2.3	-269

Gases that have a critical temperature below ambient temperature can be stored or transported as compressed gases at ambient temperatures in small quantities, but when bulk quantities are required they are usually cooled below their critical temperature, pressurised and transported as a refrigerated or cryogenic liquid.

Carbon dioxide (CO₂) can be encountered as a solid, liquid or gas. The critical temperature of CO₂ is a little over 31°C so for most of the year, when encountered in small quantities (as in the case of fire extinguishers), it will be a pressurised liquid but on a hot day it may be a gas. Small quantities of carbon dioxide can also be encountered as a solid used as a refrigerant called dry ice, which does not melt but turns into a gas as it warms up. This process by which a solid does not melt but turns directly into a gas as it warms is known as sublimation. Bulk CO₂ is transported as a refrigerated pressurised liquid.

Acetylene is different from other gases in that it can decompose into its constituent elements of carbon and hydrogen in the absence of air. This is an exothermic reaction (an exothermic reaction is one that gives off heat). 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 alone to a cold cylinder cannot initiate decomposition.

Road

Appropriate options for storing and transporting gases are set out in the ADR, which is enacted into UK law by the carriage of dangerous goods regulations.

In this system a hazard identification number (HIN) consists of two or three figures (e.g. a HIN of 2 indicates a hazard of emissions of gas due to pressure or to chemical reaction). Examples of HIN numbers relating to gases can be found in ADR hazard identification numbers (HIN) or Kemler Code.

Storage

Gases are stored in cylinders, cryogenic vessels or tanks. Hazardous gases can also be generated on-site.



Cylinders

Gases are stored in cylinders either as a compressed or liquefied gas or dissolved in a solvent (e.g. acetylene dissolved in acetone). Cylinders are subject to rigorous type testing to ensure that they are fit for purpose and are tested to 1½ times their working pressure. Some cylinders are equipped with safety devices which are designed to relieve pressure by venting gas if the cylinder heats up.

Great care is needed during the transportation, handling, storage and disposal of such cylinders.

Cylinders exist in the following construction types:

- Welded: two steel halves welded together around the centre
- Drawn steel: a single steel skin containing no weld
- Aluminium: lighter in weight than steel cylinders and used to contain specialist gases
- Composite: a woven jacket impregnated with resin and protected by a hardened plastic outer cage. This type of cylinder is mainly used for LPG but can be found with various contents. Occasionally, these cylinders can have an aluminium lining.

The cylinder construction provides little or no indication of the cylinder contents but may alter the actions required to deal with them when involved in fire, particularly composite cylinders.



Cylinder failure

All pressurised cylinders, regardless of their contents, are at the greatest risk of failure when being subjected to direct flame contact:

- Metal cylinders will begin to lose tensile strength as the shell is heated; in composite cylinders heating will also break down the resin (although steel loses approximately 50% of its strength at about 5500 C, rising gas pressure may overcome reducing steel tensile strength at about

300 °C)

- All cylinders ultimately fail because the shell reaches a point where its tensile strength weakens to such a degree (or in the case of composite cylinders the resin breaks down) that it can no longer contain the internal pressure being exerted by the gas). Acetylene is a special case as it can undergo a self-sustaining internal decomposition reaction producing heat, which may continue after the fire has been extinguished

Liquefied gases are generally of two types:

- High pressure (e.g. carbon dioxide, ethane)
- Low pressure (e.g. liquefied petroleum gas)

As the cylinder heats up in the fire, the liquefied gas absorbs some of the heat and produces more vapour, increasing the pressure in the cylinder. This will normally result in the operation of a safety relief device fitted to the cylinder valve that relieves the excess gas pressure. If the cylinder wall becomes excessively heated, the effective maximum working pressure of it is reduced and the cylinder may fail catastrophically.

Cylinders failing under heat may result in a boiling liquid expanding vapour explosion (BLEVE). This is where the boiling liquid in the cylinder rapidly vaporises and expands explosively, bursting the cylinder. If the gas released is flammable and contacts a source of ignition this could result in a fireball.

Planning

Fire and rescue services should collect and maintain information on the location and type of hazardous gases within their area. This information should be readily available to operational responders at an incident. It is important that emergency plans are developed in partnership with compressed gas site operators and should include safe rendezvous points and significant site-specific risks.

Because foreign acetylene cylinders may be imported into the UK, it is essential to 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, risk information, visual information (e.g. a cylinder connected to an oxygen cylinder or strapped to a welding trolley). The incident commander should contact the cylinder owner by telephone for specialist advice and consider asking for the attendance of a specialist at the scene, although there has to be good visibility for the attendance to be productive.

If non-acetylene cylinders have been heated but not damaged they should be cooled, or allowed to cool and then handed-over to the site operator who should be fully advised of the circumstances. In a developing fire situation cooling and carefully moving non-acetylene cylinders should be considered if there is an imminent risk that the fire will spread and involve them.

This check list can assist in risk assessment:

- Does the cylinder show signs of heat damage or direct flame contact?
- Is there any obvious fire damage to any structure or material near to the cylinders?
- Do the cylinders appear to be scorched?
- Are the labels burnt?
- Are the plastic guard or test rings melted?
- Is the cylinder paintwork burnt or blistered?
- Does the cylinder surface steam or dry out quickly when water is applied?
- Have eye witnesses seen flame impingement, etc.?
- Is there any visible bulge in the cylinder?
- Are pressure relief devices operating (the operation of a pressure relief disc or fusible plug through a fire situation indicates an increased likelihood of catastrophic failure and should not be regarded as a sign of safety)?

Because of the very high internal pressure, flammable gases such as hydrogen or methane will rapidly expand explosively following a cylinder rupture. This could actually extinguish the fire by blasting it out, but could also result in a delayed ignition of the unconfined gas cloud.

Initial crews discovering cylinders should make every effort to identify the type, contents, location and number of any cylinders involved, without exposing themselves to unnecessary risk. This will determine the appropriate course of action. In particular, crews should attempt to identify whether the cylinders contain acetylene.

Cylinder cooling

As soon as a cylinder is discovered at a fire the incident commander should, regardless of the contents, make every effort to extinguish any fire affecting the cylinder and apply cooling sprays directly on to any affected cylinders.

It is important to cool cylinders quickly with water if they have been heated in a fire. This applies to cylinders suffering direct flame contact and also those affected by radiant heat. Diagram 4 below details the process to be adopted for cylinder cooling.

Firefighters carrying out this task should continually risk assess the situation and take advantage of all available substantial shielding or cover. They should consider using ground monitors and lashed jets where severe or prolonged heating has taken place and should always wear appropriate personal protective equipment.

If firefighters encounter cylinders that have been fully involved in a severe fire for an unknown period of time they should treat them with extreme caution and adopt defensive tactics.

Where a cylinder is alight at the valve group, it should be ascertained whether or not it is alight around the cylinder neck (from the base of the valve group where it enters the cylinder) or from where the hoses attach to the valve group itself. A risk assessment needs to be carried out to identify whether the cylinder can be safely turned off. Where the cylinder is alight at the neck (i.e. the base of the valve group) this indicates that the valve group or cylinder neck is damaged and may not be able to be shut off.

In most cases, non-acetylene metal cylinders that have not failed can be made safe by cooling with water. Internal pressure will be reduced as heat is removed from the cylinder and a heat- or pressure-weakened cylinder shell will recover most or all of its original strength as it is cooled. Once water has been applied and the cylinder wall temperature reduced, the cylinder is very unlikely to fail. Consideration should then be given to reducing the hazard zone.

Support from a gas industry competent person

A support network has been established between fire and rescue services and the British Compressed Gas Association (BCGA), the trade association for all the major cylinder companies. During an incident involving cylinders, it is important to identify the gas company that owns the cylinder. This will enable it to provide assistance in identifying the contents of the cylinder and provide support to manage the incident effectively. The owner of the cylinder can be identified in a number of ways:

- Via the owner of the premises by asking for the name of the gas supplier
- From the cylinder label if it is possible to get close enough safely
- By inspecting the label on other cylinders in safe locations elsewhere on the premises.

The table below shows the 24-hour telephone numbers of the main gas cylinder companies:

Table 35 24 hour telephone contact details for main gas cylinder companies

The four main gas cylinder companies	
Company	Contact
Air products	0500 02 02 02
BOC	0800 111 333
Energas	01482 329 333
Air Liquide	01675 462 695

British Compressed Gas Association competent persons (CPs) are designated personnel from the various cylinder companies who have passed a training course specialising in the subject of acetylene cylinders in fires. The CP would normally only be requested to attend difficult or protracted incidents. The CP is able to offer telephone advice to the incident commander on the numbers and types of cylinders delivered to the premises and to support the decision making process.

It is not the role of the CP to instruct the incident commander on actions to be carried out. The incident commander, in liaison with the hazardous materials adviser should advise the CP of the situation, the actions that have been taken and proposed further actions.

The CP can also make arrangements to have cylinders collected at the end of an incident. However,

there is usually no need for this. The owner or manager of the premises should be advised that the CP will arrange subsequent collection of the cylinder during office hours. It should also be noted that to meet ADR requirements the company needs to identify and label the cylinder before transport.

In a situation where a composite cylinder is involved in direct flame contact but is not leaking, the fire can be extinguished and the cylinder cooled. However, caution should be exercised when considering moving the cylinder as the resin may have become weakened to the extent that it may begin to leak when handled. In these situations it is better to leave the cylinder in place and consult a hazardous materials adviser or product specialist.

The fire and rescue service response to incidents involving gas cylinders should be based on the following procedural flow chart. If there is doubt about the contents of a cylinder affected by heat or fire, it should be treated as an acetylene cylinder until a positive identification can be made.

Notification of the Health and Safety Executive (HSE)

The HSE should be informed whenever cylinders or pressure vessels have exploded.



Acetylene

Acetylene has the following properties:

Table 36 Acetylene properties

Flash point	-17°C
Vapor density	0.91 (Acetylene is slightly lighter than air)
Boiling point	-85°C
Flammable limits	2.5% to 100% (N.B. for practical purposes, if it has leaked it will mix with air and should be presumed to be present in an explosive mixture)
Critical temperature	36°C
Storage pressure	15.5 bar at 15 °C

Odour	Naturally odourless, but industrial acetylene smells of garlic due to impurities
Colour	Industrial grade acetylene is colourless

Acetylene gas poses an additional hazard to other flammable gases as it is also reactive. Under certain conditions, even in the absence of any air or oxygen, it can decompose explosively into its constituent elements, carbon and hydrogen

Acetylene is soluble in many organic liquids, especially acetone which is the most common solvent used in acetylene storage.



Acetylene cylinder identification

It should be easy to distinguish between LPG and other cylinders (including acetylene) on the basis of their shape (see photos).

To distinguish positively between acetylene and other non-LPG cylinders is more difficult when they have been subjected to a fire. If in doubt, treat the cylinder as though it is an acetylene cylinder, until a positive identification can be made.

When cylinders are not affected by fire they can be identified by their label, colour (acetylene cylinders are maroon) or by their markings. In addition, the cylinder industry now marks acetylene cylinders with or a ; absence of these identifiers does not confirm that the gas contained is not acetylene.

Decomposition

Acetylene is distinguished from other flammable gases by its ability to continue to 'self-heat' after a fire has been extinguished. When involved in a fire, acetylene can begin to decompose. The decomposition reaction is exothermic – it produces heat. As the heat increases, the pressure within the cylinder increases, as hydrogen gas forms.

Acetylene cylinders are designed to contain and inhibit decomposition; however, if they are left unchecked decomposition could lead to the failure of the cylinder. This means that unlike other fuel

gases, **acetylene may continue to be a hazard after the fire has been extinguished and requires specific operational procedures.**

However, only a high heat source such as direct flame contact can initiate decomposition.

Cold Shock

Mechanical shock alone to a cold cylinder cannot initiate decomposition.



Image 85 Propane gas cylinders



Image 86 Acetylene gas cylinders



Image 87 Acetylene cylinder identification



Image 88 Acetylene cylinder shoulder label

Acetylene cylinders (sometimes referred to as dissolved acetylene (DA) cylinders) differ from other compressed gas cylinders in that they contain a filler material, known as a porous mass, usually monolithic in form. They also contain a solvent, typically acetone, that is absorbed by the mass. The acetylene dissolves into the acetone and is held by it in a stable condition. The porous mass evenly distributes the acetone throughout the cylinder and prevents the presence of large internal voids. The porous mass or filler used for new cylinders is a monolithic mass poured in as slurry and baked in an oven to form a porous solid. Older cylinders may have a granular filler. The materials used for the mass or filler include:

- Lime/silica/asbestos
- Fibreglass/lime/silica
- Charcoal/kieselghur.

Cylinders containing granular-type fillers are still in use but are less common. These can suffer from settlement problems that can allow free acetylene gas to collect at the head of the cylinder, with consequential implications should a decomposition reaction occur. However, gas suppliers carry out regular inspections and maintenance to minimise this risk.

Monolithic mass-type fillers are not prone to settlement problems and investigative research on cylinders that have been subject to mechanical damage shows that the monolithic mass is extremely resilient and does not readily split or separate from cylinder walls.

Gas companies are aware of ways in which both mass-types can be adversely affected and routinely check for such problems at each re-fill.

At the top of an acetylene cylinder, just below the valve assembly, there is a small cylindrical 'gas space' hollowed out of the porous mass, which is subsequently plugged with gauze or felt. The gas space is typically around 2cm diameter and 5cm deep. It allows free dissolution of acetylene from its carrier solvent to feed free gas out through the valve assembly for use (see image below).



Image 89 Cross section through an acetylene cylinder showing the 'gas space'

Due to atmospheric pressure, the acetone will still contain a quantity of dissolved acetylene even though the gauge reads zero and the cylinder is normally considered to be empty (e.g. a large cylinder could contain up to 500 litres of acetylene). Therefore, an empty cylinder is still a potential hazard in a fire.

Historically, some acetylene cylinders were fitted with pressure relief devices such as fusible plugs or bursting discs designed to release the gas if the temperature or pressure rose excessively. In general, steel-welded-type cylinders were fitted with two fusible plugs in the shoulder of the cylinder, whilst those drawn from solid ingots were fitted with bursting discs, usually in the valve group. Some older cylinders with fusible plugs in the base may still be in circulation. The effectiveness of these devices was tested by the Health and Safety Laboratory and found to offer no significant contribution to safety. The operation of the pressure relief device allows gas (ignited or un-ignited) to leak from the heated cylinder, increasing the risk of a cylinder exploding or further feeding the fire. The main reason that pressure relief devices are ineffective is that they cannot vent gas generated by decomposition fast enough. They can also cause fresh acetylene to be drawn into a hot spot and feed the reaction and any leaking gas can form a cloud around the cylinder. Such pressure relief devices are, therefore, no longer fitted to new cylinders, and are being removed from older cylinders.

Cylinders are designed to suppress decomposition and to self-extinguish it if it does occur. The porous mass contains thousands of small pores, which act as a stabiliser by dividing acetylene into small units. If decomposition were to occur, the mass would absorb heat to the stage where decomposition can no longer continue. This enables the cylinders to withstand most flashbacks and non-severe heating.

At realistic fill pressures, acetylene has to reach a temperature of approximately 300°C to initiate decomposition. This can be caused by a flashback from welding or cutting equipment (if the flashback arrester is missing or faulty), or by exposure to intense heat. The latter is only usually

achieved by direct contact of flames on a cylinder.

Type approval testing of acetylene cylinders has shown that the porous mass does contain and effectively snuff out decomposition. However, mechanical impact or shock to a heated acetylene cylinder could cause it to burst and must be avoided. Therefore acetylene cylinders exposed to severe heat in a fire should not be approached or moved until after they have been cooled and checked to ensure that decomposition is not occurring.

Re-development of heat at the cylinder surface is a good indicator of a decomposition reaction; the wetting test or thermal imaging equipment is recommended to check the temperature of the cylinder shell.

N.B. an acetylene cylinder that has been heated and is also leaking presents an extra hazard; fresh acetylene may be drawn through the internal mass of the cylinder and if a decomposition reaction is taking place may provide additional fuel for the reaction and promote the potential for catastrophic failure.

Acetylene cylinders are normally used in conjunction with oxygen cylinders, thereby increasing the potential hazard.

The following information is specific to incidents involving acetylene cylinders and supplements the general guidance on gas cylinders.

Pre-planning

Fire and rescue services should liaise with local police, the Health and Safety Executive (HSE), Environment Agency, acetylene cylinder suppliers, users, Highways Agency, Network Rail and other local authority agencies that will be affected by this type of incident. Liaison will ensure:

- A possible reduction in the number of acetylene cylinder incidents
- All parties involved understand the implications of such an incident
- The safe and effective management of the incident
- The safe and effective handover of affected cylinders.

Types of premises likely to contain acetylene cylinders should be identified as part of an ongoing risk management plan.

Fire and rescue services need to have systems that support operational staff in dealing with incidents involving acetylene cylinders. It is vital that crews rehearse the safe systems of work described to develop relevant task management skills along with knowledge and understanding.



Acetylene cylinder procedure

Due to the risk of decomposition occurring within acetylene cylinders after any fire has been extinguished, specific operational procedures are required for acetylene incidents.

The flow chart below includes guidelines to assist in deciding if a cylinder has been involved in a fire that has caused decomposition. A common example, where a cylinder operator damages a hose, should not always be considered sufficient to initiate decomposition, provided any flames from the damaged hose are extinguished in a timely fashion.

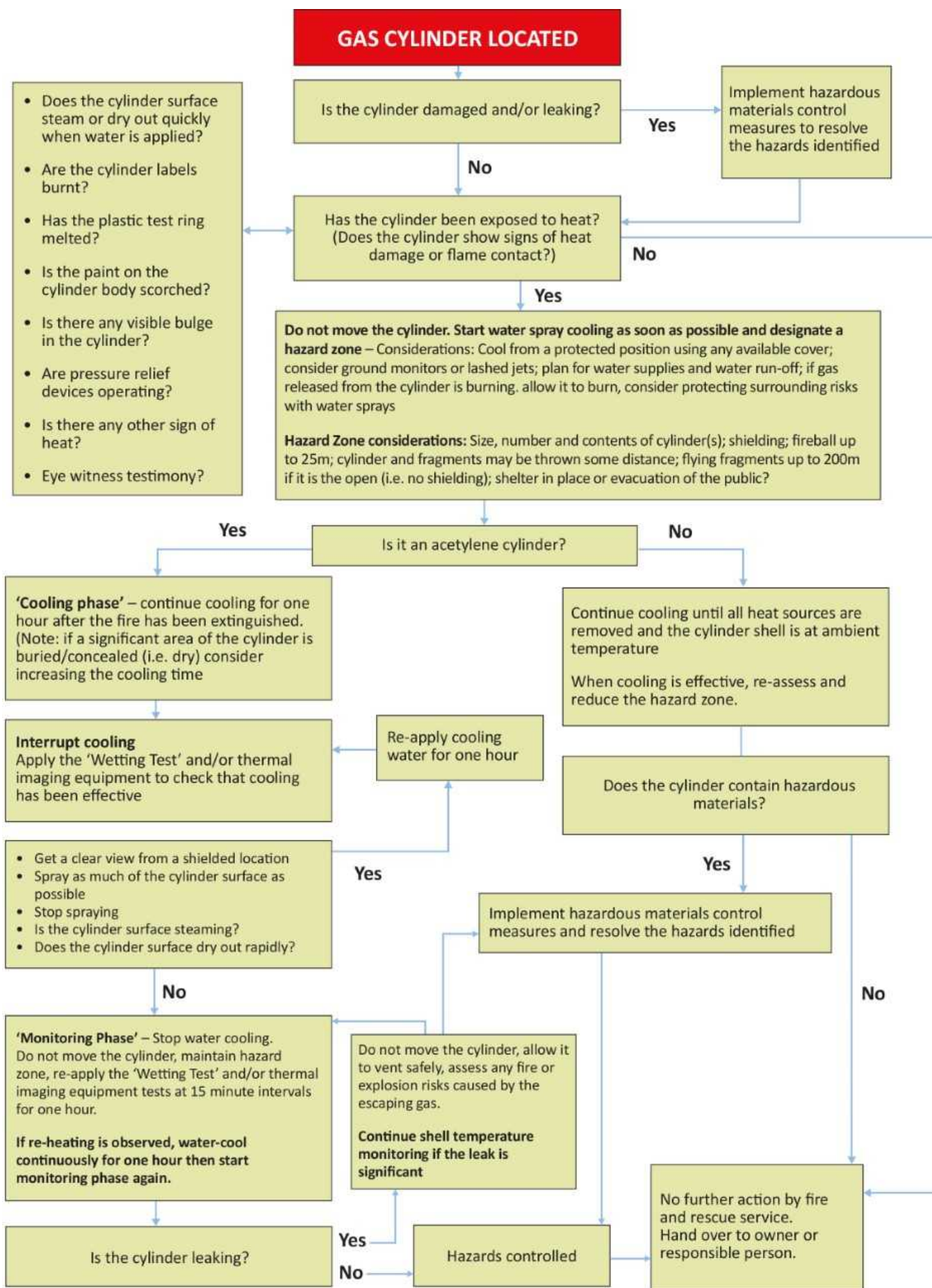


Diagram 4 Gas cylinder cooling process

Does the cylinder show signs of heat damage, flash-back or direct flame contact?

It is important to assess whether the cylinder has been sufficiently heat affected for decomposition to be initiated. It requires a significant temperature increase (i.e. above 3000C) and this is normally only achieved by direct flame contact on a cylinder.

Signs that can be used to detect possible heating:

- A visible bulge in the shell: the cylinder should be treated with extreme caution as this indicates a greatly increased likelihood of catastrophic failure
- Burnt cylinder labels
- Melting of the plastic rings around the cylinder valve
- Burnt or blistered cylinder paintwork
- The cylinder surface steams or dries out quickly when water is applied
- Pressure relief devices are operating, if fitted (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 provide information to enable the incident commander to confirm:

- Whether a cylinder has suffered direct flame contact, and if so, for how long
- The severity and duration of any heating of a cylinder
- Whether a flash back, and not a backfire (i.e. a single cracking or 'popping' sound) has occurred.

A flash back might be accompanied by a shrill hissing sound. A flash back occurs when the flame travels back through the hoses into the body of the cylinder. This may be caused by user error or poorly maintained or faulty equipment. Flash back arrestors fitted to the hoses will detect and stop reverse gas flow, preventing a flammable oxygen and acetylene mixture from forming in the hose.

Flashback arrestors are mandated under DSEAR in the UK and are designed to prevent a flashback. The arrestor is an automatic flame trap device designed not only to quench the flame but also to prevent the flame from reaching the regulator. N.B. extra care should be taken with illegally imported cylinders that may not have flashback arrestors.

Flash backs into acetylene cylinders, which may initiate decomposition, are generally due to the failure to fit a flame arrestor.

Where cylinders are in the proximity of a fire but show no signs of direct heating (see list above), they are likely to be safe to move. However, before doing so the temperature of the cylinder walls should be checked by spraying with water and seeing whether they remain wet or they should be examined using thermal imaging equipment. Personnel must be made aware of the manual handling problems associated with moving an unheated cylinder to a safe location. Acetylene cylinders are comparatively heavy in relation to other cylinders and are awkward to carry, especially when wet.

Do not move the cylinder in the cooling phase. Designate a hazard zone. Apply cooling water from a shielded location as soon as possible. Continue cooling for one hour after the fire has been extinguished.

If a decomposing cylinder is leaking or is moved, the rate of decomposition and heat generated may be increased to such an extent that the cylinder walls are weakened abnormally and rupture. Greater safety can be achieved if the decomposition process is slowed or arrested by water spray cooling.

Water cooling is currently the most effective method of preventing failure of an acetylene cylinder and should be used whenever it can be implemented without compromising the safety of firefighters (e.g. where protection is offered by suitable shielding).

The period of greatest risk is when the cylinder shell is hot, so every effort should be made to cool it comprehensively, taking full advantage of any available substantial shielding/cover and using ground monitors and/or lashed jets.

Applying water will result in the cylinder shell cooling quickly. This in turn will slow down any internal decomposition process inside the cylinder. As a consequence of this, and after carrying out a risk assessment, the incident commander (in liaison with the hazardous materials adviser (HMA), could reduce the initial cordon distance in favour of a risk-assessed hazard zone.

- Considerations when determining the hazard zone include:
- Size of cylinder(s)
- Number of cylinders
- Shielding provided by any buildings or structures
- Type and extent of adjacent structures
- Local topography (e.g. protection provided by slopes and gradients of ground levels, etc.)
- Effect of the potential blast pressure wave
- Effect of a potential fireball (of up to 25 metres)*
- Effect of the cylinder being thrown (up to 150 metres)*
- Flying fragments and other projectiles (e.g. valve assembly, which may be thrown up to 200 metres).*
- * The steel used to make acetylene cylinders is heat-treated to ensure that when cylinders do fail, they do so in ductile mode rather than as brittle failure. Many merely split open, releasing the gas contents, but if they explode the typical result is into three or four large pieces that may have high looping trajectories
- Flying glass and other structural material
- Structural damage to buildings in the vicinity
- Possible need for an exclusion zone within the hazard zone
- 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 shielding and therefore reduce the distances projectiles could travel).

Consideration should always be given to using any substantial portable materials that might offer shielding between the cylinder(s) and associated risk points (e.g. a public highway, railway or other thoroughfare), to reduce the hazard zone. This might be possible where such materials are palletted and can easily be moved into place without subjecting the operative to any undue risk. It may be necessary when cylinders cannot be water cooled, for example, due to their location within a

dangerous structure.

There may be circumstances where attempts to apply water would expose firefighters to unacceptable levels of risk that outweigh the benefit likely to be gained. At such incidents the alternative would be to leave the cylinder in place without applying water until it bursts or all sources of heating are removed. Remotely operated vehicles have been used at cylinder incidents to assist the incident commander in monitoring the condition, degree of heat damage and temperature of cylinders.

Consider contacting the gas supplier for advice

During an incident involving acetylene cylinders it is important to identify the gas supplier that owns the cylinder. This will enable the gas company to provide assistance in identifying the contents of the cylinder and to provide any help required to manage the incident effectively.

When contacting the relevant gas supplier the following information should be given:

- The fire and rescue service that is attending and the name of the caller
- The address of the incident and the premise name if applicable
- The advice required. (i.e. telephone support or on-site support)
- Number of cylinders involved and whether collection will be required
- If on-site attendance is required:
 - Map references and directions
 - Confirmation that the police service at the outer cordon are aware that cylinder supplier's representative is attending

The gas supplier will then pass the call on to the competent person. As all the companies are different in size, and therefore have different levels of resource, the way in which the first call is dealt with may vary but the technical advice offered will be standard across all companies.

If the incident commander would like on-site assistance this will be arranged by the competent person. However, before requesting a site visit certain questions need to be considered, such as:

- Is acetylene definitely involved? If unsure, the incident commander should try to gather as much information as possible from the site occupier and from the competent person over the telephone. If still unable to determine whether acetylene is definitely involved, a site visit may be required.
- Is the cylinder visible? If it is covered in debris or behind other shielding and cannot be seen, the attendance of the competent person will be unlikely to add value to the decision making process
- Is there adequate lighting for the competent person to see the cylinder/s involved clearly? If not it would be best to advise the competent person not to arrive on site until after first light.

Attendance on site by competent persons should be managed in daylight hours where at all possible unless the incident involves severe disruption such as closing major arterial routes.

The competent person will be able to help with identification and if necessary assist with providing

guidance for the wetting test (see below). They can also arrange for the cylinder(s) to be removed at the conclusion of the incident. The incident commander can discuss all relevant issues with the competent person, police service, local authority and any other relevant organisations in attendance, to make an informed decision on whether to maintain or reduce the initial hazard zone.

Applying the wetting test and/or using thermal imaging equipment to check that cooling has been effective

Decomposition of the acetylene contained within a cylinder may take place after the external heat source has been removed if there has been sufficient transfer of energy to start the reaction. Once started, decomposition will continue until all of the acetylene is consumed or until the cylinder is effectively cooled and made safe. Acetylene cylinders are designed and tested to withstand such decomposition and can cool naturally without any problem. The porous mass is designed to assist in this. Cooling will slow the reaction and allow it to self-extinguish.

It is therefore important to be able to identify if an acetylene cylinder is hot or becoming hotter by itself. This can be achieved by carrying out a wetting test and/or using thermal imaging equipment.

Testing may be performed immediately on discovering cylinders that may have been exposed to heat, or during the cooling process for cylinders known to have undergone heating.

Testing establishes and confirms:

- Whether the cylinder shell is cool
- That acetylene is not undergoing internal decomposition (a number of successful tests spread over at least one hour should be observed)

This procedure will ensure that, in the highly unlikely event of internal decomposition occurring deep within the cylinder's filler, any heat build up will be noticed externally before it can reach temperatures likely to weaken the cylinder shell or cause dangerous internal pressures.

When externally cool, the cylinder should be safe to approach as long as no gas is leaking but it must not be moved in case there is a large internal cavity due to damage to the porous mass. Movement of the cylinder may accelerate decomposition and result in catastrophic failure, hence the importance of continuing to apply wetting tests for at least one hour after a perceived test pass has been observed.

The wetting test involves:

- Getting a clear view of the cylinders from a shielded location
- Briefly spraying water on to the cylinder surface
- Stopping spraying and looking for signs of steam rising from the surface of the cylinder
- If steam is not seen rising, checking to see whether the wetted cylinder surface dries out quickly (i.e. 1-2 minutes). During the combustion process, tars and oils may be released and deposited on the cylinder surfaces; this may make the drying out part of the test difficult to interpret due to the reaction between oil and water

If either check is failed then water cooling must be reapplied for one hour before testing again. If both tests are passed then the monitoring phase should start.

Using thermal imaging equipment and remote temperature measuring equipment gives additional confidence and should be used whenever possible.

Monitoring phase:

- Stop water cooling
- Do not move the cylinder
- Maintain hazard zone
- Reapply the wetting test and/or thermal image equipment tests at 15-minute intervals for one hour.

If any unexplainable re-heating is observed water cool continuously for one hour then start the monitoring phase again.

Water cooling must be completely stopped during the monitoring phase to allow any internal heating to show itself by raising the temperature of the exterior of the cylinder shell. Testing should be carried out at 15-minute intervals so that any heat build up through decomposition will be noticed before it can reach a dangerous temperature. A written record of the test results should be maintained throughout the monitoring phase.

Effective water cooling may reduce the cylinder temperature down to the temperature of the cooling water, which may be lower than the ambient temperature. This means that during the monitoring phase, when no water is being used to cool the cylinder its temperature may rise slowly and naturally to its ambient temperature. The incident commander should take care not to misinterpret this rise in temperature as the result of internal decomposition.

The natural heating effect of direct sunlight on dark coloured or blackened cylinders will also result in a rise in the cylinder shell temperature that is not attributable to decomposition. If in doubt the incident commander should extend the monitoring phase or, if the temperature rises significantly above ambient/expected levels (i.e. enough to fail the wetting test), recommence water cooling for at least one hour.

An appropriate, risk-assessed hazard zone should be maintained throughout the monitoring phase as in the unlikely event that re-heating of the cylinder takes place, it may be difficult to quickly reintroduce cooling phase cordons due to staffing levels and adverse public reaction.

If any re-heating above ambient cylinder temperature (either steaming or rapid drying out) is observed at any of the wetting tests then the cylinder must be continuously water cooled for a further hour. After this period the wetting test and/or testing with thermal image equipment should be carried out again. If no re-heating has occurred the full monitoring phase procedure should also be started again (i.e. stop water cooling and carry out wetting tests at 15-minute intervals for one hour).

Failure of the cylinder occurs because the cylinder has reached temperatures of over 300oC and

the cylinder walls are losing their tensile strength. Cylinders at temperatures close to 300oC will cause water to violently boil off, as seen when red hot metal is plunged into cold water. The failure of the wetting test due to a hotspot does not imply that the cylinder is at immediate risk of failure unless there is an extremely violent reaction.

Is the cylinder leaking?

The monitoring phase will have established that the cylinder shell has been effectively cooled from its original temperature and, more importantly, that any decomposition reaction has stopped. However, If there is still any low-level decomposition within the cylinder then this will be fuelled and potentially accelerated if fresh acetylene passes through the area (i.e. if a leak pulls gas across the decomposition zone). The leak would need to be serious to stimulate rapid decomposition. A leak such as this would be seen from a melted fusible plug (if a fusible plug is present) or a massive release from the valve. The porous mass should be adequate to self-extinguish in the event of small leaks. If decomposition is fuelled, then the cylinder will heat up. This heating will then be detectable as the shell of the cylinder shows signs of heat once again. If there is a significant leak the incident commander should consider re-establishing the monitoring phase (i.e. cylinder shell temperature checks at 15-minute intervals for a further hour).

Leaking acetylene gas may also cause an additional fire and/or explosion hazard if it is confined around the leaking cylinder. This risk needs to be assessed and managed by the fire and rescue service.

No further action by fire and rescue service, hand over to owner or responsible person

Heat-damaged cylinders are not the responsibility of the fire and rescue service. Once the fire and explosion risk has been dealt with the site and cylinder(s) should be handed over to the responsible person, owner or operator. The incident commander should give a full brief to the responsible person, detailing the action taken and reasons why. If the cylinders are not at a premises but on public land, the incident commander should contact the local authority or Highways Agency as appropriate.

Multiple cylinders (or substantially concealed single cylinders)

Where multiple cylinders are encountered and they are very closely packed and/or concealed/buried by debris, there may be a risk that the cooling water may not come into contact with a substantial proportion of the cylinder shell, therefore limiting the effect of cooling.

If the incident commander considers that a significant area of any cylinder is dry then the cooling phase should be extended (e.g. if 50% of a cylinder is not being touched by cooling water then consider increasing the cooling phase to three hours).

In extreme circumstances, where the vast majority of a cylinder is concealed or buried and is believed to be dry, the incident commander should consider increasing both the cooling phase and the monitoring phase



Liquefied petroleum gas (LPG)

Characteristics

This section provides a brief overview of LPG.

Many hydrocarbons exist as gases at normal atmospheric temperatures but they can be liquefied under moderate pressure. As the liquids occupy only about 1/250th of the space they would occupy if they were stored as gases, from a commercial point of view, it is more practicable to store and convey the hydrocarbons as liquids.

Liquefied petroleum gas may be stored as a liquid either at ambient temperature under its own vapour pressure or in a refrigerated condition at a lower pressure. If the temperature of the storage is sufficiently low, the LPG may be stored at atmospheric pressure.

Table 37 Properties of Propane and Butane

	Propane	Butane
Specific gravity of liquid (water = 1)	0.5	0.5
Density of gas (air = 1)	1.5	2.0
Vapour pressure of 15°C	7 bars	2 bars
Boiling point of liquid	-42°C	-0.5°C
Flammability range in air	2% to 10%	1.5% to 9%
Critical temperature	97°C	152°C
Expansion ratio liquid to vapour	274	233

Given that LPG vapour is heavier than air, it will flow along the ground and into drains, etc., sinking to low levels. In still air conditions any accumulation of vapour will take some time to disperse. This means that a flammable mixture might become ignited some distance from the point of leakage with the flame travelling back to that point.

LPG is colourless, odourless, and has anaesthetic properties. For this reason LPG is usually odorised to enable detection by smell down to one fifth of the lower limit of flammability (i.e., approximately 0.4% gas in air). In some circumstances, however, the odorant would not be used.

Escaping LPG can also be recognised by its cooling effect on the surrounding air, causing condensation and freezing of water vapour in the air, showing as frost at the point of leakage. Because of this consequent lowering of temperature, LPG can cause severe frost burns to the skin.



Boiling liquid expanding vapour explosion (BLEVE)

When pressurised containers (road/rail tanker storage vessels) are heated without adequate cooling, a boiling liquid expanding vapour explosion (BLEVE) could occur. This is usually a result of an external fire heating a vessel containing a flammable liquid. The contents of the vessel are heated above their boiling point and the pressure in the vessel increases. Failure occurs when the flames impinge on an area that does not have liquid on the other side. As the liquid is heated and boils it absorbs heat; it is generally when the liquid has boiled away from the area of impingement the vessel wall will be weakened. The vessel ruptures and pieces can be propelled considerable distances. Where the material is flammable, the spillage of the overheated liquids and then their ignition can create a large fireball with explosion pressure effects. This can mean that it is extremely difficult to predict if, and when, a BLEVE will occur. A vessel that is venting in a fire does not mean that everything is safe, more than likely the opposite is the case. A BLEVE can occur at any time; some have occurred many hours into an incident.

As the pressure in the vessel rises, the pressure relief valve (PRV) will operate, intermittently at first as it attempts to relieve the pressure in the vessel. As the pressure in the vessel rises further, the PRV will operate for longer periods with shorter intervals in between.

There is usually a closing window of opportunity for a vessel to be restored to a safe condition by applying cooling water to the dry wall. Eventually the PRV will operate continuously in an attempt to relieve the rising pressure in the vessel. Continuous operation of the pressure relief valve should be seen as a dangerous precursor to BLEVE.

A vapour cloud explosion (VCE) is an event where a flammable cloud of fuel/air burns in free space, generating shock waves with the flame front accelerating from a low initial velocity to sonic velocity. One of the main differences with this type of explosion is that the explosion centre may be a substantial distance from the incident (up to 5Km) due to cloud drift, possibly creating significant additional problems for firefighters.

Table 38 Calculations of fireball diameters for containers of differing size

Vessel volume (m ³)	Diameter or fireball (m)	Duration of fireball (sec)
1600	520	29
270	300	18
180	260	16
55	170	12
45	160	11
35	150	11



Bulk flammable gas firefighting considerations

Only in the case of small leaks that have ignited and posed a contact hazard may flames be extinguished with dry agent before freeze-sealing techniques are applied.

Evacuation of the surrounding area should be considered a priority as debris may be projected over 1km from the fire site.

If it is decided to attack the fire immediate massive cooling should be applied, paying particular attention to dry wall areas. This cooling is also important in securing adequate time to evacuate the danger zone.

- Responders should be fully briefed on the potential danger of the situation.
- The incident commander should exercise strict control and supervision over crews involved.
- Ground monitors or lashed jets/branches should be employed as early into the incident as possible.
- Employing water bottoming techniques should be considered if specialist advice is available.
- Flame bending should be considered to prevent flame contact on pressurised containers.
- Reduction of tank inventory may hasten the onset of a BLEVE due to the increase in dry wall area as the tank is emptied.

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

If a BLEVE occurs, the ground flash can exceed the size of the arising fireball with the attendant risk to crews.

Unignited leaks

The primary considerations are the size of the leak, wind strength and direction, and the potential for vapour cloud ignition.

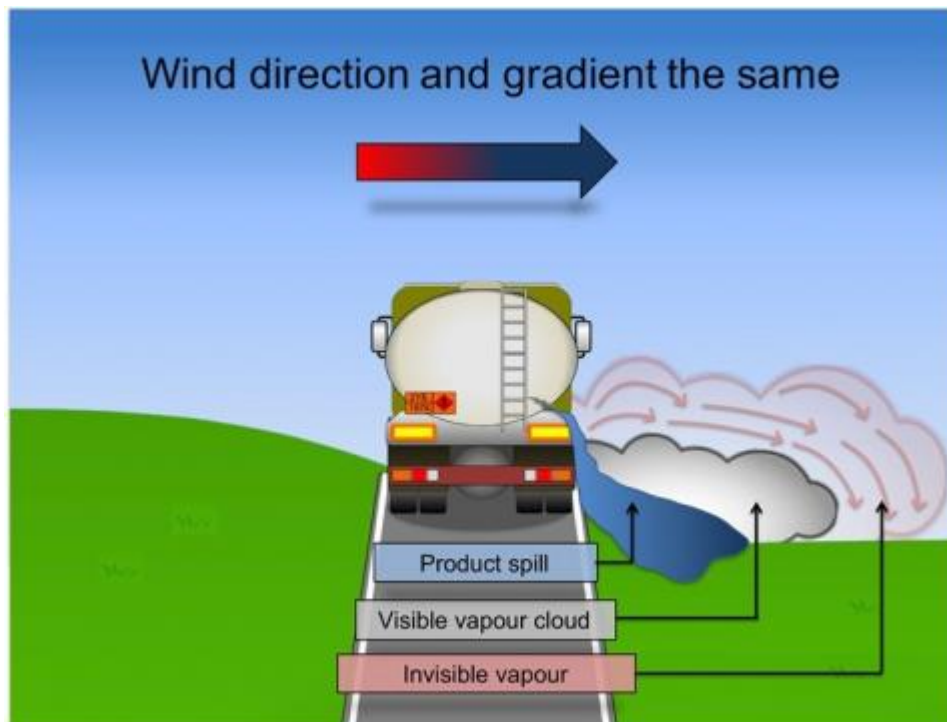


Image 91 Unignited leak considerations – wind direction and gradient the same

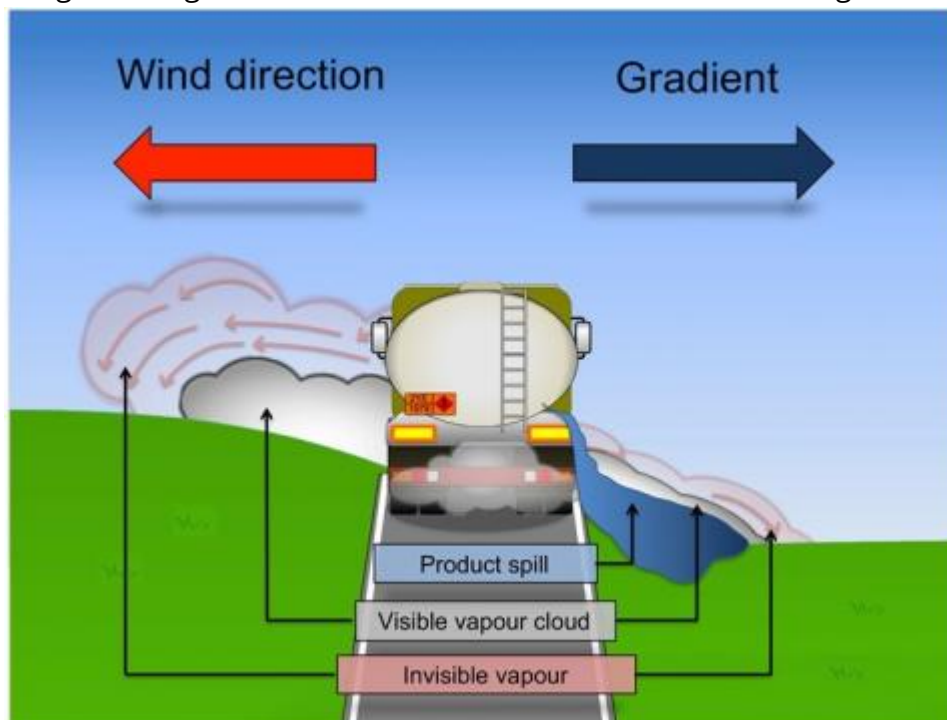


Image 92 Unignited leak considerations – differing wind direction and gradient

Elimination of ignition sources

Consider vapour containment and dispersal by using fog branches or monitors, flat fan or other ground sprays to form a barrier to movement of vapour clouds and to reduce the gas concentration to below the LEL by the entrainment of air.

Vapour clouds can be controlled by water sprays/walls but applying water to liquid spills will increase the rate of vaporisation.

Meters should be used to determine the effectiveness of procedures. They operate on the principle of resistance proportional to heat: a wire within the meter is heated; when flammable vapours entering the meter burn in the presence of the hot wire, resistance is increased which gives the reading. A flashback arrestor is installed in the device to avoid the meter igniting the vapour outside of the device.

The detection readings of an LEL meter are only accurate if the vapour being sampled has the same characteristics and response as the calibration gas. Most LEL meters are calibrated to methane.

Responders should only enter a vapour cloud in exceptional circumstances such as to carry out rescues or attempt to stem the leak. Even then, they should wear structural firefighting PPE (including flash/fire-hoods), breathing apparatus and be provided with the protection of heavy water spray or fog coverage. If necessary, the crew providing this cover should be similarly protected.

Pools of LPG should be covered by medium/high-density foam to reduce gassing-off.

The hazard area should be strictly controlled to prevent inadvertent entry to area of danger.

Possible accumulations of gas at low levels should be considered (e.g. in basements, drain and water courses).

Water injection into storage vessels (water bottoming)

If the escape of burning fuel is from an outlet near the base of the vessel and the installation includes a fire brigade inlet, water may be gently introduced into the vessel to lift the liquid above the outlet, which will extinguish the fire at this point and allow staff to approach the vessel to carry out the necessary actions to stem the flow of liquid.

However, extreme caution should be exercised when using this method, particularly to ensure that only sufficient water pressure is used to lift the vessel's contents above the outlet. If such precautions are not observed, liquid fuel could be forced out of the safety relief valves in the top of the vessel

This technique must not be used for refrigerated containers under any circumstances because the water will freeze and the refrigerated liquid will boil, with potentially catastrophic consequences.

Specialist advice is imperative prior to pumping water into a vessel to ensure that other dangers are not introduced. These include overpressure in the vessel due to admission of water in excessive quantities or at excessive rates, and freezing of leaking valves, etc., where evaporation of LPG will cause cooling below the freezing point of water, ice could form and melt later, resulting in possible

undetected leakage.



Flammable hazards

Liquefied natural gas (LNG)

When natural gas is cooled to a temperature of approximately -160°C it condenses to a liquid called liquefied natural gas (LNG).

LNG is odourless, colourless, non-corrosive and non toxic, it vaporises rapidly to form a highly flammable gas when mixed with air. It is not explosive in its liquid state; its vapour can explode when mixed with air in the right proportions.

Table 39 Liquefied natural gas main physical properties

Liquefied natural gas properties	
Boiling point	-161°C
Specific gravity of liquid (water = 1)	0.42
Flammability range in air	5% to 15%
Expansion ratio liquid to vapour	1/600

Hazards

Accidental leakage of liquefied natural gas will boil (vaporise), instantly gaining heat from its surrounding area:

LNG will ignite easily at very low concentrations in air (5% to 15%), edges of gas cloud are the most likely to find an ignition source, causing rapid burn back towards the evaporating liquid

LNG is 83-99% methane; when ignited, it generates vast quantities of heat radiation quickly (twice the heat from the equivalent quantity of petrol)

Bulk storage of LNG poses a severe cryogenic hazard.

High concentrations of LNG may cause oxygen deficiency and asphyxiation; whilst not toxic, LNG vapours can cause asphyxiation by displacing the air necessary to support life

LNG will react explosively with chlorine and bromine at room temperature

LNG may explode on contact with chlorine trifluoride



Flammable liquids

In addition to posing the threat of fire, most of these materials also present a health hazard for the worker or emergency responder. When dealing with flammable liquids it is safe to assume that they possess more than one hazard; this section deals only with those that directly influence fire hazards.

Characteristics and classification

Under GHS and UN, flammable liquids covers substances and articles that:

- Are liquids at 20°C and at a pressure of 101.3 kPa, with a melting point or initial melting point of 20°C or less at a pressure of 101.3 kPa
- At 50°C have a vapour pressure of not more than 300 KPa
- Have a flash point of not more than 60°C

This group also contains:

- Liquid substances and molten solid substances with a flash point of more than 60°C that are carried or handed over for carriage whilst heated at temperatures equal to or higher than their flash point
- Liquid desensitised explosives, which are explosive substances that are dissolved or suspended in water or other liquid substances to form an homogeneous liquid mixture to suppress their explosive properties



Image 93 UN class 3 hazard symbol for flammable liquids



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 allows the evolution of vapour and the potential size of the ignitable plume or fire. Additionally, any fire that results from a large quantity of liquid can be deeper and 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 hazards they bring will be increased above those anticipated at an open area where dispersion is possible. Toxic, flammable/explosion hazards are increased by confinement.

Pressure

Apart from the 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 is allowed to escape. Increased vapour will increase toxicity and flammability hazards. Additionally, reactions of gaseous materials are often promoted by the application of pressure.

Incompatible materials.

Some materials, especially oxidising 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

The common belief that absorbing hazardous materials makes them safer is not entirely true. Many adsorbers can act as a wick and enable materials to be ignitable below their documented flashpoints.

Location

Proximity to human or animals, property, sensitive or protected habitat will increase the risk that

any loss will be significant.

Topography and metrology

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



Factors that decrease fire risks from flammable liquids

Quantity

Decreased quantities means smaller potential surface area of any spill and fires of shorter duration.

Cooling

As flammable liquids are cooled they become less reactive and less volatile to produce less vapour.

Surface area

The smaller the surface area the less vapour will be produced; a small, deep spill will last longer than a large, shallow one of the same volume (quantity of material) but will have a smaller vapour hazard surrounding it and thus is less likely to come into contact with an ignition source.

Foam blankets

An appropriate foam can put a barrier between the flammable liquid and 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 fire growth if an ignition does take place.

Ventilation

Good ventilation can assist in dispersing flammable vapours to minimise the size of any ignitable plumes. By providing an easy path for the escape of any gases heated by an ignition, the risk of explosion is reduced.

Pressure

Adjusting pressure to match the ambient pressure decreases the hazard by reducing the strain on mechanical features, reducing the potential to explode, implode or eject the contents.

Inerting agents

By replacing the air with a gas that does not support combustion, the risk of fire can be greatly reduced or eliminated.

Absorbers and adsorbers

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.

Location

Locations remote from risk to life, property or vulnerable habitat decrease the likelihood of significant damage should ignition occur.

Topography and metrology

Strong winds can disperse vapours and gases, rain can dissolve soluble gases (washing them out of the atmosphere) and promote mixing/dilution of any vapour plume. Spills can collect in depressions in the ground to limit spread and surface area.

It is well known in the petrochemical industry that trickling leaks forming a deep pool into a bund from the base of a tank are less likely to form an explosive or flammable vapour cloud. A gushing leak from the top side of a tank or tanker where splashing, cascading and fragmentation of the liquid stream followed by rapid spreading over a large surface area and pipework will contribute to mechanically assisted vapour cloud production and accelerate the formation of an explosive or flammable vapour cloud (Note that bund walls and tarmac surfaces heated by the sun may be significantly hotter than ambient air temperature).



Substance directly involved in fire

Dealing with a flammable liquid directly involved in fire is relatively simple but hazardous. Incident commanders should consider:

- For small fires, CO₂ or dry powder may be effective media
- Not applying water to burning flammable liquid fires unless a full assessment of its physical properties has been made, as a dangerous, violent reaction, boil-over or slop-over may occur
- For larger fires, using normal foam, alcohol resistant foam or fine spray is usually appropriate; these should be applied from a safe distance, preferably using fixed monitors. Foam should be applied gently where possible using spray techniques. Care must be

exercised to avoid surface disturbance and spreading the burning liquid

Total quantity of foam solution required = application rate x application time x liquid surface area

Total amount of foam concentrate required = Total foam solution x foam concentration / 100

Generally, large scale foam attacks should not be started until all resources, including foam concentrate, are available on-site.

Whilst efforts will be made to extinguish the fire, the surrounding risks may well be a priority.

Spill fires can be most difficult to deal with, especially when being fed by a storage tank or pressurised pipeline. The source of the leak should be identified and isolated as soon as possible.

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 flowing burning liquid will flow beneath it and be extinguished.

Beware of fires involving tanks and containers of flammable liquids as over-pressurisation and explosion may occur. Cool any affected containers with water spray.

Beware flammable liquids entering drains, sewerage systems and other confined spaces where it may vaporise and cause explosive atmospheres.



Flammable solids

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 included can exhibit special risks. This section highlights some of the more important problems associated with these hazardous materials.

Characteristics, classification and hazards



Image 94 Division 4.1: Flammable solids, self-reactive substances and desensitized explosives

This division includes:

- Desensitized explosives such as those wetted with sufficient water, alcohol, or plasticiser to suppress explosive properties (e.g. UN 1356 trinitrotoluene (TNT), wetted with not less than 30 per cent water by mass or UN 3319 nitroglycerine mixture desensitised, solid)
- Readily combustible solids that may cause a fire through friction, such as matches (e.g. UN 1331 matches strike anywhere or UN 1327 hay, straw or bhusa or UN 2000 celluloid)
- Self-reactive materials that thermally unstable and can undergo a strongly exothermic (heat-evolving) decomposition even without the presence of oxygen (air). Certain exclusions apply, such as when the material meets the definition of an explosive, oxidiser or organic peroxide; in these cases they will be classified under that group.



Image 95 Division 4.2: Substances liable to spontaneous combustion

These are substances (solids and liquids) that are liable to spontaneous heating under normal conditions encountered in transport, or to heating up in contact with air, and being then liable to catch fire.

Spontaneously combustible materials include:

- Pyrophoric (literally, 'fire-loving') materials are materials (solids and liquids) that can ignite with no external ignition source within five minutes of coming in contact with air (e.g. UN 1854 barium alloys, pyrophoric)
- Self-heating materials are those that exhibit spontaneous ignition or heat themselves to a temperature of 200°C during a 24-hour test period in the presence of air but in the absence of an energy supply; this behaviour is called spontaneous combustion (e.g. UN 2002 celluloid)

Generic advice on dealing with these materials is contained in data sources such as Chemdata or the Emergency Response Guidebook (ERG).

Other considerations

A range of factors influence whether solids are included in hazard division 4.1 or 4.2, including those included here.

Normally it is the vapours produced from liquids or solids that burn, not the actual materials themselves. In practical terms, solids rarely produce enough vapours at ordinary temperatures to be ignitable; naphthalene and camphor are 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.

Similarly, the shape and surface area of solids also affects the ignition temperature. For example, it is considerably more difficult to ignite a bar of metal where the access of oxygen in the air to the metal surface is limited and heat is rapidly spread throughout the bulk of the solid, than to ignite a similar weight of finely divided metal dust where the access of oxygen is much increased and the ability of the metal particles to lose heat quickly is reduced (i.e. the particles heat up more quickly than the bar of metal); should the dust be confined in any way then the ignition process may give way to a deflagration reaction.

Some elements can exist in different structural forms called allotropes; graphite and diamond are allotropes of carbon. All allotropes contain exactly the same atoms of the element, but as the atoms are bonded together in different ways they have different properties. Graphite and diamond are chemically inert except at very high temperatures; pure graphite and oxygen will not react until about 700 °C. Amorphous forms of carbon (i.e. forms of carbon that can have varying structures) are much more reactive than their allotropic forms. Coal, coke, charcoal and animal charcoal are examples of amorphous forms of carbon that will burn readily provided they are suitably activated.

Phosphorus is another example of an allotropic element and exists as:

- White phosphorus (or yellow phosphorus)
- Red phosphorus
- Black phosphorus (extremely rare)

White phosphorus is toxic and in air fumes will readily ignite at relatively low temperatures (~30 °C); it is normally stored under water. Due to its reactivity with air (oxygen), it is normally classified as a UN hazard division 4.2 material. Red phosphorus, on the other hand, is of low toxicity, only ignites at about 260 °C and does not need to be stored under water because of its low reactivity with air (oxygen). In industry, red phosphorus is used in the manufacture of matches, phosphate fertilisers and insecticides; it is also used in the illegal production of methamphetamine.



Image 96 Division 4.3: Substances that when in contact with water emit flammable gases

These are substances (solids and liquids) that, by interaction with water, are liable to become spontaneously flammable or to give off flammable gases in dangerous quantities.

Examples include:

- Aluminium phosphide (liberates phosphine gas)
- Calcium carbide (liberates acetylene on contact with water)
- Sodium

Health hazards

It is relatively easy to reduce exposure to flammable solids as a group, unless they are reacting. The primary hazard is inhalation of dusts and finely divided powders, as they are easily inhaled. Some dusts, such as sodium metal, react with the moisture in lungs to form a caustic solution that burns sensitive tissues.

The mixture of some metallic dusts with moisture on the body may result in chemical burns. It is imperative to avoid all clouds of smoke as they may include toxic by-products of the burning metal.

Most flammable solids can be handled easily unless they are on fire or otherwise reacting in some fashion.

Flammable solids should not be allowed to mix with other materials unless the resulting reaction is certain.

Some flammable solids are very active chemically, so great care must be taken to ensure compatibility with other stored materials and their containers.

Some solid spills can be covered with a heavy plastic sheet to minimise dust blowing around or water contact from rain.

Regardless of the material involved, water should not be added until satisfied the situation will not worsen.

One exception to using flammable solids is contamination through skin contact. In such cases, it is usually best to brush off as much powder as possible followed by applying large amounts of water to reduce tissue damage and prohibit the creation of a toxic paste on the casualty's body.

Beware of dust explosions. Increasing the surface area of a combustible solid enhances the ease of ignition. This means that dust burns more rapidly than the corresponding bulk solid. In some ways, particles behave similar to gas and a flammable dust and air mixture can form within certain limits. A dust explosion occurs when the suspended dust particles are ignited. Dust explosions are relatively rare but can involve an enormous energy release.



Oxidising hazards

Oxidising agents are not compatible with fuels due to the potential for a reaction to occur, igniting the fuel when the two substances are mixed. Normally oxygen (from the air) is the main oxidising agent in combustion reactions but other materials can possess a similar behaviour.

The term oxidation has several levels of meaning:

Combination with oxygen

At the simplest level, oxidation may be defined as combination with oxygen. Most oxidation processes of practical importance are exothermic; many take place slowly (e.g. rusting iron) but if heat is produced quickly, the process is a typical combustion process.

Combination with any supporter of combustion

In a wider sense, oxidation may be defined as combination with any supporter of combustion. For example, when heated magnesium is placed into a jar of oxygen gas, it burns with a brilliant white light and produces dense clouds of white smoke; exactly the same things are observed when heated magnesium is placed into a jar of chlorine gas. Both reactions are considered oxidation processes, as is combination with any supporter of combustion.

Oxidising agents

Oxidising agents may be defined in two ways, in parallel with the two definitions of oxidation:

- Substances that supply oxygen to another substance
- Substances that supply any supporter of combustion to another substance

Substances that supply oxygen to another substance are the most relevant to a fireground situation, since most combustion processes involve rapid combination with oxygen. However, large quantities of other supporters of combustion (particularly chlorine, but also fluorine and bromine) may be encountered in the chemical industry, so an awareness of oxidation in the sense of the second definition is also very important.

Classification of oxidising agents

Two criteria must apply to oxidising agents that supply oxygen to another substance:

- They must contain some oxygen
- They must be able to supply this oxygen to another substance

Many substances fulfil the first criterion, (e.g. oxygen itself oxides, as does any compound with a name ending in -ite or -ate) but, of these, only a limited number fulfil the second.

Thus, although sodium chlorate (NaClO_3), is a powerful oxidising agent, calcium carbonate (CaCO_3) and calcium sulphate (CaSO_4) are not, because although they contain at least as much oxygen as sodium chlorate, they do not easily give up this oxygen to another substance.

Identification

Fire hazards of oxidising agents

The fire hazards presented by oxidising agents depend on whether they come into the category of inorganic or organic oxidising agent.

Inorganic oxidising agents



Image 97 Division 5.1 Oxidising substances other than organic peroxides

These are the most commonly encountered oxidising agents.

In terms of the fire triangle, these materials belong not to the fuel side of the triangle but to the supporter of combustion side.

These substances are non-flammable, even though some of them (such as sodium chlorate and, particularly, ammonium nitrate) may decompose explosively when heated, especially if present in large quantities in a confined space.

The main problems arise when inorganic oxidising agents come into contact with combustible materials, thus putting two sides of the fire triangle together:

The oxidising agent oxidises the fuel. This process is exothermic, generating heat so that the temperature rises. This accelerates the oxidation process, producing more heat, raising the temperature more, and the process accelerates further. Eventually sufficient heat is generated to raise the fuel to its ignition temperature, and it begins to burn. Spontaneous combustion often happens when fuels are allowed to come into contact with oxidising agents. Sometimes the combustion occurs almost immediately (e.g. highly concentrated hydrogen peroxide in contact with wood) sometimes after a short delay (e.g. glycerol in contact with potassium permanganate) and sometimes after a prolonged period (e.g. rags soaked in linseed oil in contact with atmospheric oxygen).

Many fuel and oxidising agent combinations appear to be free from the spontaneous combustion hazard. However, problems still arise when the fuel becomes ignited, perhaps by contact with an ignition source; the combustion no longer depends on the limited availability of oxygen from the surrounding air because the oxidising agent ensures the presence of available oxygen in a concentrated form. The fuel will burn much more fiercely than would otherwise be the case. This

situation could arise if cellulosic material, such as a wooden floor or shelves, becomes impregnated with an oxidising agent, such as sodium nitrate or even concentrated nitric acid.

Fuels and oxidising agents should be stored in such a way that accidental contact between them is not possible.

Organic oxidising agents



Image 98 Division 5.2 Organic peroxides

The main class of materials under this heading consists of organic peroxides, widely used as catalysts in the manufacture of plastics. Typical examples are dibenzoyl peroxide (DBP) and methyl ethyl ketone peroxide (MEKP).

These substances are particularly hazardous because as well as being oxidising agents, their organic nature ensures that they can also burn, unlike inorganic oxidising agents. Therefore, two sides of the fire triangle are already present in an organic peroxide; the input of only a little energy may complete the triangle, and the peroxide will burn very fiercely, possibly explosively (particularly in a confined space).

The extra energy may be supplied as heat; organic peroxides possess a self-accelerating decomposition temperature (SADT), above which the decomposition proceeds spontaneously. The SADT for both DBP and MEKP is over 50°C, but for some organic peroxides it is so low that they must be stored under refrigeration.

If warmed, organic peroxides are also likely to become sensitive to heat, shock and friction.

These substances are so hazardous in the pure state that the safest way to store and handle them is to dilute them with a chemically inert material, and they are normally encountered in this form. For example, DBP can be obtained as a 50% paste with phthalate plasticizer or with water, or as a 50% powder, mixed with an inert powder; even in these forms, the material may burn very fiercely when ignited.

Other hazards of oxidising agents include:

- Toxicity: many concentrated oxidising agents are corrosive towards living tissue, such as the skin and, especially, the eyes; they may also be toxic for additional reasons
- Water reactivity: many oxidising agents do not react with water and may safely be diluted

(e.g. hydrogen peroxide); others are violently water-reactive. For example, sodium peroxide reacts rapidly with water, producing hydrogen peroxide and considerable heat. If sodium peroxide in contact with cotton wool is wetted, the cotton wool immediately ignites and burns fiercely. Other peroxides formed from reactive metals behave similarly.

It is essential to understand fully the potential hazards that oxidising agents present at an incident. fire and rescue services should particularly consider:

- That these agents can be extremely unpredictable.
- The possibility of sudden container failure (for example, peracetic acid will detonate if its concentration rises above 56%; this can happen when a container has been incorrectly stored, allowing acetic acid to evaporate)
- There may be impact or frictional ignition hazards.
- Separating oxidising agents from fuels, if this is practicable.
- Using ventilation and sprays to cool containers or oxidising agent/fuel mixtures.
- If a fire has developed, using an extinguishing agent; water may be the best choice but consider the problems of water reactives and environmental damage (water and/or soil pollution, in particular)
- The danger of impregnating combustible material in the area with water containing dissolved oxidising agents that may become spontaneously flammable much later on, when the water evaporates
- If water is used to extinguish a fire, ensuring appropriate application of water to achieve a maximum cooling effect (fog or fire spray).
- If organic peroxides are involved in, or exposed to, fire, evacuating the area and attacking the fire from a safe location. Structural cover for firefighters, lashed branches and ground monitors should be considered.



Cryogenics

Cryogenic liquids are liquefied gases that are kept in their liquid state at very low temperatures. All cryogenic liquids are gases at normal temperatures and pressures.

The vapours and gases released from cryogenic liquids remain very cold. They often condense the moisture in air, creating a highly visible fog.

Each cryogenic liquid has its own specific properties but most cryogenic liquids can be placed into one of three groups:

- Inert gases: these do not react chemically to any great extent; they do not burn or support combustion (e.g. nitrogen, helium, neon, argon and krypton)

- Flammable gases: some cryogenic liquids produce a gas that can burn in air; the most common examples are hydrogen, methane and liquefied natural gas
- Oxygen: many materials considered as non-combustible can burn in the presence of liquid oxygen. Organic materials can react explosively with liquid oxygen. The hazards and handling precautions of liquid oxygen must therefore be considered separately from other cryogenic liquids.

Cryogenic liquids are shipped and used in thermally insulated containers. Cryogenic liquid containers are specifically designed to withstand rapid temperature changes and extreme differences in temperature.

Laboratory liquid dewar flasks

Laboratory liquid dewars have wide-mouthed openings and may not have lids or covers. These small containers are primarily used in laboratories for temporary storage.



Image 99 Laboratory liquid dewar flasks

Liquid dewar flasks

Liquid dewar flasks are non-pressurized, vacuum-jacketed vessels, somewhat like a Thermos flask. They should have a loose fitting cap or plug that prevents air and moisture from entering but allows excess pressure to vent. Flasks containing helium, hydrogen and other low boiling point liquids have an outer vessel of liquid nitrogen for insulation.

Liquid cylinders

Liquid cylinders are pressurised containers specifically designed for cryogenic liquids. This type of container has valves for filling and dispensing the cryogenic liquid, and a pressure-control valve and a pressure-relief valve with a frangible (bursting) disk as backup protection. Three major types of liquid cylinders are designed for dispensing:

- Liquid or gas
- Only gas
- Only liquid



Image 100 Cryogenic liquid cylinders

Hazards

Four groups of hazards are associated with cryogenic liquids:

- Extreme cold
- Asphyxiation
- Toxicity
- Fire and explosion

Extreme cold

Cryogenic liquids and their associated cold vapours and gases can produce a thermal burn. There is no initial pain, but there is intense pain when frozen tissue thaws.

Unprotected skin can stick to metal that is cooled by cryogenic liquids. The skin can then tear when pulled away. Prolonged breathing of extremely cold air may damage the lungs.

Asphyxiation

When cryogenic liquids form a gas, the gas is very cold and usually heavier than air. This cold, heavy gas does not disperse very well and can accumulate near the floor. Even if the gas is non-toxic, it displaces air. Oxygen deficiency is a serious hazard in enclosed or confined spaces.

Small amounts of liquid can evaporate into very large volumes of gas. For example, one litre of liquid nitrogen vaporises to 695 litres of nitrogen gas when warmed to room temperature (21°C).

Toxicity

The chances of fire and rescue services encountering toxic cryogenic substances is extremely remote, as they are only likely to be found in tiny quantities in one or two research establishments in the world. If they are encountered, the safety data sheet should be referred to for information about the toxic hazards of a particular cryogen.

Fire hazard

Flammable gases such as hydrogen, methane, liquefied natural gas and carbon monoxide can burn

or explode. Hydrogen is particularly hazardous as it forms flammable mixtures with air over a wide range of concentration; it is also very easily ignited.

Oxygen-enriched air

Liquid hydrogen and liquid helium are both so cold that they can liquefy the air they contact. For example, liquid air can condense on a surface cooled by liquid hydrogen or helium. Nitrogen evaporates more rapidly than oxygen from the liquid air. This action leaves behind a liquid air mixture that, when evaporated, gives a high concentration of oxygen.

Liquid oxygen hazard

Liquid oxygen contains 4,000 times more oxygen by volume than normal air. Materials that are usually considered non-combustible, (such as carbon and stainless steels, cast iron, aluminium, zinc and Teflon (PTFE)) may burn in the presence of liquid oxygen. Many organic materials can react explosively, especially if a flammable mixture is produced. Clothing splashed or soaked with liquid oxygen can remain highly flammable for hours.

Explosion due to rapid expansion

Without adequate venting or pressure-relief devices on the containers, enormous pressures can build up. The pressure can cause an explosion called a boiling liquid expanding vapour explosion (BLEVE).

Unusual or accidental conditions such as an external fire or a break in the vacuum that provides thermal insulation may cause a very rapid pressure rise. The pressure relief valve may not be able to handle this increased pressure. Therefore, the containers must also have another backup device such as a frangible (bursting) disc.

Once cryogenic products have escaped from their containment vessel there is no mechanism for recovering the product.

Large volumes will eventually absorb enough heat from the atmosphere to boil and form a gas, which can then be dispersed.

This process can take a long time and the freezing of land or structures that results can cause other problems.

Cryogenic products will form dense vapour clouds.



Section 4: Health hazards



Acute and chronic health hazards

Toxic (poisonous) and infectious substances are those liable to cause death or injury if swallowed, inhaled or absorbed through skin contact. Within UN class 6 there are two divisions:

Division 6.1 toxic substances: a poisonous material, other than a UN Class 2.3 gas, known to be so toxic to humans that it presents a health hazard during transportation.



Image 101 Division 6.1 Toxic substances





Division 6.2 infectious substances – a material known to contain or suspected of containing a pathogen. A pathogen is a virus, micro-organism or proteinaceous infectious particle (prion) that has the potential to cause disease in humans or animals.



image 102 Division 6.2 Infectious substances

Table 40 below shows the five GHS categories of acute health effects or acute toxicity. Each is based on the severity of the toxic substance, based on their lethal dose (LD50) values. These are:

Table 41 GHS categories of acute health effects or acute toxicity

Category	Ingestion (mg/kg bodyweight)	Absorbption (mg/kg bodyweight)	Inhalation (parts per million - ppm 4 - hour exposure)	Symbol
Category 1	5 or less	50 or less	100 or less	
Category 2	50 or less	200 or less	500 or less	
Category 3	300 or less	1000 or less	2500 or less	
Category 4	2000 or less	2000 or less	20000 or less	
Category 5	Substances that have relatively low toxicity but could present a danger to vulnerable populations.			

Chronic health effects warnings are only communicated through the CLP label for the majority of materials. The transport classification and labelling systems do not include classifications for chronic hazards; therefore only acute health effects are considered. Materials that cause chronic effects can only be identified through the CLP labelling.

Chronic hazards are divided into several categories.



Mutagens

A mutagen is a substance or agent that is capable of altering genetic material in a living cell. This increases the frequency of mutations, which can lead to health effects for the person who has been exposed. It is also possible that the effect can be passed through to the next generation.

Labelling

Table 42 below shows the CLP regulated labelling, for products that have mutagenic properties and are placed on the market:

Table 42 CLP regulated labelling for mutagenic products

Classification	Pictogram	Signal word	Hazard statement
Mutagen category 1A or 1B		Danger	H340: may cause genetic defects
Mutagen category 2		Warning	H341: suspected of causing genetic defects



Carcinogens

Carcinogens are defined as materials that cause cancer or increase its incidence.

Labelling

Table 43 below shows the CLP regulated labelling, for products that have carcinogenic properties and are placed on the market:

Table 43 CLP regulated labelling for carcinogenic products

Classification	Pictogram	Signal word	Hazard statement
Carcinogen category 1A or 1B		Danger	H350: may cause cancer
Carcinogen category 2		Warning	H351: suspected of causing cancer

Reproductive toxicity



Reproductive toxicity is split into two sub-groups:

- Adverse effects on sexual function and fertility e.g. alterations to the male or female reproductive system
- Adverse effects on development of the offspring; this includes effects that occur before or after birth

Labelling

Table 44 below shows the CLP regulated labelling, for products that have reproductive toxicity properties and are placed on the market:

Table 44 CLP regulated labelling for reproductive toxicity products

Classification	Pictogram	Signal word	Hazard statement
Reproductive toxicity category 1A or 1B		Danger	H360: may damage fertility or the unborn child
Reproductive toxicity category 2		Warning	H361: suspected of damaging fertility or the unborn child

Specific target organ toxicity – single exposure



This is a specific, non-lethal, target organ effect following a single exposure to a material. All significant effects that can impair function (both reversible and irreversible, immediate and/or delayed), which are not covered in other classification groups, are included in this classification.

Labelling

Table 45 below shows the CLP regulated labelling, for products that have specific target organ toxicity properties from a single exposure and are placed on the market:

Table 45 CLP regulated labelling for specific target organ toxicity (single exposure) products

Classification	Pictogram	Signal word	Hazard statement
Specific target organ toxicity category 1		Danger	H370: Cause damage to organs

Classification	Pictogram	Signal word	Hazard statement
Specific target organ toxicity category 2		Warning	H371: May cause damage to organs
Specific target organ toxicity category 3		Warning	H335: May cause respiratory irritation; Or H336: May cause drowsiness or dizziness



Specific target organ toxicity – repeated exposure

This is a specific, non-lethal, target organ effect following repeated exposure to a material. All significant effects that can impair function (both reversible and irreversible, immediate and/or delayed), which are not covered in other classification groups, are included in this classification.

Labelling

Table 46 below shows the CLP regulated labelling, for products that have specific target organ toxicity properties from repeated exposure and are placed on the market:

Table 46 CLP regulated labelling for specific target organ toxicity (repeated exposure) products

Specific target organ toxicity category 1		Danger	H372 - causes damage to organs through prolonged or repeated exposures
Specific target organ toxicity category 2		Warning	H373 - may cause damage to organs through prolonged or repeated exposure



Toxic substances - characteristics, classification and hazards

Toxicity is the capability of a poison, or toxin, to produce injury in an animal, a human being or the environment. Many poisons cause harm to living tissues at very small doses because they interfere with one or more of the large number of complex chemical processes that take place continuously in all living creatures. These processes are catalysed by enzymes and often a poison works by blocking the action of an enzyme or by changing the direction of a particular process.

To appreciate the hazards presented by poisonous substances it is helpful to know some general principles that apply to all living creatures.

All living things are composed of cells. One of the simplest creatures is the amoeba, which is in fact a single cell about the size of a full stop. It may be found in pond water and can carry out all the processes necessary to live in itself – breathing, eating, elimination of waste products and reproduction (where it divides into two identical cells). A human body is composed of about 250 different types of cell. All living cells have certain common features and a typical living animal cell is shown below. It is important to note that red blood cells do not have a nucleus as they are designed to transport oxygen, and lose their nuclei after they are fully grown, before being released from the bone marrow into the blood stream.

The two parts of a cell that are especially sensitive to poisons are:

- The mitochondrion (the power-house of the cell)
- The nucleus (the control centre of the cell)

The mitochondrion

In the mitochondrion a chemical called adenosine triphosphate (ATP) is generated by a complex series of reactions in what is referred to as the 'respiratory chain'.

The overall reaction may be represented as: $4H^+ + O_2 + 4e^- = 2H_2O$

As a result of the energy liberated by this process, 34 molecules of ATP are generated. The oxygen comes from the air inhaled and every living cell must be adequately supplied with oxygen if it is to function properly. All cells require a continuous supply of ATP, which supplies the energy necessary to sustain life. All muscle cells are powered by ATP, so breathing and the beating of the heart depend on a continuous supply of ATP to the relevant cells. All nervous impulses depend on ATP, so to think or to use any senses requires a continuous supply of ATP. Each adult uses and synthesises many millions of ATP molecules every minute of the day. Many acute poisons act by reducing supplies of ATP to the cells or vital organs of the body, so that muscles or nerve cells cease to function normally.

The nucleus

This contains the chromosomes, which in turn are made up of genes. The basic material of all chromosomes and genes is deoxyribonucleic acid (DNA); all the functions of the cell are controlled through the DNA. If a cell is to divide into two healthy cells to replace cells that become worn out, the DNA must be copied perfectly. Anything that affects the DNA may injure the cell.

Three possible effects of a poison are to:

- Slow down the cell
- Kill the cell
- Cause the cell to go out of control and develop into a tumour, or a cancer (here the time-scale may be many years, because even a small tumour will contain about 1,000,000,000 cells)

Important characteristics of different types of cell

Some cells are replaced on a regular basis, such as those that line the intestine or red blood cells (made in the bone marrow). Skin cells are also continuously renewed; the outer layers of skins are dead cells that are shed continuously. However, nerve cells and brain cells do not change very much and are not replaced if they get damaged.

Absorption of poisons

Chemicals can cause poisoning if they reach sensitive parts of a person or living organism in sufficiently high concentrations and for a sufficient length of time. For a chemical to cause harm it must enter the body. Poisons may be absorbed into the body in four main ways:

Inhalation - Through the lungs

Gases and vapours, mists, smokes and dusts and fibres (depending on their size and shape) can all be absorbed in this way. The peak retention depends on aerodynamic shape with particles of 1-2 micrometres (μm) being retained most effectively. Larger diameter dusts do not penetrate the lungs but tend to be trapped further up the respiratory tract where cilia eventually return them to the oesophagus. From the oesophagus, dusts tend to be excreted through the gut and it is possible that the dusts may cause toxic effects as though they were ingested like food. Most inhaled dust will enter the gut directly and may chemically react with the gut or interfere with micro-organisms living in the gut. Systemic action is also possible (affecting the whole body or many organs).

Irritation by dust particles is also possible, but tends to depend on the solids being dissolved. Asbestos fibres cause fibrosis and cancer even though they are insoluble; a similar effect can occur with man-made mineral fibres. Insoluble particles such as coal and silica dusts readily cause fibrosis of the lung.

The volume of air inhaled and exhaled with each normal breath increases with physical exertion; the rate of physical work will directly affect the amount of toxic material a person inhales from a contaminated atmosphere.

Ingestion: Through the gastro-intestinal tract

Such a process could occur through bad housekeeping, such as eating food in laboratories, but generally results from accidental exposure.

The physical state of a toxic substance can have an important bearing on the ease with which it may be absorbed by the body. Fine sub-division, and in some cases, the fact of solubility or insolubility in water, may aid absorption. Barium chloride, which is soluble in water and is a component of ternary eutectic chloride (a well known fire-extinguishing medium), is very poisonous, whereas the insoluble barium sulphate is not poisonous, and is used in the barium meal administered to patients for X-ray photographs of their gastro-intestinal tract.

Dermal absorption: Through the skin

There is far lower awareness of this mode of absorption. Certain liquids, including methanol (methyl alcohol), organic mercury compounds, organophosphate pesticides and benzene can be absorbed in this way.

Toxic materials may also enter the body through cuts and grazes, although this is not a common entry route.

Injection: Through an opening in the skin

Normal skin provides an excellent barrier to most chemicals. When the skin is punctured in some way (e.g. by a syringe needle, from handling animals or broken glassware, from cuts and grazes, etc.) this protection is bypassed. Any poison or toxic contamination on the skin or on the device causing the puncture wound is capable of directly passing into the bloodstream and eventually finding its way to internal organs where it may exert its toxic effect.

When decontaminating skin, care should be exercised to not rub so hard that it becomes damaged. Reddening of the skin is a sign that it is being damaged and further decontamination effort may be counter-productive as it may require injection.



Descriptive terms used in poisoning

Terms used to describe cases of poisoning:

- Acute: adverse health effects occur within a short time (typically up to a few days) after exposure to a single dose (or given concentration) of poison.
- Chronic: delayed health effects that occur many years after exposure to a poison and that persist over a long period of time. In industry the effects generally occur by repeated exposures over a period of days, months or years.
- Local: the site of action of an agent and means that action takes place only at the particular

area of contact between the organism and a toxic material. Absorption does not necessarily occur. Local effects occur usually to the skin, eyes and respiratory tract.

- **Systemic:** the site (target organ) or region of toxic action is other than at the point of contact between the organism and the poison and presupposes that absorption and distribution of the toxin has already taken place in the body. With systemic effects the whole body or many organs can be affected. Methylene chloride is an example of a substance causing systemic toxicity; once inhaled this material can be metabolised to carbon monoxide that initially may cause feelings of euphoria (similar to alcohol). At higher concentrations unconsciousness can result and repeated exposures to the material can lead to permanent brain damage.
- **Teratogen:** substance that causes mental or physical harm to an unborn foetus. The harm cannot be passed on to future generations. The drugs lysergic acid diethylamide (LSD), methyl mercury, rubella virus (German measles) and herpes virus are teratogens (X-rays and gamma rays also can act as teratogens).
- **Mutagen:** can cause physical or mental harm to an unborn foetus. The harm can be passed on to future generations.
- **Carcinogen:** material that can cause cancer.
- **Irritant:** chemical that is not corrosive but that causes a reversible inflammatory effect on living tissue by chemical action on the local site of contact. This effect is often referred to as irritation and typical sites of contact on the body are skin, eyes and the respiratory system.

Allergens and hypersensitivity - an allergy is the tendency of the body to react adversely to certain substances; hay fever, hives and some types of asthma are typical examples of allergies. Allergens are different from irritants as they require interaction with the body's immune system to generate their effect (see below). The allergic effect depends on the individual's sensitivity to the allergen; whereas an irritant acts on an individual in a non-specific manner (i.e. the effect of an irritant on an individual is largely not dependent on that individual's sensitivity to the irritant).

An allergic reaction is really composed of two contacts with a foreign substance. In the first contact the defence mechanisms of the body detect the foreign substance, an antigen, and manufacture antibodies against it. This change in the body is sometimes referred to as sensitisation and any subsequent exposure to the same antigen provokes a massive response from the body; the condition known as an allergy. In some allergic reactions, cells affected by the antigen-antibody reaction may liberate toxic chemicals such as histamine, which is responsible for some of the symptoms that accompany certain allergies, including a runny nose, itching eyes and hives. Thus, anti-histamine drugs are sometimes prescribed.

The chemical most widely known as an individual cause of allergy is toluene di-isocyanate (TDI). One exposure can sensitise a person, so that subsequent exposures can cause severe asthmatic attacks.

Some people maintain that certain food additives, such as the yellow dye tartrazine (E102), can cause allergies in certain cases.

Convulsant: a material that results in violent, abnormal, uncontrollable contraction or series of contractions of muscles in the body. The convulsions produced are often referred to as seizures. Convulsions may have an organic origin or may be induced using drugs. Some typical causes of

seizures are:

- High fever (e.g. in heatstroke, infections)
- Brain infections (e.g. meningitis, malaria, tetanus)
- Metabolic disorders (e.g. high/low levels of sugars or sodium)
- Inadequate oxygen supply to the brain
- Structural damage to the brain (e.g. through accident, stroke)
- Exposure to toxic drugs/substances (e.g. amphetamines, lead, strychnine)
- Withdrawal after heavy use of alcohol or sedatives including sleeping pills
- Prescription drugs.

It is believed that seizures are caused by disorganised and sudden electrical activity in the brain.

Dose

A major factor in cases of poisoning is the dose received. Substances not normally regarded as poisonous may become so if the dose is sufficiently massive (usually resulting in acute effects). It is therefore not always easy to make a clear-cut distinction between poisonous and non-poisonous substances. The concentration of poisonous material is not the only factor to be considered when assessing the degree of poisoning experienced, and other factors can also have an important influence:

- Duration of exposure
- Sizes of particles or physical state
- Affinity for human tissue materials
- Solubility in human tissue fluid
- Sensitivity of human tissues and organs
- Age of a person
- Health of an individual



Occupational exposure limits (OEL)

In an attempt to limit long-term damage to industrial workers by chronic exposures to poisons, the Health and Safety Executive (HSE) has, via the COSHH Regulations, established limits to the airborne concentrations of poisons to which workers can be exposed.

The ideal underlying the original occupational exposure limits (OELs) was that it was possible to define average levels of substances in air that could be inhaled continuously by an industrial worker during a working shift (normally taken as eight hours/day), every week (normally taken as five working days) for their working life (normally taken as 40 years), without any ill effects

occurring. That is still the ideal, but it is not always possible to achieve it; this was recognised in the COSHH Regulations.

OELs are intended to be used to control the exposure of workers to airborne hazardous substances in the workplace and are not designed to deal with serious accidents or emergencies such as a major gas release arising from plant failure.

Airborne control levels for hazardous substances that are recommended in the COSHH Regulations are reproduced in the current Health and Safety Executive (HSE) Workplace exposure limits, which is reviewed periodically. The document contains information on a single type of OEL known as the workplace exposure limit (WEL).

These control levels for gases and vapours in air are usually expressed in parts per million (ppm) by volume or parts of gas per million parts of air. Concentrations of dusts, smokes and fumes are often quoted as milligrams per cubic metre (mg m⁻³) of air at a standard temperature and pressure.



Workplace exposure limits

Workplace exposure limits (WELs) are OELs set under the COSHH Regulations to protect the health of workers. WELs are defined as the maximum concentrations of hazardous substances in air averaged over a reference period (i.e. a time-weighted average or TWA) to which employees may be exposed by inhalation.

An eight-hour reference period is used to control exposures to a hazardous substance during a typical work shift. WELs quoted for this period of time are known as long-term exposure limits.

A 15-minute reference period is used to prevent acute effects such as eye irritation, coughing, etc. that may arise following exposure for a few minutes. WELs for this period of time are known as short-term exposure limits. For substances where a long-term limit is quoted but no short-term limit is specified, it is recommended that a figure of three times the long-term limit is used as a guideline for controlling short-term peaks.

When making an assessment on the chronic risk of a substance, it would be prudent to identify any hazard statements associated with the material to ascertain the long-term health effects on affected humans. Under the CLP Regulations these statements must appear on packaging labels when the materials are transported, unless they are exempted.

Every employer, including the fire and rescue service, has a responsibility to identify the materials in the workplace that may put employees' health at risk, to assess that risk and introduce the necessary controls to ensure exposures are below WELs and as low as reasonably practical (ALARP).

Employers have a legal responsibility to inform their staff about those materials in the workplace that may damage their health and to identify the effects of those materials. When managing an incident at which hazardous materials will be encountered, this responsibility falls to the incident commander.



Odour threshold concentration

Many poisonous substances have a characteristic smell (carbon monoxide is a well-known exception). In some cases the threshold of smell, or odour, is above the OEL value. That means a person can suffer from toxic effects without realising that a poisonous gas or vapour is present. Two common examples are benzene (WEL = 1 ppm, threshold odour concentration is about 100 ppm) and methyl alcohol (WEL = 200 ppm, threshold odour concentration is about 2000 ppm).



Other systems

If information on the OEL is not available then it may be possible to use the threshold limit value (TLV) which is a roughly equivalent limit imposed on employers in the USA. Other limits associated with these basic TLVs are:

- Short-term exposure limits (STELs) for a 15-minute reference period
- Ceiling exposure limits (TLV-Cs) are for concentrations of materials that must never be exceeded, even instantaneously

Lethal dose 50 per cent (LD_{50})

This is the concept used to assess the acute toxicity of a material.

It has long been recognised that if similar quantities of poison are given to different people (or animals) in a population, it will produce differing health effects. To have a quantifiable response to a poison, death is chosen as the discriminator as it is easily measurable. For this reason, lethality studies are normally carried out on animals. To obtain a representative value for lethality for an animal species, it is necessary to carry out tests on a group (or population) of animals so a statistical determination can be made on the amount of poison necessary to kill a certain percentage of the group in a certain time.

The lethal dose 50 per cent is thus defined as:

'the quantity of poison that will kill one half of a batch of ten or more animals within 14 days'.

The LD₅₀ is expressed as milligrams per unit body weight (mg/kg).

When quoting values for the LD50 it is necessary to quote the animal species being tested and the route the poison was given to the animal. For example the LD50 may be quoted as:

LD₅₀ (oral, rat) = 414 mg/kg indicating that poison introduced to a group of 10 or more animals by ingestion (oral) at the level of 414mg/kg caused the death of half (50%) of the group within 14 days.

Owing to the above-mentioned dosage values being obtained mainly from studies of rats, mice and guinea-pigs, they should be regarded with caution, and if evidence concerning human beings is available it should be used in preference to that obtained from animal experiments. Individuals vary greatly in their susceptibility to poisons for reasons that are not well understood, and conditions that may be safe for some are not safe for all.



Other terms

Lethal concentration 50 Per Cent (LC₅₀) is used to denote the concentration of a gas present in the atmosphere for a given period of time that eventually kills half of a batch of ten or more animals within 14 days.

LD_{LO} and LC_{LO} denote the lowest published lethal dose and concentration respectively. These figures, unlike LD₅₀ and LC₅₀, are not statistically derived and are often obtained from post-mortem examinations on accidental death victims.

When managing a release of toxic material, particularly when monitoring equipment is available, other limits or levels where symptoms may start to appear are more appropriate to use. This is particularly relevant to action taken to protect the public.

Internationally, levels such as Acute Emergency Guideline levels (AEGs) and Immediately Dangerous to Life and Health (IDLH) are widely available from data sources and can be used to predict likely consequences of people exposure to a certain concentration for a predicted period of time. Figures are usually given in PPM.



Acute emergency guideline levels

The acute exposure guideline levels (AEGs) describe the human health effects from once-in-a-lifetime, or rare, exposure to airborne chemicals. Used by emergency responders when dealing with chemical spills or other catastrophic exposures, AEGs are set through a collaborative effort of the public and private sectors worldwide. AEG values represent threshold levels for the general public. As mentioned, that includes susceptible sub-populations, such as infants, children, the elderly, people with asthma and those with other illnesses.



Immediately dangerous to life and health hazards

These levels are established by the American National Institute for Occupational Safety and Health (NIOSH). As exposure to airborne substances that are likely to cause death or immediate or delayed permanent adverse health effects or prevent escape from such an environment. They are used by respirator manufacturers and provide an upper limit for this type of respiratory protective equipment.



Biological or infectious agents/hazards

Biohazards/infectious substances – characteristics, classification and hazards

A biological hazard, or biohazard, is any micro-organism, cell culture or human endoparasite, including any that have been genetically modified, that can cause infection, allergy, toxicity or otherwise create a hazard to human health.

Biohazards arise from exposure to a range of pathogenic organisms. Acute or chronic infectious diseases may be caused by bacteria, viruses, protozoa or fungi. The pathogen can enter the body

via skin contact, puncture wounds, cuts, inhalation of aerosols or dusts and also by ingestion of contaminated food or drink.

These pathogens are found almost everywhere in varying forms and exist as a biohazard when the numbers exceed what is regarded as an infective dose.

Pathogenic organisms

Most biohazards arise from single-celled organisms of various types, which are collectively referred to as pathogenic organisms. These can be grouped into four different classes:

- Bacteria (Escherichia coli (E.coli), tuberculosis (TB), salmonella, legionella, etc.)
- Viruses (hepatitis B, C, HIV, etc.)
- Protozoa (toxoplasmosis,, malaria, etc.)
- Fungi and spores (ringworm, etc.)
- Prions - transmissible spongiform encephalopathies (TSE's) (Creutzfeldt-Jakob disease CJD)

Included within the above list is a serious health risk to firefighters: the transmission of infectious diseases (zoonoses) through direct or indirect contact with animals that are alive or dead and with animal waste. Examples of zoonoses are rabies and ringworm. Contact between pregnant firefighters and sheep and goats carrying chlamydia psittaci can also result in miscarriage.

Bacteria

- About 0.01mm in length.
- Primarily found in moist medium with small hairs used for locomotion.
- Rapidly increase in numbers in ideal conditions.
- Not able to withstand high temperatures (above 60° for half an hour will destroy them), and large doses of gamma radiation will kill them.
- Many bacteria are harmless.
- Necessary in soil, human and animal bodies

Some can produce toxins and cause symptoms of disease such as TB, anthrax, tetanus or bubonic plague.

Viruses

- Much smaller than bacteria, consisting of nuclear material (DNA or RNA – ribonucleic acid) surrounded by complex outer coat of protein.
- Attach to host cell to reproduce and then infect other cells.
- Typical viruses include Lassa fever, herpes, influenza, HIV, rabies and smallpox.

Protozoa

Larger, single celled-organisms similar to bacteria.

Often water-borne, including malaria and amoebic dysentery.

Fungi and spores

- Live as parasites on a host.
- Examples include thrush, athlete's foot and ringworm.

Categorisation of micro-organisms

The Advisory Committee on Dangerous Pathogens (ACDP) advises the Health and Safety Commission, the Health and Safety Executive (HSE) and appropriate government ministers on all aspects of hazards and risks to workers and others from exposure to pathogens. In 1995 the ACDP issued guidance on the categorisation of biological agents, which classified biological agents into four categories:

Hazard group 1: unlikely to cause disease.

Hazard group 2: can cause disease and may be a hazard to employees, is unlikely to spread to the community and there is usually an effective prophylaxis or treatment available (e.g. measles and mumps).

Hazard group 3: can cause severe human disease and may be a hazard to employees, may spread to the community but there is usually an effective prophylaxis or treatment available (e.g. hepatitis B and tuberculosis).

Hazard group 4: causes severe human disease and is a serious hazard to employees, is likely to spread to the community and there is usually no effective prophylaxis or treatment available (examples include Haemorrhagic fevers (Ebola and Lassa).

The ACDP issues an approved list of biological agents which is updated regularly and available at: <http://www.hse.gov.uk/pubns/misc208.pdf>

Notification

The ACDP has placed a duty on employers to identify hazards in the workplace and to understand and control the infection risk where a hazard group 4 containment exists (based on COSHH principles).

The Management of Health and Safety Regulations 1999 (MHSR99) recommends the appointment of a competent person such as a safety officer/adviser, to assist the employer with:

- Notifying local authority fire services in advance of substances to be handled that may be a hazard to firefighters in the course of their duties (as part of the emergency plan)
- Responsibility for decontamination procedures
- Disposal of infectious waste.

COSHH Regulations require the Health and Safety Executive (HSE) to be notified of the intention to use, store or transport certain hazard groups.

Hazards

Additional hazards are associated with biological agent research and development premises and may include:

- High security levels such as including electronic locking mechanisms, preventing unauthorised access
- Premises containing hazard group 3 and 4 materials are required to maintain negative pressure (up to -100Pa) to prevent the release of biological agents outside the building.
- An uninterruptible power supplying lab equipment and building facilities
- Regular disinfection of labs, which generally takes the form of gaseous formaldehyde fumigation over a 36-hour period
- Various types of animals used for research purposes
- Gases, including nitrogen, hydrogen, helium and oxygen
- Chemicals, including acids, bases, alcohols, volatile agents and toxic or carcinogenic organic compounds such as benzene
- Various radiation sources for tracer experiments
- Liquid nitrogen for cryogenic storage

Biohazard usage

Biological hazards may be encountered in a wide range of situations:

- Hospitals (isolation wards, post mortem areas, medical schools, laboratories, etc.)
- Biotechnology laboratories using genetically modified organisms
- Universities or colleges
- Veterinary laboratories, quarantine kennels or abattoirs
- Government research establishments
- Biological, medical, animal research establishments
- Farms, zoos, wildlife parks
- Sewers, sewage treatment plants and flood water
- Casualty handling/cadavers at fires, transport incidents or other special service calls
- Residential premises where people may be infected
- Post offices and mail delivery couriers
- Funeral parlours/embalmers
- Biological warfare or terrorist sites
- Pharmaceutical laboratories
- Government establishments

Biohazard transportation, packaging and storage

Transportation

The transport categories are defined as:

- Category A: infectious substance transported in a form that, when exposure to it occurs, is capable of causing permanent disability, life-threatening or fatal disease to humans or animals.
- Category B: infectious substance that does not meet the criteria for inclusion in category A

For all substances a triple packaging system is used. This includes:

- A primary, watertight and leak-proof receptacle surrounded by sufficient absorbent material to absorb any spills caused by breakage
- A secondary, watertight and leak proof packaging, again containing sufficient absorbent material to absorb any spills
- An outer packaging that protects the secondary packaging from physical damage

The outer wrapping of any package should bear the international warning signs and a warning that the package should be neither opened nor touched. On the outer packaging there should be an indication of the nature of the contents, together with the name and address of both the consignor and consignee. These details should also be provided with the package.

For transportation, infectious substances will be assigned to UN 2814, UN 2900 or UN 3373. Vehicles used for the transportation of biological agents will come under UN hazard classification 6.2 and may display the warning triangle for 'substances containing disease-producing micro-organisms'.

Postal

Hazard group 4 materials must not be sent through the postal system. Special arrangements apply to their transportation, nationally and internationally.

Hazard group 2 and 3 materials may be transported either by post or by an authorised courier provided they comply with the packaging requirements and bear the international warning signs together with the names and addresses of the sender and recipient.

Organisations that regularly send such materials through the post should have procedures for contacting competent personnel in the event of an accident.

Location and meaning of signs

Many establishments will display the international biohazard sign. However, the use of this sign varies considerably. Other black and white signs may relate to animals (e.g. Do not remove, May be removed in cages, etc.).

Where biological agents are present within a building there should always be a warning symbol present at the entrances to laboratories and refrigeration units for agents of hazard groups 2, 3 and 4, but they may not be found externally.



Biohazard pre-planning

Contact

COSHH requires that any premises containing biohazards of hazard groups 3 or 4 have written contingency plans for dealing with an emergency. In premises where hazard group 4 agents are in use expert advice will be available at all times.

Establishments handling hazard group 4 organisms are required to appoint a safety officer/adviser with whom contact should be made. This should include out-of-hours contact facilities.

Most laboratories and research establishments generally have a rota of knowledgeable persons; some work on an alert basis during times that the substances are present. Staff must stay on the premises in case of an emergency.

Nature of hazards

The type, quantity and level of hazards will determine the extent of fire and rescue service pre-planning. There could be hazards involving toxins that present an immediate threat to human life (e.g. typhoid, tetanus, etc.). Other hazards cause a threat to fish and marine life or plants, but pose no direct hazard to humans.

The physical state of the organism presents different levels of risk. Some may be frozen and stored in plastic bags. Some are kept in water, which may boil in the event of a fire, sterilising them. Some are kept in the dry state in glass phials or bottles with a risk of aeroionisation and subsequent inhalation of the powder. Some may be found in bulk, usually in glass or stainless steel vessels.

Extent of hazards

At a fire or other incident, the extent of the possible hazard to firefighters from such materials may vary. Most micro-organisms are killed in temperatures in excess of 60°C but some are thermophilic; they live and multiply in higher temperatures.

Guidance should be sought on how the micro-organisms react in fire and perhaps how long the fire would have to burn before micro-organisms are destroyed.

In addition to the biohazard, consider other laboratory risks such as:

- Chemicals (acids, alkalis, toxics and flammables)
- Gases (hydrogen cylinders, cryogenics for storing bacteria and viruses)
- Radiation (used for sterilisation and biological tracers).

The exact location

In some laboratories the main concentration of pathogens would be found in the main laboratory, but other smaller concentrations may be found elsewhere (i.e. freezers, cold stores or incubation rooms where temperatures may be controlled). Culture collections of freeze-dried materials may also be present.

All establishments handling infectious substances are required to have a safety manager and

emergency plans.

These plans can vary from returning all substances to cabinets to sealing rooms and evacuation in hospitals.

Expert assistance

In premises where group 4 agents are in use, expert advice will be available at all times. Other premises may be hazard-free most of the time and then go on alert, during which time staff must live on the premises.

Fire and rescue services will need to consider the levels of multi-agency liaison and advice that are required to resolve all foreseeable incidents involving biological agents within their areas.

Stakeholders likely to provide positive benefits in this include:

- Public health agencies
- Local resilience forum (LRF)
- Emergency planning departments
- Environment agencies
- Environmental health department
- Police service
- Ambulance service
- Health and Safety Executive
- Highways Agency (for incidents on major roads)
- Industry experts (for specialist advice)
- Hospitals



Other operational considerations for fire and rescue services

- Approach upwind and uphill as appropriate (note Firemet information).
- Any decision to use controlled burn tactics at a fire should be made on the basis of prior discussion with the site safety officer/adviser, or other subject matter advisers, and a thorough written risk assessment.
- The use of water should be minimised and any run off should be prevented from entering water courses.
- All staff and other responders should be strictly controlled to restrict the potential for exposure, including restricting the number of staff entering the hazard zone.
- A thorough safety brief must be carried out before personnel are deployed into the hazard zone
- The incident commander or hazardous materials adviser should maintain constant liaison

with the on-site specialist or safety officer/adviser. The incident commander should also appoint and brief safety officers to strictly supervise the inner cordon; this cordon should be based on pre-planning or specialist advice.

- Personnel should be made aware of the potential risks of disease and infection at off-site incidents such as animal incidents and road traffic collisions.
- All responders should be prohibited from eating, drinking and smoking whilst at the incident.
- At animal testing establishments, the likelihood of biologically infected animals escaping during an incident is remote, however, capturing such animals could be dangerous and no attempt should be made without specialist advice.
- Where an intense fire is involved and micro-organisms could be carried into the atmosphere by convection currents, downwind evacuation should be considered.
- In cases of suspected exposure to HIV or Hepatitis virus, incident commanders should consider the need for post-exposure prophylaxis (PEP) within one hour.
- When dealing with incidents involving sheep, incident commanders should be aware of the risks of infection to women firefighters who could be in the early stages of pregnancy; women firefighters can become seriously ill and possibly miscarry if infected with chlamydia psittaci (enzootic abortion).
- Specialist advice about on-site decontamination may be required, especially if the incident involves group 3 or 4 pathogens.
- Generally, personal protective equipment should be washed down with disinfectant (hypochlorite solution of 10,000 ppm recommended) but advice from subject matter advisers must be sought.
- Contaminated chemical protective clothing and other equipment should not be removed from the incident until thoroughly disinfected, and then only with authorisation from subject matter advisers

The level of PPE required will depend on:

- The nature of any biohazard present
- The potential for exposure to known biohazards and taking the nature of the incident into account, whether those biohazards could reasonably be expected to be present (e.g. at animal rescues, road traffic collisions, etc.)
- The advice of biohazard subject matter advisers
- Operational circumstances (e.g. immediate life saving rescues, fires etc.)

Other hazards to consider:

- High security levels, including electronic locking mechanisms, preventing unauthorised access
- Premises containing hazard group 3 & 4 are required to maintain negative pressure (up to -50Pa) to prevent the release of biological agents outside the building
- An uninterruptable power supply to lab equipment and building facilities
- Regular disinfection of labs generally takes the form of gaseous formaldehyde fumigation over a 12-hour period
- The presence of:
 - Various types of animals used for research purposes
 - Other pressurised gases, including nitrogen, hydrogen, helium and oxygen

- Chemicals, including acids, bases, alcohols, volatile agents and toxic or carcinogenic organic compounds
- Radiation sources for sterilisation

Records of anyone exposed to biohazards during operations should be kept, together with details of the organism encountered. Medical advice should be sought.



Health surveillance

Arrangements should be in place for the effective health surveillance of all personnel suspected of being exposed to any bio-hazards during an incident. While the incident is still in progress, this may be through an on-site specialist, occupational health provider or public health agency; certain circumstances may require antibiotic prophylaxis to be given for potential exposures.

Plans should be in place for monitoring and recording bio-hazard exposure. COSHH requires that employers keep a list of all personnel exposed to hazard group 3 and 4 agents be kept for at least ten years (for those agents with delayed effects this list should be kept for 40 years).

Staff should also be provided with follow-up monitoring by the occupational health provider as necessary. This will enable more sensitive whole-body monitoring or analysis of biological samples, such as urine, etc. to be carried out.



Materials containing asbestos

Asbestos is the generic name given to the fibrous forms of naturally occurring silicate minerals. Asbestos-containing materials (ACMs) were used in commercial products because of their high tensile strength, flexibility, low electrical conductivity and resistance to fire, heat and chemicals. Asbestos became prevalent in building construction from the 1950s onwards and was used extensively until it was prohibited in construction. Blue and brown asbestos were banned in 1985, white asbestos in 1999.

When work with asbestos, or work which may disturb asbestos, is being carried out, the Control of Asbestos Regulations require fire and rescue services to prevent exposure to asbestos fibres.

Where this is not reasonably practicable, they must make sure that exposure is kept as low as reasonably practicable by measures other than using respiratory protective equipment.

The spread of asbestos must also be prevented. The Regulations (Approved code of Practice and Guidance L143) specify the work methods and controls that should be used to prevent exposure and spread.

Exposure of personnel must be kept as low as reasonably practicable and below the airborne exposure limit. The Regulations specify control limits for all types of asbestos; these can be found on the Health and Safety Executive's website.

All work with asbestos requires a licence issued by the Health and Safety Executive (HSE), unless it is exempted from current Regulations.

The HSE can issue certificates of exemptions from certain requirements of the Regulations, such as the requirements to hold licenses to work with asbestos or to notify work with asbestos in advance. The exemptions are normally subject to specific conditions such as compliance with a specific method statement.

Any exemption will only relieve fire and rescue authorities of administrative requirements but not of the need to manage their work with asbestos-containing materials to reduce risks as required by Regulations.

The presence of ACMs does not necessarily mean that they will adversely affect the safety of those at the incident. To safeguard human health, the emphasis must be on continuous risk management and the implementation of appropriate and proportionate control measures at all incidents.

Characteristics and classification

Three main types of asbestos have been used in asbestos products: crocidolite (blue) asbestos, amosite (brown) asbestos and chrysotile (white) asbestos. Blue and brown asbestos are amphibole minerals while white asbestos is a serpentine mineral. The two mineral types have different physical properties and characteristics that lead to differences in their hazardous nature and disease potential.

Amphiboles (blue and brown asbestos)

Amphibole fibres are needle shaped and can split to form many new fibres from an initial single unit. The fibres are also more durable than white asbestos fibres and consequently have a greater potential to cause disease.

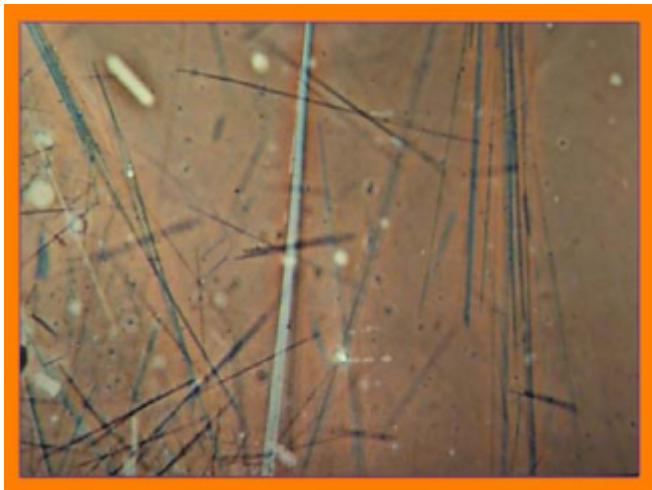


Image 104 Amphibole fibres 'caught on a membrane filter

Serpentine (white asbestos)

Serpentine fibres are curly in nature and will usually split longitudinally when disturbed or subject to impact. Therefore their potential to generate fibres is lower than for amphiboles and their disease potential is also lower.

While the three main types of asbestos are often described in terms of their common names, which are based on colour, in practice this is not a reliable guide to identifying the type of asbestos. Colour is often distorted by deterioration, age, painting and heating. It is also common to have different types of asbestos mixed together.

Blue (crocidolite)	Brown (amosite)	White (chrysotile)
UN 2212 EAC 2X (amphibole)	UN 2212 EAC 2X (amphibole)	UN 2590 EAC 2X (serpentine)

Hazards

Inhalation of asbestos fibres is the major hazard to human health. If inhaled, the smallest of the fibres may remain deposited in the lungs. Symptoms may not occur for 15-60 years after exposure. The principal diseases known to be caused by exposure to asbestos fibres are asbestosis, lung cancer, malignant mesothelioma and asbestos pleural disease.

Asbestosis

Asbestosis involves fibrous scarring of the lung in which the tissue becomes less elastic, making breathing progressively more difficult. It is irreversible and may progress even after the exposure to asbestos has ended. Asbestosis is an industrial disease arising from high levels of repeated exposure to airborne dust. There is no risk of contracting this disease from normal levels of environmental exposure to asbestos.

Lung cancer

An increased incidence of lung cancer has been found amongst people who have worked with asbestos. The increased risk depends on the degree of exposure and is very much greater for smokers than non-smokers.

Mesothelioma

Mesothelioma is a cancer of the inner lining of the chest or of the abdominal wall. The incidence in the general population is very low; the majority of cases are attributable to occupational or, more rarely, para-occupational exposure to asbestos (i.e. those living in the same house as an asbestos worker).

Asbestos pleural disease

This is a non-malignant disease that causes scarring of the thin membranes lining the lung and chest.

Other diseases and conditions

Asbestos may cause cancer of the digestive tract, colon, larynx, oesophagus, kidney and some types of lymphoma. These asbestos -related diseases may be due to swallowing some of the longer asbestos fibres that are caught in the upper airways and carried to the throat in mucus. However, the risk here is much smaller than those diseases caused by inhalation.

Skin and eye irritation may arise from acute exposure to fibres.

Hazards from chrysotile (white asbestos)

Crocidolite (blue), amosite (brown) and chrysotile (white asbestos) all cause cancer and have been classified by the International Agency for Research on Cancer as category 1 human carcinogens. It is recognised that chrysotile (white asbestos) is less potent (i.e. has a lower cancer risk) than the other types but it is still a carcinogen. In addition, many asbestos products contain a mixture of asbestos types and exposure to chrysotile will not be in isolation. Consequently all three forms should be treated the same.

Hazards posed to the general public at serious fires

In all cases of incidents involving asbestos-containing materials it is important to put the health risks to the general public into perspective. Asbestos is a naturally occurring substance and also a widely distributed industrial pollutant and consequently is found in low to moderate levels everywhere in the UK. These levels can be as high as 1000 fibres per cubic metre of air in urban or industrial areas. Exposure to these background levels is therefore unavoidable (Source data from the World Health Organisation)

Material containing asbestos that is in good condition and left undisturbed and in place cannot cause ill health, as fibres will not be released. Handling or touching ACMs in good condition will also generally not present a risk. However, handling would require precautionary controls (such as

wetting and personal protective equipment) in case the material had been damaged or crumbles/breaks up during movement. In such situations fibres are likely to be released.

The key factor in the risk of developing an asbestos-related disease is the total number of fibres inhaled. Inhaled fibres can become lodged in the chest tissue and the body's natural defences may not be able to easily break them down.

Asbestos will be encountered in a number of products (ACMs). The asbestos form and material that the fibres are mixed with, will define the level of hazard.

- Lower hazard - means asbestos cement products and textured coatings only. With these products, the asbestos is firmly embedded and the fibres are more difficult to release.

Other ACMs are also classified as minor or less-significant hazards under the Regulations (asbestos paper, rope seals, etc.) but they have not been included in the lower hazard category in the hazard identification process for fires because of their increased potential to release asbestos fibres in a fire

- High hazard - all other ACMs.

Construction materials

Prior to being banned, asbestos was predominantly used in the building industry as heat resistant insulation, lagging and roof sheeting. Asbestos is likely to be present in the vicinity of heating and ventilation systems, pipe work, boilers, structural insulating panels or as a roofing material.

It is estimated that approximately six million tonnes of asbestos has been used in the UK in the last 100 years. It may be found in the form of cement sheeting, impregnated cloth and rope or sprayed onto structures as slurry. Composites containing asbestos have also been used in decorative coatings and cladding for both internal and external use.

Table 48 High hazard asbestos containing materials

High hazard (N.B. . if disturbed or involved in fire)	
Asbestos coatings	<p>Widely used mixtures containing asbestos that were used to provide fire protection, acoustic properties, heat and condensation control by:</p> <ul style="list-style-type: none"> • Spraying onto structural beams, girders, etc. • Loosely packing between floors and in partition walls • Lagging e.g. on pipework, boilers, calorifiers, heat exchangers, insulating jackets for cold water tanks, around ducts <p>Typical buildings include office blocks, cinemas, theatres, swimming pools, multi-storey car parks, cold stores, hospitals, shops, derelict industrial buildings where old lagging has not been maintained, etc.</p>
Asbestos insulating boards (AIB)	<p>Used for fire protection and thermal insulation (e.g. ceiling tiles, partition walls, soffits, service duct covers, fire breaks, heater cupboards, door panels, lift shaft linings, fire surrounds, backing panels for radiators, heater and boilers).</p>
Asbestos insulation	<p>ACMs which were not applied as coatings in practice. They include preformed sections for pipe insulation, laggings, void infills and packing around cables that pass through floors, millboards used for electrical as well as thermal insulation.</p>

Table 49 Lower hazard asbestos containing materials

Low hazard	
Asbestos cement products	<p>These generally contain between 10% and 15% asbestos and the potential for fibre release is usually low. However, contamination can arise when asbestos cement is damaged or removed without suitable controls. Cement products include flat or corrugated roof sheets, wall cladding, guttering and downpipes, water tanks, bath panels, boiler and incinerator flues, fire surrounds, etc.</p>

Low hazard	
Certain textured coatings	Such as 'Artex' prior to the mid-1980's)



Image 105 Moulded and sprayed asbestos pipe lagging. This is an example of a potential high hazard ACM



Image 106 Asbestos cement roof sheeting removal. This is an example of 'lower/minor/less significant hazard' asbestos



Asbestos in buildings

Asbestos in buildings

The use of ACMs peaked in the 1960s and early 1970s, so premises built or refurbished during this time are the most likely to contain them.



<https://staff.london-fire.gov.uk/login.html?redirect=www.msftconnecttes...>

Ships

All types of asbestos have been widely used in a processed form in shipping, because of their properties of heat resistance, insulation and the strengthening of other materials when used as reinforcement. On board a ship, asbestos is likely to be found in:

- Cladding of fire-retardant bulkheads
- Glands of high temperature valves
- Friction materials in machinery
- Lagging on boilers and steam pipes



Railway rolling stock

Asbestos-containing materials that remain in refurbished rail vehicles used on Network Rail's infrastructure have been securely encapsulated. Therefore, fibre release and possible exposure to the fibres will only occur in the event of a catastrophic failure of the vehicle (e.g. as a result of a serious collision).



The environment

Asbestos is non-degradable and if released into the environment it could constitute a public health hazard. The relevant health protection agency, local authority and environmental agency should assess and manage this risk.

Once released into the air, fibres will be dispersed in natural air currents and by wind movement.

Land contaminated by ACMs and/or fibres may present a clean-up issue for the landowner or responsible person where significant amounts of fibres have been released during an incident. The public health agencies and the local authority may consider asbestos sampling to assess if the risk is above that normally encountered in the environment or for public reassurance (to show nothing has been detected above normal background levels).

Consideration should always be given to the potential hazards posed by water run off. Water may run into drains but may also collect on hard surfaces which, after drying off, may contain an asbestos residue.



Fire and rescue service exemption

In June 2005 an application was made by HM Fire Service Inspectorate on behalf of fire and rescue services for an exemption from the requirement to hold a licence to work with asbestos insulation, asbestos coating or asbestos insulating board in Regulation 3(1) of the Asbestos (Licensing) Regulations 1983 as amended.

With the enactment of the Control of Asbestos Regulations 2012 (CAR 2012) It was necessary for each fire and rescue service to update their exemption, which is subject to certain conditions.

Firefighters are regarded as licensed to work with asbestos according to CAR 2012; licensable work with asbestos is work:

- Where the exposure to asbestos of employees is not sporadic and of low intensity; or
- In relation to which the risk assessment cannot clearly demonstrate that the control limit will not be exceeded; or
- On asbestos coating; or
- On asbestos insulating board or asbestos insulation in most cases

Due to the unpredictable nature of the incidents that fire and rescue services attend, it cannot be demonstrated that their work will always fall outside these descriptions. Firefighters may have to do work with asbestos that would require them to hold a licence. The purpose of licensing is to allow the enforcing authority to monitor asbestos work that is being carried out. The Health and Safety Executive recognises the impracticality of the licensing and notification requirements being applied to fire and rescue services in their emergency service role, and as permitted by CAR 12 Regulations have issued a certificate of exemption from the requirements of licensing and notification.

The exemptions conditions include:

- An agreed method of work between HSE and fire and rescue services be used when asbestos or asbestos containing materials are being handled
- There is an equipment specification for decontamination of those engaged in work involving exposure to asbestos
- A written record is kept of work activities that involve possible exposure of personnel to asbestos



Planning and liaison

The Control of Asbestos Regulations require duty holders (the person or organisation in control of premises) to manage asbestos in non-domestic premises. To achieve this, they must prepare a written plan (commonly known as an asbestos register or asbestos survey report) identifying where asbestos is, or is likely to be, present and the measures taken to manage the risk. The plan should be readily available on site for anyone to examine. The duty holder is also required to ensure that information about the location and condition of any asbestos is made available to the emergency services.

It is unlikely that fire and rescue services will be made aware of all the asbestos in their area; where information does come from surveys or registers, this information may not be completely accurate or up-to-date. Fire and rescue services should therefore augment the information provided by duty

holders by gathering data themselves. Ways of gathering data include:

- Risk information visits (e.g. 7(2)(d))
- Fire safety inspections
- Operational intelligence
- Site exercises

Planning for hazardous materials incidents should include how fire and rescue services will train their staff to raise awareness of asbestos-containing materials reduce the risk of exposure and protect themselves, the public and the environment.

Known licensed asbestos removal

The Health and Safety Executive or the local authority environmental health department receive notifications of work involving the removal of asbestos by licensed contractors. Fire and rescue services should ensure that local protocols are in place for relevant information to be shared with them where significant risks to firefighters are foreseeable.

Where there is doubt as to whether or not materials contain asbestos, fire and rescue services should mobilise a hazardous materials adviser or subject matter adviser to the incident to assist the incident commander. Their training, knowledge and experience will improve the risk assessment process and they may be able to arrange analysis of suspected asbestos-containing materials.

Strict occupational exposure control limits must not be exceeded. It is difficult to measure the amount of asbestos fibres that may have been released during operational incidents; any release is likely to be unpredictable, variable, intermittent and short-term (peaks). When carrying out their risk assessment, it is therefore prudent for fire and rescue services to assume that all activities will require control measures such as respiratory protective equipment, even when any possible exposure to released fibres may be below the exposure limits (e.g. ACMs in which the fibres are firmly embedded).



Asbestos hazard identification guidance

Due to the nature of fire and rescue services operational activities, it will not always be practical to identify asbestos at incidents or events. Fire and rescue services have therefore adopted a precautionary policy for asbestos. Fire and rescue services should implement asbestos standard operating procedures whenever it is foreseen that ACMs may be present at the incident and involved in such a way that fibres may be released and inhaled by those present.

The following three step hazard identification process will assist the incident commander's risk

assessment:

- Step 1: are ACMs present?
- Step 2: can asbestos fibres be released or disturbed?
- Step 3: do responders have to enter the hazard zone?

Step 1: are ACMs present?

Sources of information that may be available to establish the presence of ACMs are:

- Asbestos hazard signage
- Visual appearance of construction/materials (e.g. asbestos cement roofs, insulation on plant/pipes, etc.)
- Age of building/materials (those constructed between 1950-1980, but note that white asbestos –particularly asbestos cement products – may be present up until 1999)
- Hazardous materials adviser/subject matter adviser
- Operational intelligence (7(2)(d) inspections, asbestos register, etc.)
- Multi-agency information sharing agreements (e.g. asbestos removal licences shared by the local authority)
- Premises asbestos management plan and/or asbestos register, available from the duty holder of the building
- Knowledge of building stock (the local authority building control department may be able to assist)
- Clues such as the age of the building/alterations and visual appearance of materials may support the risk assessment process but they should not be relied on as the only evidence for discounting the presence of ACMs.

Once the presence, or suspected presence, of ACMs is established, the next part of the assessment process is to determine the risk of responders inhaling asbestos fibres.

Step 2: can asbestos fibres be released or disturbed?

Asbestos is not hazardous to health if it remains intact and undamaged. The asbestos-containing material should be assessed and ideally visually examined to determine its condition (e.g. smashed/broken boards or sheets, damage with debris, degradation of bonding such as weathering) and as a result the likelihood that fibres or composite particles can be released into the air.

The risk is lower in ACMs with a strong bonding material such as asbestos cement sheeting. This contrasts with other ACMs such as sprayed coatings and lagging, which generally have a greater, more hazardous fibre content and are loosely bound, releasing fibres relatively easily when damaged or disturbed.

It should also be ascertained whether the ACM has been mechanically altered (cut, sanded, smashed, machined, etc.) as this will release asbestos dust, fibres or composite particles. The risk of releasing fibres is lower for work with hand tools than powered tools.

There may also be occasions where asbestos dust, fibres and composite particles have been released prior to the arrival of crews. Where this is suspected the quantity and likelihood of disturbing the fibres should be assessed.

Note that using positive pressure ventilation could disturb damaged ACMs.

Asbestos fibres are extremely small and light; they are not visible to the naked eye. Therefore it can be difficult to detect them without air sampling equipment. However, in any disturbance asbestos dust and fibres will always be released. The extent of fibre release may not be visible but it will generally reflect the amount of dust/composite particles created. The greater the extent of destruction and the greater quantity of asbestos material, the greater the extent of dust and fibre release. Dust and fibres will generally disperse fairly quickly where there is good unrestricted air movement. It is highly unlikely that this will appreciably increase the normal background level of fibres.

The risk of fibres being present above background levels will be lower where ACMs are in the open air as opposed to those releasing fibres inside buildings.

Step 3: do responders have to enter the hazard zone?

The hazard zone is the area where asbestos fibres or composite particles could be airborne, or made airborne by the activities being carried out. If responders do not need to go into the hazard zone then the risk of inhaling fibres is eliminated.

If responders do need to enter the hazard zone then asbestos standard operating procedures must be followed and the ACM should be categorised by the level of hazard posed. For simplicity and safety at fire-related incidents it is recommended that they be designated as:

- Lower hazard
- High hazard

Work area

The following actions should be taken:

- Establish a hazard zone and ensure it is controlled and monitored
- Where it is known that asbestos is involved at the address of the incident, fire control rooms should provide wind direction information to responders
- Crews should select a route to known, or suspected, asbestos incidents from the upwind direction where they believe there is a risk of inhaling asbestos dust, fibres or composite particles (i.e. asbestos fibres attached to a bonding material)
- Where appropriate, crews should notify fire control rooms of the best approach route for other response vehicles to follow.
- If different ACMs are present within a large incident site, it may be necessary to have a number of hazard zones each with their own control measures
- Keep the number of responders at the incident to the minimum required to deal with it safely
- Allow only essential staff to enter the hazard zone and ensure that they use appropriate

respiratory protective equipment (RPE) and personal protective equipment (PPE)

- Use and monitor PPE and RPE in line with the asbestos hazard assessment and the response plan
- Ensure appropriate and proportionate decontamination is carried out when leaving the hazard zone
- Ensure equipment is washed down prior to leaving the incident
- Brief all staff on the asbestos hazards
- Smoking, drinking or eating should not be allowed on-site unless designated rest areas with appropriate hygiene facilities are set up
- Ensure good personal hygiene both during and after the incident
- Notify other responders (police service, ambulance service, utility workers, etc) of any asbestos risk as soon as possible and ensure effective liaison
- Liaise with the police service and health protection agency on the risk of exposure to members of the public
- Inform the relevant environmental agency, health protection agency and the local authority environmental health department of the asbestos hazard

Work method

The following precautions are required:

- Avoid disturbing ACM (e.g. cutting away an area to gain access) unless essential. If this is the case, the material should be wetted and disturbance kept to a minimum.
- Leave individual pieces of ACM intact if the fire has disturbed and distributed it over a wide area
- If disturbed, ACM should be moved; ensure that it is wetted using a fine spray and moved as short a distance as possible to a safe place within the hazard zone.
- Water use should be kept to a minimum and the run-off controlled where possible
- Avoid use of positive pressure ventilation (PPV) fans unless essential as they may cause the release of airborne asbestos fibres and composite particles from disturbed/damaged structures. If PPVs are used, consider introducing water into the PPV stream to aid fibre management.
- Do not intentionally break any ACM into smaller pieces unless necessary
- Where possible, use hand tools in preference to abrasive or power tools when cutting away as their use reduces the amount of potential fibre release
- Avoid using cleaning methods such as dry sweeping that will increase airborne dust/particles.
- Keep the movement of ash and debris (e.g. turning over) to a minimum and ensure it is carried out carefully to prevent/reduce the amount of fibres and composite particles that may be released



Mobilisation to incidents involving

asbestos

Where it is known that asbestos is present at the incident fire control rooms should provide wind direction information to responders.

Arrival and gathering information

Fire and rescue service crews should approach known or suspected asbestos incidents from the upwind direction where they believe there is a risk of inhaling asbestos dust, fibres or composite particles (i.e. asbestos fibres attached to a bonding material). Where appropriate, crews should notify fire control rooms of the best approach route for other responding vehicles to follow.

The incident commander should ensure that all response vehicles and staff not yet deployed at the incident are kept (as far as possible) in an upwind marshalling area or rendezvous point. An initial cordon should be established around the suspected hazard zone and access into the cordon should be strictly controlled.

Any immediate rescue actions should be carried out using breathing apparatus (BA) and structural firefighting PPE as a minimum level of personal protective equipment.

As part of both their initial and ongoing risk assessment, incident commanders should ascertain whether asbestos-containing materials are present at the incident and whether they present a hazard to those attending. If a hazard exists, it should be managed using appropriate control measures.

Where there is doubt as to whether ACMs are present, the incident commander must be advised by an officer suitably trained and competent in providing advice on hazardous materials and environmental protection (hazardous materials adviser). Their training, knowledge and experience will improve the risk assessment process and they may be able to arrange analysis of suspected ACM.

Strict occupational exposure control limits must not be exceeded. It is difficult to measure the amount of asbestos fibres that may have been released during operational incidents. Any release is likely to be unpredictable, variable and intermittent. When carrying out their risk assessments, it is therefore prudent for fire and rescue services to assume that all activities will require control measures including respiratory protective equipment, even when any possible exposure to released fibres may be below the exposure limits.



Planning the response for

incidents involving asbestos

The incident commander must ensure that a risk assessment is carried out before personnel are deployed into the hazard zone, to develop a response plan with appropriate asbestos control measures.

The incident commander should assess the risks and, if asbestos is likely or known to be present, select the most suitable personal protective equipment and respiratory protective equipment taking into consideration existing policies and procedures, the tasks that need to be achieved and on-site monitoring of the hazards. The options available to the incident commander are:

- Breathing apparatus
- Chemical protective clothing

Chemical protective clothing should be worn at high hazard asbestos incidents (removing asbestos lagging from a boiler or ancillary pipe work, etc) to allow more effective decontamination.

Chemical protective clothing should not be worn in a fire if the heat or flames could have a detrimental effect on the effectiveness of the protective clothing or expose the wearer to excessive heat.

Breathing apparatus and structural firefighting personal protective equipment

Structural fire fighting kit should be worn where chemical protective clothing is not appropriate, such as during firefighting tasks or other operations where the disadvantages (i.e. heat stress, impaired visibility and mobility, etc) outweigh the advantages (i.e. ease of decontamination).

Other respiratory protective equipment and structural firefighting PPE

Respiratory protective equipment (RPE) other than breathing apparatus may be worn for lower hazard asbestos incidents (i.e. asbestos cement and textured coatings) and where staff will not be involved in hot zone working that would disturb composite particles (e.g. assisting with decontamination where there is a very low risk of airborne fibres, dust and composite particles).

Such circumstances might include fire investigation activities that do not involve disturbing asbestos-containing materials, re-inspecting incidents that do not involve the disturbance of ACM or operating in areas where there are asbestos cement sheeting fragments, etc. Other than breathing apparatus, RPE should not be used at a fire where the harmful products of combustion could be inhaled.

All RPE used at asbestos incidents must be marked with a CE symbol (the CE marking means that the RPE meets minimum legal requirements for its design and manufacture by conforming to a European Standard) and its use must be subject to face-fit testing procedures. In all cases where responders are working hard and there is a risk that a face seal may be compromised, BA should be worn.

The incident commander should liaise with a hazardous materials adviser to identify appropriate and proportionate decontamination procedures.

Responsibility for mitigating the environmental impact and subsequent site cleaning rests with the owner/occupier of the premises. However, every effort should be made within the response plan to mitigate the impact of the incident on the environment.



Asbestos decontamination procedure

Decontamination is the physical and/or chemical process of reducing contamination to minimise the risk of further harm occurring and the risk of cross-contamination.

Decontamination area

Decontamination arrangements should be in place and communicated to personnel before any work in the hazard zone, except where there is an immediate life risk.

All decontamination should take place on-site to avoid spreading asbestos. In exceptional circumstances, personnel may need to continue decontamination off-site; following cleaning, a thorough visual inspection of any area used should be conducted to check for the presence of any dust.

The visual inspection is the most important assessment. If there is no visible dust/material then there is unlikely to be no significant risk.

When considering the site of the decontamination area the incident commander should:

- Establish routes of access to and egress from the building
- Establish sufficient distance from the hot zone to the decontamination area to ensure that no airborne contamination can reach the decontamination area (while remaining close enough to contain any decontamination run off to the initial site and limit the spread of asbestos)
- Determine numbers of personnel requiring decontamination
- Consider location of the BA entry control point
- Take wind direction into account
- Establish the location of the pump and availability of hose reels for washing off and damping down
- Consider the slope of ground and drainage
- Where possible, use a hard standing with good vehicular access
- Take into account weather conditions and the welfare of personnel

Decontaminating chemical protective clothing wearers

Chemical protective clothing wearers should be decontaminated using standard wet or dry methods as appropriate.

Decontaminating breathing apparatus wearers in structural firefighting PPE

Use a standard procedure. Breathing apparatus wearers should:

- Carry out visual inspection of each other for any exposed skin or hair, noting any areas/locations they find
- Vacuum each other with class H BS 8520-3:2009 vacuum cleaners that have true or absolute high efficiency particulate arrestor filters. Dry decontamination using a vacuum cleaner is [c1] [RM2] normally the appropriate first step in decontamination although it is not a complete decontamination process, particularly in wet and/or windy conditions. It should be followed by wet decontamination. Fire and rescue services should ensure that suitable equipment for decontamination is readily available;
- Damp down all areas of personal protective clothing to ensure that any particles cannot become airborne. They should start at the highest point (i.e. helmet) and work down, paying particular attention to folds and creases in the PPE
- Gently remove debris and dust using water spray, sponges, cloths, etc
- Remove helmets
- Gently wash off and wipe BA facemask and dampen fire hood
- Wash off boots and gloves
- Step into the undressing area or bag (in the dirty area)
- Remove contaminated gloves and don disposable gloves
- Remove firehood and BA set; the method used to remove the BA set must ensure that no residual contamination can be inhaled by the wearer
- Remove tunic
- Roll down overtrousers over boots, ensuring that they are inside out
- Carry out secondary check for contamination of skin and hair
- Thoroughly wash any areas found on either the initial inspection or this secondary inspection
- Carry out inspection of the clothes layer under the structural firefighting PPE. If any clothes are believed to have been contaminated, they must be damped down and removed.
- Step out of dirty area and into the decontamination clean area
- Remove disposable gloves and deposit in dirty area

All contaminated clothing and equipment must be assessed and cleaned appropriately. Generally, hard items can be wiped and rinsed clean. Soft or textured items may require a more thorough cleaning process. Fire and rescue services should decide on appropriate decontamination procedures for their specific PPE, RPE and other equipment in liaison with local competent cleaning contractors, and add this to their asbestos standard operating procedures.

Contaminated protective clothing that cannot be disposed of must be placed in dust tight bags and washed by a specialised laundry.

Where contamination is heavy or the number of wearers is large, this process can be enhanced by using decontamination operatives wearing appropriate RPE and PPE, based on a risk assessment of

the hazards and the likelihood of cross-contamination between wearers and operatives.

Decontaminating firefighters wearing respiratory protective equipment (other than breathing apparatus) and structural firefighting PPE

This level of decontamination should only be considered for lower hazard asbestos incidents (i.e. asbestos cement and textured coatings) and personnel who have not been involved in hot zone .

When decontaminating, the principle should be to vacuum/wet/wash/wipe areas that are visibly contaminated (e.g. dirt, dust, debris etc), or areas that are known to have contacted asbestos-containing materials (e.g. boots and gloves).

Procedure

- Make a visual inspection for any exposed skin or hair that has been visibly contaminated and note any areas/locations if they are found
- Remove and rinse helmet
- Wash off and sponge-wipe the areas of personal protective equipment that are visibly contaminated or have been touched by ACM
- Wash off gloves
- Wash off boots
- Wash any areas of skin or hair with visible contamination thoroughly
- Remove the RPE.

If the incident commander, hazardous materials adviser or decontamination director has any doubt about the effectiveness of the decontamination procedure, or the asbestos hazard level, the decontamination procedures for breathing apparatus (BA) wearers in structural firefighting PPE should be used.

Assessment of the effectiveness of decontamination of lower hazard asbestos (i.e. asbestos cement and textured coatings only)

If decontamination has effectively cleaned all visible deposits (dirt, dust, debris etc.) from personal protective equipment and other equipment then no further decontamination action should be necessary.



Where asbestos is discovered during an incident

The presence of asbestos-containing materials may not be confirmed or apparent until the closing stages, or even until the end, of an incident and personnel may already have been exposed if fibres have been released. In such circumstances, the unintentional spread of fibres may have already

occurred via:

- Clothing: fibres trapped in fabrics
- Breathing apparatus sets: fibres trapped on webbing, etc.
- Equipment: fibres trapped in crevices, etc.

Where asbestos is discovered during the course of an incident:

- Stop non-critical operations in the hazard zone and immediately assess the asbestos hazards
- Identify staff that may have been exposed and carry out decontamination measures
- Prevent personnel from coming into contact with smoke, fire plumes and airborne debris wherever possible
- Inform the fire control room, who may mobilise additional resources
- Reassess the response plan, tactics and working practices and implement asbestos procedures

Decontaminating appliances and equipment

If contamination is found on the outside of an appliance it should be removed using water spray. The likelihood of contamination of appliance interiors is considered to be extremely low provided all the procedures described above are followed. However, if it occurs, cabs should be ventilated and cleaned using disposable damp cloths which should be disposed of as asbestos waste. Lockers and equipment should be washed and wiped down with disposable cloths. Hose and other hard-surfaced equipment should be cleaned using water spray. The level of personal protective equipment and respiratory protective equipment for personnel carrying out this task will depend on the degree and nature of the contamination. This procedure should be carried out at the scene of operations to avoid the potential spread of ACM.



Closing incidents involving asbestos

Asbestos waste must be consigned to a site that is authorised to accept asbestos waste. Contaminated cloths and any other asbestos waste must be appropriately bagged, marked as asbestos waste and sent for specialist disposal.

At the end of any incident involving asbestos, further control measures will include:

- Liaison between the incident commander and the fire investigation officer: the fire investigation officer must be briefed on the location, condition, type and actual involvement of asbestos at the incident. This will allow them to carry out a risk assessment and decide on the appropriate level of personal protective equipment /respiratory protective equipment for their task. Consideration should also be given any need for decontamination.

- Handover of the incident to the appropriate authority: this will be the owner or occupier in most instances but if the site or building is derelict, unoccupied or it is not possible to contact the owner/occupier then the site should be handed-over to the police service or local authority, who have responsibility in these circumstances. The findings of the asbestos risk assessment must form part of the incident handover. Where there is a significant risk to the general public and it is not possible to hand over the site to a responsible person, consideration should be given to the positioning of appropriate warning signs.
- Extent of public health protection requirement: the local environmental health department and public health agencies should be informed whenever a service has attended an incident where asbestos is involved.
- Environmental impact and control measures: asbestos is an environmentally hazardous substance. Environmental agencies should be informed of substantial asbestos releases or informed as agreed in the local memorandum of understanding.

Responsibility for the clean up

The responsibility for the environmental impact and cleaning up rests with the owner/occupier of the premises.

Documentation

Fire and rescue services should maintain the following documentation and have it available for inspection by the Health and Safety Executive as required:

- Training records
- Details of decontamination procedures
- Maintenance records of all decontaminated equipment and test certificates, where appropriate
- Method statement (i.e. standard operating procedure for dealing with asbestos incidents)
- Risk assessment
- Records of respiratory protective equipment (RPE) inspections and tests
- Records of work activities involving possible exposure of staff to asbestos
- Exposure records for personnel.

Health records

Fire and rescue services must maintain a written health record for each individual who has carried out work activities that have involved exposure to asbestos (i.e. inhaled or ingested asbestos fibres). These records must be held for 40 years. Fire and rescue services should have procedures to record the individual circumstances of the exposure along with the asbestos risk assessment. Procedures should also exist for recording details of staff they suspect have been exposed.

Additional operational considerations when involved in fire



Image 108 Fire health hazards

Effect of fire and heat on asbestos

The mineral structure of asbestos fibre can be changed following prolonged exposure to heat. Research has shown that at temperatures above 450°C[1] asbestos fibres are denatured, rendering them of lower hazard than non-heated fibres. In fires, the outer layers of asbestos-containing materials are altered with the interior often remaining unaffected. This means those asbestos fibres present in the debris and ash may still present a risk to firefighters when turning over and damping down, albeit the risk is reduced.

Effect of fire and heat on cement asbestos-containing materials

It can be anticipated that temperatures in excess of 450°C would be required to release asbestos fibres from cement-bonded ACMs. Therefore, the risks from asbestos fibres and composite particles released from asbestos cement products during intense fire conditions is of lower risk than other operational scenarios. Also asbestos that exists within a cement material is heavily bonded within the cement matrix and consequently is far more difficult to get into a respirable form. Even where fibres are released, for example, following intense heating of asbestos cement roofing sheets where a characteristic popping of the sheeting can occur, they will not be released in isolation. It is highly likely that the vast majority of fibres, or composite particles, will be attached to larger fragments of cement. This means that the risk to health from asbestos inhalation is lower than for other ACMs as the body deals better with larger composite particles should they enter it.

Effect of fire and heat on chemical protective clothing

The current EAC for ACMs states chemical protective clothing (CPC) should be worn. However, most CPC offers very little protection against heat and fire. CPC is likely to melt, burn or malfunction in fire conditions, therefore it is extremely hazardous to commit staff wearing CPC to such environments and this should be avoided.



Hazards posed to the general public at serious fires involving asbestos

Public Health England has offered the following advice on serious fires in buildings involving asbestos-containing materials:

- The main health effect may be anxiety about potential health effects and contamination
- There is no evidence of direct health effects of asbestos particles released in fires, although the data are limited
- Available epidemiological evidence shows that long-term health effects are negligible
- The majority of asbestos involved in fires is likely to be chrysotile (white asbestos), which is considered to pose a lower hazard than other forms of asbestos, but there is the possibility of all forms of asbestos being involved in a fire
- Risks from short-term inhalation contribute only very slightly to total lifetime risk – one estimate of an extreme exposure scenario following a fire indicated that this would add a less than one in a million extra lifetime risk
- If in a good condition (unweathered) and if dampened down to suppress any potential release of fibres, ACM debris does not present a hazard to human health if handled carefully.

Public health mitigating factors

(“The public health significance of asbestos exposures from large scale fires” by KR Smith and P Saunders.)

- Not all asbestos-containing material (ACM) may be involved in the fire
- Fibres may be entrapped in larger pieces of material, etc.
- Respirable fibres will be a fraction of the total released
- Some fibres may be denatured at the temperatures involved
- Atmospheric dispersion and deposition (particularly as a result of rain) will reduce concentrations
- The duration of exposure will be short



Corrosive hazards

Materials whose primary hazard is corrosive will be assigned to U.N hazard class 8. It covers substances and articles which by chemical action attack epithelial tissue of skin or mucous membranes with which they are in contact, or which in the event of leakage are capable of damaging or destroying other goods or means of transport, and may also cause other hazards. The heading of this class also covers other substances that form a corrosive liquid only in the presence of water, or that produce corrosive vapour or mist in the presence of natural moisture of the air.

The corrosive nature of a material may be established practically by testing the solution with either litmus paper or pH paper. This is most easily done if the unknown material is in a liquid state; damp paper can be used on gases and solids although the results should be used with caution.

Most corrosives encountered are either acids, bases, alkalis or salts but a number of other materials in U.N. classes other than class 8 may have a corrosive hazard, e.g. chlorine, which is an oxidising, toxic, corrosive gas. Chlorine is a U.N. class 2 material because its primary hazard is that it is a gas, but anyone unwise enough to spray a leaking chlorine vessel will find that the spray will dissolve some of the chlorine to form a corrosive liquid that may attack the container or other unprotected metal surface. The [ADR](#) HIN will indicate if a material is corrosive (chlorine's HIN is 268).

Characteristics, classification and hazards of acids

Acidic materials

An acid is a material that will liberate H^+ ions into solutions in excess of any OH^- ions.

Characteristics:

Many acids react and corrode many metals to produce hydrogen gas but whether a particular reaction will occur or not depends on the particular acid and metal concerned and also on the conditions; whether the acid is concentrated or dilute and whether it is hot or cold. The hydrogen produced is both lighter than air and likely to produce flammable/explosive atmospheres in confined spaces.

Acids will produce carbon dioxide from a carbonate, e.g., sodium carbonate (soda ash). This reaction may be used as a test for an acid and in certain circumstances can be used to deal with acid spillages.

Acids are neutralised (potentially violently) by bases (or alkalis) to give salts and water. For this reason, it is not recommended that alkalis be used as neutralising agents for acid spills unless specialist advice is sought.

All acids have a sour taste in dilute solution. This can be observed in the organic acids contained in lemon juice (citric acid), vinegar (acetic acid) and sour milk (lactic acid).

Acids change the colour of some dyes and are consequently referred to as indicators. The best known of these substances is litmus; aqueous acids turn blue litmus paper to red

Acids are often corrosive to metal or flesh and hence toxic to some extent.

Acids, in solution, have a pH below 7.

Somewhere in the chemical formula of an acid (at the front for mineral acids) there will be at least one H (e.g. HCl , HF , HNO_3 , H_2SO_4). In the case of an organic acid the important H may not be so visible, as in the case of CH_3COOH . This is important, because unlike the other H s that can be found in chemical formulae, these H s can be released as H^+ ions into solution to carry out the typical reactions of an acid. Other H s found in the chemical formula are not freely available as H^+ and hence do not behave in the manner of an acid (e.g. methane (CH_4) or ethanol (C_2H_5OH)). Some experience of chemistry is required to recognise an acid from its chemical formula.

To determine how much acidic behaviour a material can exhibit, the chemical industry will determine how many H^+ are potentially released into each litre of acid and how many actually have been released.

The first parameter – how many H^+ can potentially be released – is expressed in terms of the concentration of the acid. A concentrated acid contains a lot of acid and a little water; a dilute acid contains a lot of water and a little acid. Unfortunately the assessment of how corrosive a material is cannot be limited to its concentration as not all acids are equally good at releasing all their H^+ all at once. The ability to release H^+ is described in terms of the strength of the acid. A strong acid will be good at releasing its H^+ while a weak acid not so good.

Operationally, the incident commander should be interested in how much acid is involved and how corrosive it is likely to be. The quantity can be used to consider the options available to deal with it and its corrosiveness can be used to assess the corrosion hazard.

The lower the pH values, the stronger and generally more concentrated the acid is; even a very concentrated weak acid is incapable of establishing a pH of less than three. A pH of less than three will mean the acid in question will be a strong acid. Almost all organic acids are weak acids.

The lower the pH, the greater the likelihood that the acid can corrode metals to form an atmosphere containing a flammable proportion of hydrogen, especially in a confined space where appropriate precautions will be demanded.

Concentrated and dilute may be applied to solutions of alkali in the same way that they apply to acids. These materials are essentially the opposite of acids as they take H^+ out of solution or release OH^- ions. A solution containing a lot of material potentially capable of doing this would be concentrated, while a material particularly effective at doing this rapidly would be strong. Any solution with a pH of more than 7 is an alkali and the more concentrated and stronger alkali solutions would have a pH close to the maximum value of 14. Weak alkalis would not be capable of establishing a pH of more than 12.

The pH scale is a logarithmic scale; when we dilute an acid to increase its pH we must increase the volume by a factor of 10 to increase the pH by one unit (e.g. to dilute 10l of acid pH 2 to increase the pH to 4 will require making the 10l into $10 \times 10 \times 10 = 1000l$ – doubling the volume will not halve the pH).

For further information see - [Corrosivity and pH](#)

Organic acids

Organic (carbon-based) acids are weak acids. Unlike their inorganic counterparts, organic acids will burn.

Unusual acids

- Picric acid is explosive when dry
- Peroxyacetic acid is a fairly typical organic peroxide
- Oxalic acid is toxic



Some important inorganic (or mineral) acids

Nitric acid (HNO_3) (aquafortis) is sold as a 70% solution and is referred to as concentrated nitric acid. It is possible to obtain 100% nitric acid, which is referred to as fuming nitric acid. The chemical behaviour of nitric acid depends on concentration:

- Very dilute solutions show typical acid properties
- Concentrated solutions also show oxidising properties.

With some metals (e.g., copper), concentrated nitric acid reacts to produce the brown toxic gas nitrogen dioxide (nitrous fumes). However, not all metals react in this way; for example, iron, aluminium and chromium react rapidly with nitric acid to form a layer of oxide. This oxide is insoluble even in concentrated acid and consequently prevents further corrosion (attack). Nitric acid is said to render these metals passive.

When heated, as in a fire, nitric acid readily decomposes, yielding nitrogen dioxide and oxygen. It falls into the assists fire category (oxidising).

Hydrochloric acid (HCl) (spirits of salt, muriatic acid) is marketed in the UK as concentrated hydrochloric acid, a solution that contains about 35% dissolved hydrogen chloride.

Hydrochloric acid is obtained by dissolving hydrogen chloride gas in water. On heating hydrochloric acid it releases fumes of hydrogen chloride, which are very pungent and irritating. As hydrogen chloride dissolves very readily in water, inhaling these toxic corrosive fumes results in the formation of hydrochloric acid in the lungs causing irritation and possible oedema.

Hydrochloric acid is not oxidising but does exhibit all the characteristics of a typical acid.

Sulphuric acid (H_2SO_4) (oil of vitriol): concentrated sulphuric acid can be marketed in two forms:

- Approximately 98% sulphuric acid
- Fuming sulphuric acid, oleum or pyrosulphuric acid, all names given to sulphuric acid containing dissolved sulphur trioxide (SO_3)

The properties of sulphuric acid may be considered under three headings:

- Behaviour towards water: sulphuric acid in concentrated solution is a very powerful dehydrating agent: it has the ability to remove and/or absorb large quantities of water. It does this with the evolution of a large quantity of heat, sufficient to boil the added water. Hence diluting such acid with water is a dangerous process and should be done with extreme care. For spillages requiring dilution, large volumes of water should be added from a safe distance (assuming neutralisation is not practical). Some organic compounds containing carbon, hydrogen and oxygen may be dehydrated (have water removed from them) by concentrated sulphuric acid. For example, sugar is dehydrated by concentrated sulphuric acid to produce sugar charcoal (i.e. carbon). Similarly any cellulosic material, cloth, paper, etc. undergoes a burning reaction with the acid.
- Behaviour as an acid: concentrated sulphuric acid (98%) contains little water and consequently shows little reaction towards metals at room temperature (at higher temperature the oxidising properties of the acid are significant: see below). When the concentration is reduced to a lower level, say 60%, the reactivity of the acid increases considerably. These facts suggest that if a spillage of concentrated sulphuric acid occurs, dilution with water will produce a more corrosive acid unless sufficient water can be added to make the acid very dilute; at this point the reactivity would again decrease.
- Behaviour as an oxidising agent: concentrated sulphuric acid is a vigorous oxidising agent, especially when hot, and is accompanied by production of the gas sulphur dioxide (SO_2). For example, copper can be oxidised to copper sulphate; the sulphur dioxide produced can dissolve in water to give the weak acid sulphurous acid (H_2SO_3). Sulphuric acid can ignite some organic compounds, especially if also in contact with another oxidant such as nitric acid, potassium dichromate, potassium chlorate, etc.



Other halogen acids

The other hydrogen halides, hydrogen fluoride, hydrogen bromide and hydrogen iodide, are all gases that dissolve in water to give acid solutions.

Hydrofluoric acid has the unusual property of dissolving glass and for this reason it is employed in

industries where etching or frosting of glass is performed. It is generally transported and handled in polyethylene containers.

When the toxicity of the common acids is compared, hydrofluoric acid is by far the most hazardous. Inhalation of hydrogen fluoride vapour causes oedema of the lungs, an abnormal accumulation of fluid in the lung cavities.

Due to its solubility in water, the acidic vapour dissolves easily in the eye and can permanently damage sight.

Externally, hydrofluoric acid causes more painful and usually more severe burns than the other mineral acids. Burns occur almost instantaneously from solutions stronger than 60%. Extremely severe burns can result from even a very mild exposure to the acid; tissues beneath the skin are destroyed, the destruction spreading even to the bones.

Chemdata and safety data sheets refer to the use of calcium gluconate antidote to treat hydrofluoric acid burns. Where an hydrofluoric acid risk is known to exist, preplanning should include the provision of the antidote cream.



Bases/alkalis - characteristics, classification and hazards

Basic (or alkaline) materials

Bases can be defined as any metal oxide, or as something that will react with acids to produce only a salt and water (sometimes violently).

Characteristics:

- Water soluble bases are referred to as alkalis
- Alkalis can corrode some metals to release hydrogen
- Bases can be very effective at removing flesh from bones; the strong concentrated alkalis are perhaps more corrosive to flesh than many strong concentrated acids
- Spills of bases can make surfaces very slippery, notably ladders and walkways
- Alkalis turn red litmus paper to blue, and have a pH above 7

Some important bases/alkalis

Sodium hydroxide and potassium hydroxide are important members of the alkalis:

- Sodium hydroxide (NaOH): caustic soda
- Potassium hydroxide (KOH): caustic potash

Both are white solids at room temperature and are marketed in pellet, flake and stick forms; all are very soluble in water. They are corrosive towards aluminium, zinc and lead but do not attack most other common metals. Concentrated solutions dissolve silk, wool and animal tissues.

Calcium hydroxide ($\text{Ca}(\text{OH})_2$) (slaked lime) is a white solid that dissolves only slowly in water to give a weakly alkaline solution, often called limewater.

Calcium oxide (CaO) (lime, quicklime) reacts exothermically with water to give calcium hydroxide. As with other alkalis, lime is corrosive towards eyes, skin, etc.

Ammonia (NH_3) gas dissolves readily in water to give ammonium hydroxide. It is frequently referred to as a weak base. Ammonia is encountered as a pressurised liquid (anhydrous ammonia) and in aqueous solution. The concentrated aqueous solution is known as 880 ammonia, where 880 indicates the specific gravity, or relative density is 0.88. Ammonia is flammable, although it has a relatively high LEL.

Organic bases: ammonia (NH_3) is a base and if one or more of the H's are replaced by organic groups then an organic base results (e.g. using CH_3 – a methyl group – to replace H we get methylamine (CH_3NH_2) and if we replace two H with two CH_3 we get dimethylamine ($(\text{CH}_3)_2\text{NH}$). As bases are corrosive and, to some extent, toxic and organic materials are flammable, it would be wise to expect these materials to be flammable, toxic and corrosive.



Other corrosives

Many materials are corrosive to flesh and metal although they are neither acids nor bases. Although the primary hazard of chlorine is that it is a gas, it is a notable corrosive as are other halogens and many of their compounds encountered as solids, liquids or gases. Virtually all non-metal chlorides, fluorides and bromides are corrosive along with some metal chlorides, notably aluminium and ferric [iron III].

Salts (not common salt, sodium chloride)

- II. should not assume that as a salt is the product of neutralisation then it is safe. Sodium cyanide is a salt but is highly toxic. Sodium peracetate is also a salt and is explosively unstable. Nitrates are generally strong oxidising substances. Many chlorides made by neutralising hydrochloric acid are corrosive in their own right. Sometimes the hazards of the parent acid are not exhibited by the salt (for example, sulphates made by neutralising sulphuric acid or otherwise are not water-reactive).

Neutralisation may remove the corrosive hazard of the acid or alkali, but it may accentuate other

hazards and generate a salt that is itself corrosive or hazardous in some other way. A list of common salts and the acid from which they were formed is shown below.

Table 50 List of common salts and the acid from which they were formed

Acid	Derived salt
Sulphuric	Sulphate
Sulphurous	Sulphite
Nitric	Nitrate
Nitrous	Nitrate
Hydrochloric	Chloride
Hydrofluoric	Fluoride
Acetic aka Ethanoic	Acetate, Ethanoate
Oxalic	Oxalate
Carbonic	Carbonate

The other half of the name of the salt comes from the base with which it has reacted (e.g. sodium hydroxide will produce sodium salts and ammonium hydroxide will produce ammonium salts).

Acids and alkalis are normally transported at very high concentrations (e.g. 90-95 % sulphuric acid, 65% nitric acid, 36% hydrochloric acid, 50% sodium hydroxide and 50% phosphoric acid). At these concentrations, the pH value is not important; the substances are simply very corrosive.

Corrosive substances can attack and corrode many materials, such as cloth, paper and several metals. Decomposition often produces heat and gases, and in some cases extremely flammable hydrogen gas.

It can take some time before the consequences of corrosive effects are visible.

Accidental mixing of different corrosive materials can in some cases lead to violent reactions which may give off large volumes of gases.

In the case of strong alkalis there is a latent period before a feeling of burning on the skin is experienced. By then the damage is already done. Skin contact with strong acids produces an immediate feeling. Both types of corrosive substances can cause serious skin and eye damage.



Radioactive materials

Radiation is the general term given to the process by which energy is transmitted away from an energy source. The term can equally be applied to heat, light, sound, microwave, radio or atomic sources of energy. This guidance is only concerned with the radiation arising from atomic sources as these alone have the property of causing ionisation when they interact with other substances and are often referred to as ionising radiations.

Ionising radiation generally arises by one of two processes:

- Radioactivity: this is the phenomenon by which unstable isotopes [*Isotopes are different forms of the same atom which are distinguished by having different numbers of neutrons in the nucleus but the same number of protons.*] of some atoms break down to form a more stable isotope of a different atom by expelling a small amount of matter from the nucleus (centre) of the unstable atom. Although there are several ways in which this can occur, by far the most dominant are by alpha emissions or by beta emissions. Shortly after an alpha or beta emission has occurred it is usually, but not always, followed by a gamma emission. Radioactive materials continue to undergo this process, often many millions of times per second until all the original unstable atoms have changed into the new stable atoms; the radioactive material then ceases to exist. Radioactivity cannot be destroyed other than by being allowed to decay away. The time taken for a radioactive source to reduce to half its original quantity is known as the half life. If a radioactive material is burned in a fire, the equivalent amount of radioactivity will still exist in the smoke and the ash.
- X-ray emission: this occurs when electrons are accelerated by high voltages inside an evacuated tube and are allowed to collide with a target made from a heavy metal, usually tungsten. The energy associated with the colliding electron is transmitted to the tungsten target and stimulates the emission of an X-ray from the target metal. Since X-rays can only be created through the application of a very high voltage, as soon as the electrical power is switched off, all X-ray emission ceases.

Radiological emergency incidents differ to other hazardous materials incidents in the following ways:

- Firefighters generally have no experience of radiation emergencies as they are very rare
- Even very low levels of radiation, which pose no significant risk, can be detected rapidly with simple, commonly available instruments
- Radioactive materials can cause radiation exposure even when firefighters are not in contact with them
- The health effects resulting from radiation exposure may not appear for days, weeks or even years

- The public, media and firefighters often have an exaggerated fear of radiation

Characteristics and classification

When describing radioactive processes extremely large numbers and very small numbers are frequently discussed. It is therefore necessary to be able to use multiples and sub multiples of the units used.

Table 51 Commonly used multiple and sub multiples

Fraction	Number	Prefix	symbol
10^{-9}	0.000,000,001	nano-	n
10^{-6}	0.000,001	micro-	μ
10^{-3}	0.001	milli-	m
10^0	1		
10^3	1000	kilo-	k
10^6	1000,000	mega-	M
10^9	1,000,000,000	giga-	G
10^{12}	1,000,000,000,000	tera-	T
10^{15}	1,000,000,000,000,000	peta-	P

As described above, there are in effect three types of radiation arising from radioactivity.

- Alpha radiation has the greatest ionising potential of the three types. However, partly because of this, it has very poor penetrating power. Typically, alpha radiation can only travel about three centimetres in air and is completely absorbed by very thin layers of other materials (e.g. paper, layers of dead skin or water droplets).
- Beta radiation has moderate ionising power. The penetrating range of beta radiation in air is approximately one metre. It is fully absorbed by relatively small thicknesses of metals and plastics (e.g. one-centimetre thick Perspex)
- Gamma radiation has the lowest ionising potential of the three types but by far the greatest penetrating power. Gamma radiation will travel many hundreds or even thousands of metres in air. It is capable of passing through solid materials such as brick, concrete and metals

although it will be attenuated as it does so. The more matter it passes through, the more its intensity is reduced. For this reason, dense metals such as lead or steel are the most efficient at absorbing gamma radiation.

Other nuclear processes give rise to radioactive emissions but these are much less common and are therefore beyond the scope of this guidance.

When measuring radiation (alpha beta, gamma or X-ray), two properties need to be classified; the activity (or strength) of the source and the dose (or amount) of ionising energy that is being absorbed by the body.

The modern unit of activity that has been adopted throughout Europe is the Becquerel (Bq). All radioactive sources found in the UK legally have to be measured in Becquerels. However, the Becquerel is an extremely small quantity (defined as one nuclear disintegration per second) and most sources will have activities of thousands, millions, billions or even trillions of Becquerels. This means that the usual SI multiples of kilo-, mega-, giga-, tera-, etc. are often encountered when recording the activity of a source. It should be noted that an older unit, the Curie, is sometimes encountered, particularly if the source originally came from the USA. Becquerels and Curies measure the same dimension in much the same way as centimetres and miles measure the same dimension but on a different scale and magnitude of measurement.

The modern unit that has been adopted throughout Europe for measuring the radiation dose received by a person is the Sievert (Sv). All personal dose (and dose rate) measurements must legally be expressed as Sieverts. In contrast to the Becquerel, the Sievert is a very large unit, and the common SI sub-multiples of milli- and micro- are commonly encountered.

Another unit of dose, the Gray, is also widely used throughout Europe. Under most circumstances the Sievert and the Gray are numerically identical. The differences between the two units are beyond the scope of this guidance and can be ignored.

Different units for dose measurement are used in the USA; the Rad (dimensionally equivalent to the Gray) and the Rem (dimensionally equivalent to the Sievert); one Rem is equal to 10 millisieverts (mSv).

Most hand-held monitoring equipment measures the dose rate, which is the speed at which dose is being accumulated, although only the total dose received is relevant as the cause of health problems.

A simple analogy that may assist firefighters in understanding the difference between dose and dose rate is a journey in a car:

- The dose a firefighter has received, usually measured in millisieverts (mSv), can be compared to the distance travelled as shown the car's odometer (miles)
- The dose rate, usually measured in millisieverts per hour (mSv/hr), can be compared to how fast the car is travelling at any given moment, as shown on the car's speedometer (miles per hour)

Hazards

Two principal hazards arise from radioactivity, regardless of the type of radiation:

- Irradiation, which presents an external risk (i.e. from outside the body)
- Contamination, which presents both an internal (i.e. inside the body) and possibly an external risk



Irradiation

Irradiation is mainly a problem with materials that emit gamma radiation or from X-ray machines. Ionising energy is radiated out from the source and passes through a person's body. As it does so, some of the energy is absorbed by the body tissues and the ionising properties can cause chemical changes in human cells. This can lead to damage and possibly disease. However, the source material never enters the body but a hazardous materials exposure has occurred and a radiation dose will be received.



Radioactive contamination

Contamination is a potential problem with any radioactive material except electrically generated X-radiation. If a material that contains radioactive isotopes is in a form that is easily dispersed (i.e. dusts, powders, liquids, gases) the radioactive substance can become attached to the exterior of the body by direct contact or airborne dispersion (e.g. dust, spray, mist, etc.). It may also enter the body through inhalation, ingestion or through an open cut or wound. In this sense, internal radioactive contamination poses much the same threat as any other chemical toxin or hazardous materials exposure. Once inside the body, alpha and beta emissions, which were not considered high risk in terms of external contamination, may produce damaging ionising radiation directly into the cells of the lymph system, blood and internal organs.



Sealed and unsealed sources

It is important for emergency responders to make a distinction between sealed (closed) sources of radioactivity and unsealed (open) sources of radioactivity.

A sealed source is a radioactive source encapsulated into a solid material, usually metal. The encapsulation is intended to prevent radioactive material escaping, while allowing the radioactive energy to pass through. Sealed sources are designed to withstand rough handling and elevated temperatures without releasing the radioactive material. Because the radioactive source substance is encapsulated or plated onto a surface, sealed sources do not present a contamination hazard under normal conditions; however, they can present an irradiation hazard.

Unsealed sources consist of powders, liquids or sometimes gases that contain radioactive elements and that could easily be released from their containers through leaks and spillages and dispersed into the environment. The main hazard with unsealed sources is contamination, although there may also be a significant irradiation hazard from the bulk material.

Shielding – both sealed and unsealed sources are generally stored or transported in such a way that they are shielded by solid materials, usually their containers. These prevent or limit irradiation hazards. If a source's shielding is removed or damaged the radioactive hazards are increased.



Damage caused by radiation

The damage caused by radiation may be divided into two different categories:

- Deterministic effects are those that occur at a relatively high dose; the severity of the effect is proportional to the dose. In all cases it is necessary to exceed a threshold dose before the effect is experienced at all. The most common effects in this category are skin reddening, hair loss, impaired fertility, lowered blood count, nausea, vomiting and diarrhoea. The threshold for detectable deterministic effects is about 100mSv. At this level no symptoms would be exhibited, but tests on blood may start to show signs of damage. As dose levels increase the severity of effects and the rapidity of their onset increases. Doses above 5000 millisieverts in a short period of time are life threatening.

- Stochastic (or probabilistic) effects are those where the probability of experiencing the effect is proportional to the dose but the severity of the effect is independent of the dose. The most common effect in this category is cancer; the likelihood of contracting cancer increases with the dose but the severity of the disease is the same irrespective of the dose that caused it. Genetic effects are also believed to be stochastic although these have never been demonstrated in humans. As such, it is assumed that any level of dose of radiation carries some risk and therefore all doses need to be kept as low as possible.

In summary, if the total dose is kept below 100 millisieverts, there will be no risk of any immediate effects such as skin reddening, hair loss, reduced fertility, nausea, etc. However, the maximum annual dose to all radiation workers (male and female) is set much lower than this to additionally ensure longer term risks are kept very low (See Dose Limits)

All doses referred to in this document are whole-body doses unless otherwise stated. The IRR allow for higher annual doses if the radiation is delivered only to localised parts of the body. However, this is a very specialised area of workplace safety and is beyond the scope of this guidance document.

Table 52 Summary of whole body dose and effect

Dose	Effect	Comments
5 Sieverts (5,000 mSv, or 5,000,000 Sv)	Probable lethal dose	Very dependent on rate of delivery and health of individual
3 Sieverts (3,000 mSv or 3,000,000 Sv)	Erythema (skin reddening)	May not appear for several days
3 Sieverts (3,000 mSv or 3,000,000 Sv)	Depilation (Hair loss)	Temporary between 3 and 7 Sv; permanent above 7 Sv.
1 Sievert (1,000 mSv, or 1,000,000 Sv)	Threshold for radiation sickness	Dependent on other factors, e.g. health, rate of delivery, skin type, etc.
700 mSv (700,000 Sv)	Threshold for temporary sterility	Can be permanent at higher doses in excess of 3 Sv

Dose	Effect	Comments
100 mSv (100,000 Sv)	Chromosomal changes in blood cells detectable. Small increase in existing cancer risk	Minimum dose at which any physical changes can be detected. No noticeable effects by the person receiving the dose
5 mSv (5000 Sv)	Very small increase in overall cancer risk	No immediate observable effects

This table is designed to give a general awareness of the order of magnitude required for various effects to be observed and should only be regarded as a very approximate guide. In practice, many other factors would be likely to influence the response to various levels of dose.



Use of radioactive materials

Radioactivity has a number of uses in society; these may be summarised in an approximate order of severity of hazard:

Weapons



Image 109 Vanguard class submarine carrying trident nuclear missiles

Nuclear weapons and their use, manufacture and transportation are subject to the highest levels of security; it is unlikely that fire and rescue services would ever be called on to attend an incident involving a nuclear weapon without there also being an emergency response with expert advice from the military. The Ministry of Defence (MoD) maintains a Nuclear Accident Response Organisation (NARO) to respond to an incident involving defence nuclear assets, including any

arising through terrorist acts. For fixed MoD sites, local arrangements should be in place to integrate the fire and rescue service response with that of the base site.

For road convoys, hazardous materials information and other safety information is available from the Convoy Command Team.

For air accidents involving nuclear materials, a response team will deploy by helicopter to assist at the incident.

Further information is available in the [Local Authority and Emergency Services Information \(LAESI\)](#); Defence Nuclear Materials Transport Contingency Arrangements on the MoD website.

Power production

The UK currently has several sites where electricity is generated by nuclear means. These are all based in coastal locations. As part of the nuclear fuel cycle, there is also a nuclear fuel production facility near Preston in Lancashire and the nuclear reprocessing works at Sellafield in Cumbria. The power stations themselves are secure locations with their own emergency teams. The hazards associated with the reactor and with stored nuclear fuel on site are high, although the risk of an accident is generally accepted to be low.

Spent nuclear fuel (i.e. fuel that has been removed from the core of the reactor, is highly radioactive and probably represents the greatest potential radiation hazard anywhere in the UK. When fuel is removed from the reactor it is stored on-site for several months in ponds, before being transported to Sellafield by rail in specially-constructed steel containers known as fuel flasks. These are extremely robust, but they are filled with water for cooling and shielding purposes; loss of cooling water could be a potentially serious problem. The total inventory of a fuel flask is likely to be hundreds of TBq or more.



Image 110 Fuel flask used to transport spent fuel back to Sellafield

New fuel is not highly radioactive and is transported to power stations by road. Uranium ore, ore concentrate and uranium hexafluoride are the raw materials used by the fuel production facility. The chemical properties of these materials are usually more problematic for the emergency services than their radiological properties.

Sterilisation plants

Very large sources of gamma radioactivity, usually cobalt 60 with activity of up to 10 PBq, are used

to sterilise instruments and utensils. These are always sealed sources and therefore the main hazard arises from irradiation.

Medical diagnostics

The main type of radiation used in diagnostics is X-rays. These do not pose a risk to firefighters if the power has been switched off.

Specialist departments within hospitals may use radioactive materials that are either ingested or injected into the patient prior to the radiation emissions being detected in a scanner. These tend to be materials with a short half-life, because the doctors do not want the radioactivity to remain in the body longer than necessary. The most commonly used material is technetium 99m (Tc-99m). It is usually supplied by a pharmaceutical company and is delivered by road. Other radioactive pharmaceuticals (e.g. iodine 131) may also be produced by a company and sent to hospitals or clinics. Sometimes these materials are shipped to or from the UK by air. It is not unusual for fire and rescue services to be requested to attend radiation incidents in the cargo handling areas of airports where packages have been compromised. These radioactive pharmaceuticals are usually encountered in MBq quantities.

Some hospitals may have their own facilities for producing short lived radioactive isotopes; these are produced in a particle accelerator known as a synchrotron.



Image 111 Iodine 131 packages damaged in cargo warehouse

Medical treatment

The main types of medical treatment are chemotherapy, which involves injecting radioactive drugs into the body, and radiotherapy, which involves the external exposure of body to highly collimated (directional) beams of gamma radiation. Radiotherapy sources are usually highly active but are well shielded in steel and lead housings. Radiotherapy frequently uses cobalt 60 as the source, with activity up to about 10 GBq.

Brachytherapy sources are also used, which are inserted into the body to deliver a localised radiation dose (e.g. Cs-137)



Image 112 Brachytherapy sources used for localised radiation therapy

Industrial radiography

These instruments are often found on construction sites and are used during the construction of load-bearing structures to check for defects. Powerful gamma emitting radionuclides are housed inside a shielded metal box with a shutter at one end. The box is placed in front of an engineering structure (usually during the construction phase), to take an X-ray (in fact it is a gamma ray) image of an engineering component to determine if it is free from defects and therefore able to withstand the load being applied to it. The shutter is normally opened and closed remotely by using a bicycle cable operating system. Although often referred to as X-rays, these instruments do contain radioactive sources and cannot be made safe by simply cutting the power supply.

These instruments typically contain iridium 192 with activity in the range of 10 to 6000 GBq.

Industrial process measurement (level gauges, density/moisture gauges)

Level or thickness gauges may often be encountered on production lines. They generally use a beta source such as strontium 90 to determine whether or not the objects passing between the source and a detector are of the correct thickness or filled to the correct level. The size of the source is typically 1 MBq.

Combined density and moisture gauges are often used on site in civil engineering projects for testing road surfaces. These use a caesium 137 source of approximately 300 MBq and an americium 241 source (combined with beryllium to produce neutrons) of approximately 1.5 GBq.

Agricultural sources

Combine harvesters sometimes have a yield gauge that may contain an americium-241 source of approximately 35 MBq.



Image 113 Massey Ferguson combine harvester with grain level gauge

Teaching and research

The size and type of radiation are subject to wide variation dependent on the particular research interests of the establishment concerned. The largest sources are likely to be found in the physics department of a university or the medical research department of a hospital.

Anti-static devices

These are used to prevent the build up of static electricity in some industrial processes by ionising the air around them. The most widespread application is in a car body repair work shop where paint spraying is conducted. Spray shops typically use sources of polonium 210 with activities up to 5 GBq.



Image 114 Anti-static brush

Scientific instruments

Small radioactive sources are sometimes used, particularly in measuring instruments, to ionise the material under test to allow its analysis. Typically, the sources are fairly small in the region of 1 kBq to 1 MBq.

Luminising

Radioactive materials are sometimes mixed with light emitting materials known as phosphors to convert radiation energy into light energy (e.g. the luminous hands on a watch). Any modern luminous article will be fully encapsulated so that little or no radiation can be measured outside of the article. However, older articles (typically manufactured between the 1940s and the 1960s might contain significant quantities of radium 226, such as the original instruments on a Second World War Spitfire). There are a number of sites around the country where luminising operations have taken place in the past, which may have resulted in significant contamination of the ground and/or buildings.



Image 115 Luminised watch dial

Gaseous tritium light devices

Tritium is a radioactive isotope of hydrogen. It is sometimes used as an energy supply inside a glass tube to energise phosphor coatings that then emit light. These are known as gaseous tritium light devices (GTLD). They are self-contained light emitting devices, i.e. they have no external power source. They may be encountered in various locations where self-luminous signs or objects are in use. It is worth noting that the amount of tritium in individual devices will not give rise to a significant risk even if broken and the tritium is released. However, if fire and rescue services are mobilised to a premises where these devices are manufactured or stored in bulk, there may be terabecquerel amounts on site and special precautions may be appropriate.

At any incident involving tritium, the principal concern will always be contamination rather than irradiation. Tritium emits weak beta radiation only and has one of the weakest energy emissions of any radioactive material. Because of this it presents a unique problem in that no hand-held instrumentation sufficiently sensitive to detect it is available to fire and rescue services.

It is therefore recommended that if a fire and rescue service is mobilised to an incident involving a potential release of tritium, appropriate chemical protective clothing and breathing apparatus is donned if entering a building. It is recommended that all responders contaminated by a significant release of tritium should undergo biological monitoring, as it can breach chemical protective clothing in certain circumstances. This will require the personnel affected to provide urine samples, which will be analysed subsequently to determine the quantity of any tritium absorbed and to calculate any resultant internal dose.

It is worth noting that tritium may be found stored in a glass flask in gaseous form, or it may be found as either tritiated water (HTO) or organically bound tritium (OBT) where the radioactive form of hydrogen is substituted for normal hydrogen. If gaseous tritium is involved, it readily exchanges with normal hydrogen atoms in molecules and therefore firefighting water run off may quickly become a source of tritium and could spread contamination widely.



Image 116 Luminous key rings incorporating tritium

Smoke detectors

A small source of americium 241 typically 50 kBq is used in some domestic smoke alarms.

Lightning conductors

In the past, radium 226 up to 500 kBq has been used as part of the construction on lightning conductors to improve their efficiency. Although they are no longer used in modern lightening protection systems, these sources may still be found in older buildings, particularly in church steeples.



Image 117 Lightning conductors



Transportation of radioactive materials

The transport of radioactive materials within the UK is governed by strict regulations

The general requirements for all packaging and packages used for the transportation of radioactive substances and articles are that:

- The package shall be so easily and safely transported and shall be designed that it can be properly secured in or on the conveyance during transport
- Any lifting attachments on the package will not fail when used in the intended manner and shall take account of appropriate safety factors to cover snatch lifting
- As far as practicable, the packaging shall be designed and finished so that the external

surfaces are free from protruding features and can be easily decontaminated

- As far as practicable, the outer layer of the package shall prevent the collection and the retention of water. Any features added to the package at the time of transport that are not part of the package shall not reduce its safety.
- The package shall be capable of withstanding the effects of any acceleration, vibration or vibration resonance. In particular, nuts, bolts and other securing devices shall be designed as to prevent them from becoming loose or being released unintentionally, even after repeated use.
- The materials of the packaging and any components or structures shall be physically and chemically compatible with each other and with the radioactive contents. Account shall be taken of their behaviour under irradiation.
- All valves through which the radioactive contents could otherwise escape shall be protected against unauthorised operation
- The design of the package shall take into account ambient temperatures and pressures that are likely to be encountered in routine conditions of transport
- For radioactive material having other dangerous properties, the package design shall take into account those properties.

There are five basic container types for the transportation of radioactive materials:

- Excepted packages: may survive a minor accident
- Industrial packages: may survive a minor accident
- Type A packages: survive a minor accident
- Type B packages: survive a major accident
- Type C packages: survive an air accident

Excepted packages

These are for certain very small quantities of radioactive materials, marking with the UN number is a requirement under the latest transport regulations. Common examples are radiopharmaceuticals, calibration sources and some experimental apparatus. Surface dose rates must be below 0.005 mSv per hour. Excepted packages can be conveyed by all modes of transport in the UK (including the postal service)

Industrial packages

These are for materials with very low concentrations of radioactive material, possibly also in forms that are not easily dispersed. They are basic containers used for materials of low specific activity (LSA) or surface contaminated objects (SCO), such as natural uranium ores or depleted uranium and worn protective clothing such as gloves and overalls. These containers are not necessarily expected to survive accident conditions. These packages are usually transported by road, rail or sea, although some air transport does occur.

Type A packages

These are for relatively large quantities of radioactive materials (compared with Industrial packages) such as radiopharmaceuticals or radiochemical. Packages are designed to withstand

minor accidents and only release a small fraction of their contents in a more serious accident. Surface dose rates are normally limited to no more than 2 mSv per hour. These packages are normally conveyed by all modes of transport, especially air, as this reduces travel time for short-lived isotopes.

Type B packages

These are for larger amounts of radioactive materials, such as irradiated nuclear fuel, nuclear wastes or large radiation sources for radiotherapy. They are very strong packages and typically contain large quantities of radioactive material. They are specially designed containers able to withstand accident conditions. Surface dose rates are generally much less than 1 mSv per hour, and are limited to 2 mSv per hour under standard conditions. Type B packages are the predominant package type conveyed by rail, they are also transported by road, air and sea.

Type C packages

These are for large amounts of radioactive materials carried by air. They are robustly designed packages for high-activity dispersible sources, including fissile material exclusively for air transport. Testing these packages ensures that the package remains intact should it be involved in an air accident. Type C packages are relatively rare internationally.

Other packages

In nuclear engineering, a fissile material is one that is capable of sustaining a chain reaction of nuclear fission. Fissile materials can be used to fuel:

- A nuclear reactor (e.g. at a nuclear power station)
- A nuclear explosive

Fissile material can be carried in industrial packages, Type A packages, Type B packages or Type C packages, but in this case the package will be designed to withstand accidents similar to the Type B or Type C package.

An additional type of package is used for uranium hexafluoride. These packages may be any of the above types (except not normally Type C). However, they require special treatment in emergencies, particularly in fires. These packages are normally cylindrical and range in size. They may be contained in a protective outer box, which gives the package protection against severe accidents. The material they carry is corrosive in nature, reacting with water to form hydrofluoric acid and this may be the major concern in an emergency. The radioactive material they carry is often of such a low concentration that there is little risk from radiation.



Marking and labelling

Radioactive materials are classified under UN category 7.

Unless the package is an excepted package (in which case it is unlabelled), all packages are labelled according to the external radiation hazard associated with the individual package, as represented by the maximum radiation dose rate at the surface of the package. This rate of surface radiation is defined by the term transport index (TI). TI is used to express the external radiation hazard arising from a package in practical terms. The TI is determined by measuring the radiation dose rate at one metre from the package in $\mu\text{Sv}/\text{hour}$ and dividing the measured value by 10. If the material is fissile, the TI is accompanied with the 'criticality safety index', which is defined and measured differently. For further information regarding the transport index see the Regulations for the Safe Transport of Radioactive Materials, published by the International Atomic Energy Agency (IAEA).

For the purpose of labelling, type A and type B packages are divided into three categories:

- Category I – white
- Category II – yellow
- Category III – yellow

The images 118 -119 show labels for radioactive substances. They must include the radiation trefoil symbol, the name or symbol of the radionuclide, the activity (in Bq multiples) and the TI in the case of category II and III packages. Labels must be fixed to two opposite sides of the outside of the package.

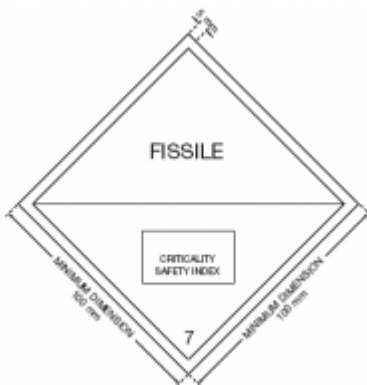


Image 118 Fissile material



Image 119 Radioactive substance



Where the consignment in the freight container or tank is unpackaged LSA-I or SCO-1, or where an exclusive use consignment in a freight container is packaged radioactive material with a single United Nations number, the appropriate United Nations number for the consignment shall also be displayed in black digits not less than 65 mm high, either in the lower half of the placard and against the white background, or on the placard.



Image 121 Category I-WHITE label



Image 122 Category II-YELLOW label



Image 123 Category III-YELLOW label



Documentation of radioactive materials

ADR does not require that a transport document (consignment note) be prepared by the consignor and accompany the package when it is transported, but in practice it usually is. If the package is to be transported by more than one mode of transport, it is accepted practice for a single transport document to be provided; for example, in the case of a package travelling by road to the airport, thence by air, the document provided would be the airline's shippers' declaration for dangerous goods.

The transport document must include a signed declaration by the consignor and specified information relating to the package, including the UN number and proper shipping name assigned to the material. In addition, the consignor must provide the carrier with a written statement of any additional actions required of the carrier, such as any supplementary operational requirements relating to the loading, stowage, transport or handling, and any emergency actions appropriate to the consignment. Where no such supplementary operational requirements are necessary, a written statement to this effect must be provided to the carrier.

ADR requires that all transport documents are provided for excepted packages, and specifies that the information be provided in respect of each package.

The information contained in the documentation will give details such as:

- Name and address of the consignor
- Contact telephone number
- Name of material(s) being carried
- Description of materials
- Activity of material
- Package category
- Transport index

Other warning signs to be displayed

In the UK, unless the vehicle is carrying only excepted packages, it must also display either:

- A fireproof notice (a stamped metal plate) in the vehicle cab that it is plainly visible to the driver
- Rectangular, reflective, orange-coloured plates at the front and rear of the vehicle

The fireproof notice or orange-coloured plates must be removed or covered when the vehicle is not

carrying radioactive consignments.

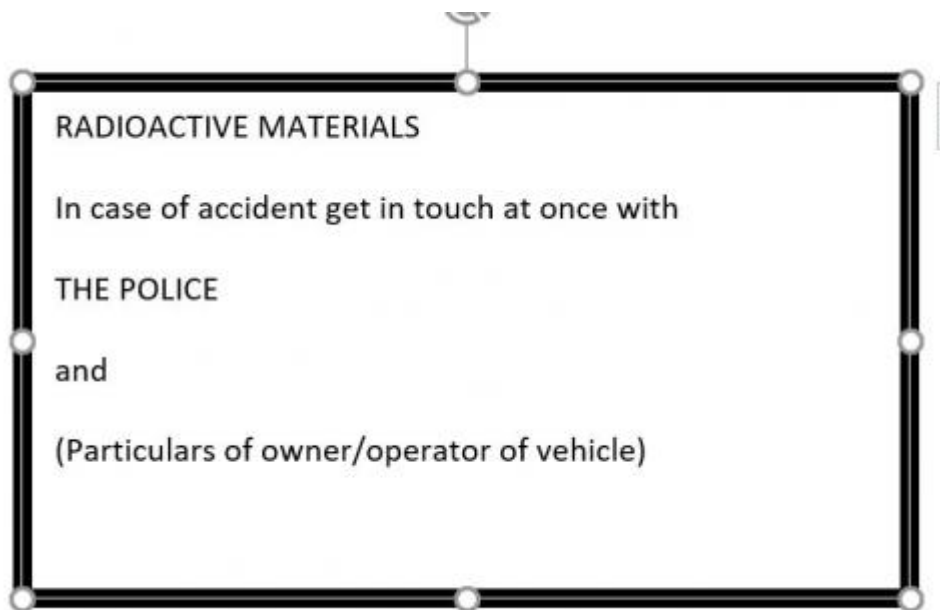


Image 124 Fire proof notice



Vehicle placarding for transport of radioactive materials

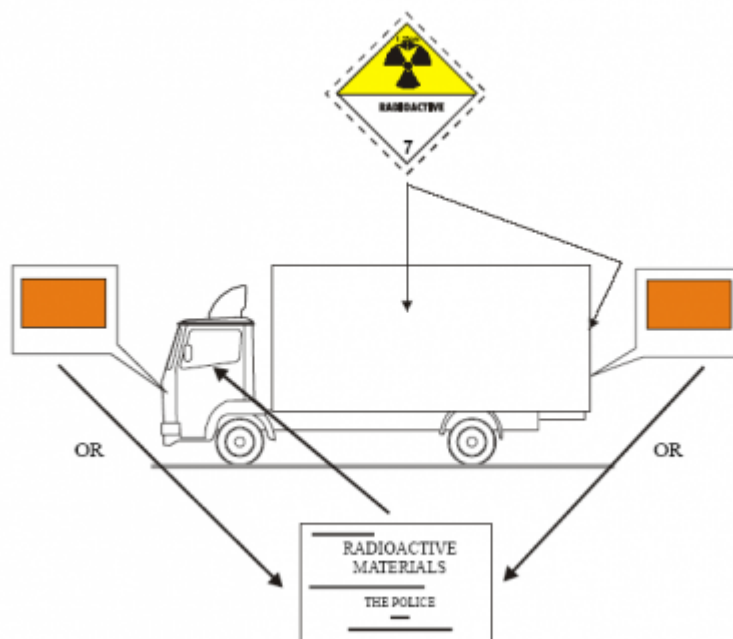


Image 125 Vehicle placarding for radioactive materials



Storage of radioactive materials

The storage of radioactive materials is regulated via the Environmental Permitting Regulations 2010 (EPR2010), and the Radioactive Substances Act 1993 (RSA93). EPR2010 came into force on 6 April 2010 in England and Wales, whereas RSA93 is still in force in Scotland and Northern Ireland. Section 23 of EPR2010 contains most of what was previously contained in RSA93.

Any operator handling or storing radioactive materials must be registered under RSA93 or EPR2010.

- Section 7 of the Act deals with the storage conditions of sealed and unsealed sources.
- Section 10 deals with the storage of mobile sources.
- Sections 13 and 14 deal with the conditions under which sources may be accumulated and disposed of

If an operator stores sealed sources with activity in excess of a certain limit (limits vary according to the type of source) the High Activity Sealed Sources and Orphan Sources 2005 (HASS regulations) must also be complied with. These regulations are now incorporated into the Environmental Permitting Regulations in England and Wales (Section 23).

HASS is designed to ensure the security of high-activity sealed sources to prevent them falling into the hands of terrorist groups. Among other things, the organisation seeking to store the sources must contact the counter terrorism security adviser of the local police service who will give recommendations on the physical security of the storage. An authorisation under RSA 93/EPR2010 will now only be issued if these recommendations have been followed.

In addition HASS requires the organisation to have suitable management processes in place to control and account for the use of the radioactive materials. Provision must also be made in the financial accounts to cover the cost of final disposal.

Pre-planning

Fire and rescue services should, wherever possible, adopt a proactive approach to identifying potential radiation sources within their response area. The use of radioactive materials is tightly controlled in the UK through the Radioactive Substances Act 1993 (RSA93) and the Environmental Permitting Regulations 2010. All users of radioactive materials must be in receipt of an authorisation under Section 8 of the Act to hold radioactive materials. The authorisation states the maximum activity of each radionuclide the user may hold and whether the source is sealed or unsealed.

Copies of all such authorisations are sent to the relevant fire and rescue service. It is recommended

that an easily accessible central register of all these notifications is maintained. When the fire and rescue service has compiled a register of the location of the registered source users, it is good practice for the local fire station to arrange for familiarisation visits. The fire and rescue service may need to prioritise the visits according to the nature of the sources or possible complexity of on-site processes.

Ionising Radiation Regulations (IRR)

The [Ionising Radiation Regulations](#) (IRR) are made under the Health and Safety at Work Act. They place a duty on the employer (i.e. the fire and rescue authority) to put systems in place to ensure that employees are protected from excessive exposure to radiation. As part of the pre-planning procedure fire and rescue services must have a written procedure stating how they will manage a radiation incident and how they intend to discharge their duties under the ionising radiations regulations. In particular, the document must address the following points:



Dose limits

The maximum annual dose to all radiation workers (male and female) is 20 mSv. Firefighters attending a radiation incident fall under the definition of a radiation worker. There is an additional limit on women of reproductive capacity of 13 mSv in any three-month period; this additional restriction is to protect a recently conceived foetus in a woman who may be unaware of her pregnancy. In this sense it is not so much a restriction designed for the protection of women, but is a restriction designed to protect a foetus.

Under the IRR, Further restrictions apply to women who have announced they are pregnant or breast feeding but it is assumed that women firefighters would not be used in an emergency operational capacity once the pregnancy was declared.

Dose constraints

The regulations stipulate that, where appropriate to do so at the planning stage, dose constraints are used to restrict exposure to radiation as far as is reasonably practicable. This dose constraint will usually be significantly lower than the legal dose limits. Fire and rescue services should consider any possible operations not involving situations immediately threatening to life where they may wish to impose a dose constraint below the legal annual limit. This could possibly be the case at a protracted incident or if it was considered possible that crews may have to attend more than one radiation incident within a 12-month period.

It is recommended that a dose constraint of 5 mSv per incident is introduced at operational incidents. The reasons for this level of constraint are:

- It corresponds to the alarm setting on the electronic personal dosimeters supplied through the fire and rescue service national resilience project, which would naturally prompt staff to leave the hazard zone
- It is in line with dose reference levels used by the ambulance service
- It does not legally preclude women firefighters from entering the hazard zone as it is less than 13 mSv
- If a firefighter were to receive a dose in excess of one third of any formal dose limit (i.e. 1/3 of 20 mSv), the employer must conduct an investigation into the circumstances. This would equate to approximately 6 mSv for a whole body dose as measured by an EPD; by using 5 mSv as the dose constraint level this should avoid crossing this reporting threshold.

'As low as reasonably practicable'

At all times, it is not simply sufficient to avoid exceeding dose constraints or dose limits, fire and rescue services must take active measures to ensure that all doses received are as low as reasonably practicable (ALARP). Dose limits are not aspirational; they are the last line of defence. In practical terms, this means that if a task can be carried out in more than one way and one method is likely to result in lower radiation doses, this method must be used if reasonably practicable.



Emergency exposure to radioactive materials

Although the preceding paragraphs are based on the legal requirements under IRR, there is an exception to these dose limits. Under the Radiation (Emergency Preparedness and Public Information) Regulations 2001 (REPPPIR) it is permissible to disapply the IRR dose limits at a licensed nuclear site or at an incident involving transport by rail if in doing so it might be possible to save life or maintain critical infrastructure.

these instances it may be permissible for an informed volunteer to be exposed to a dose of up to 100 mSv [*The figure of 100 mSv is not stipulated in the REPPPIR, it has been arrived at through multi-agency collaboration. Where fire and rescue services have licensed sites within their turn-out areas they should develop risk-assessed emergency exposure procedures with site operators*]. The authorisation for the disapplication of dose limits (i.e. allowing emergency exposure to take place) must be given by an officer or manager within the fire and rescue service who has received appropriate training.

The REPPPIR Regulations state that employees of the emergency services who may receive emergency exposures should be pre-identified as part of the planning process. Fire and rescue services should liaise with radiation risk operators or carriers, as appropriate, to obtain the expert advice needed to plan for emergency exposures.

Fire and rescue services that develop emergency exposure operational procedures disapplying the

dose limits in IRR should record specific risk assessments on this aspect of their plans. Even when operating under emergency exposure conditions the principles of ALARP should still be taken into consideration

For CBRN(E) incidents, fire and rescue service should note that REPIIR applies to premises and transportation where a known source of certain strength exists. This is clearly not the case in a terrorist attack involving a radiation source at other premises. In this case, the IRR cannot legally be disapplied and the limitations in the regulations indicated above will apply. This anomaly in law has been recognised and after consultation with the Nuclear Installations Inspectorate the following has been determined:

“Terrorist incidents are not considered by HSE to be applicable to either the [Ionising Radiation Regulations](#) (IRR) or The Radiation (Emergency Preparedness and Public Information) Regulations 2001 (REPIIR). However REPIIR does provide a good framework which can be used for planning and management of risk with regard to intervention at this type of incident”.

Informed volunteers

An informed volunteer in terms of the application of the REPIIR Regulations is a radiation worker who has agreed to receive an emergency exposure above the limits imposed by IRR.

To be considered as an informed volunteer a firefighter should have received:

- Appropriate training in the field of radiation protection
- Suitable and sufficient information and instruction for them to know the risks to health created by exposure to ionising radiation and the precautions that should be taken
- A briefing* on the risks and control measures associated with the specific emergency tasks in question

*informed volunteers should be asked to confirm their agreement to potentially receive an emergency exposure at this briefing.

The REPIIR Regulations also require that employers of informed volunteers:

- Provide equipment that is necessary to restrict the exposure of informed volunteers to radiation
- Identify, and appropriately train, managers/officers who are authorised to permit informed volunteers to be subject to an emergency exposure in the event of a radiation emergency
- Make arrangements for medical surveillance by an appointed doctor or employment medical adviser to be carried out without delay in the event of a radiation emergency
- Make arrangements with an approved dosimetry service (ADS) for the assessment of doses during emergency exposures, and for the separate recording of such doses in dose records. Further information and the names of ADS approved under the REPIIR Regulations can be found on the [Health and Safety Executive's website](#)
- Ensure that no employee under 18 years of age, no trainee under 18 years of age and no woman employee who is pregnant or breast-feeding is subject to an emergency exposure



Radiation dose control measures

Where it is known that the only radiation at an incident is from a sealed source (i.e. there is no contamination risk) protection will depend on a combination of time, distance and shielding:

- Time: the shorter the duration of exposure the smaller the accumulated dose
- Distance: the greater the distance from the source of radiation the lower the dose rate. Note that there is an inverse square relationship (e.g. Doubling the distance from a radiation source quarters the dose received)
- Shielding: in general, the higher the density and greater the thickness of the shielding, the better the protection

Response vehicles should approach the incident from the upwind direction wherever possible, as a precaution. This is essential if it is believed that there has been a significant release of contamination from an unsealed source of radiation.

Initially, response vehicles should be parked a safe distance from the incident.

The table below gives generic initial cordon distances based on the guidance given by the International Atomic Energy Agency (IAEA) in the Manual for First Responders to a Radiological Emergency. This manual provides practical guidance for those responding within the first few hours of a radiological emergency. It does not address the response to emergencies involving facilities or operations for which specific emergency arrangements should have been developed. Further information can be found at www.iaea.org

Table 54 Radiation Incidents – Generic initial cordons

Outside buildings	
Unshielded or damaged potentially dangerous source	50 metres around
Major spill from a potentially dangerous source	100 metres around
Fire, explosion or fumes involving a potentially dangerous source	300 metres radius

Outside buildings	
Suspected bomb (exploded or unexploded)	400 metres radius or more to protect against an explosion
Inside buildings	
Damage, loss of shielding or spill of a potentially dangerous source	Affected and adjacent areas (including the floor above and below)
Fire or other event that can spread a potentially dangerous source materials throughout the building (e.g. through the ventilation system)	Entire building and outside distances detailed above

If immediately available, a survey meter (e.g. RADOS 200) should be deployed to check that the vehicles are not parked in an area affected by any gamma radiation. As a general guide, the reading should be in the range 0.04 to 0.2 microsieverts per hour which is the normal background range. At a large site, there may be a formal rendezvous point (RVP) and at some sites there may be several RVPs to take account of differing wind directions. If survey meters are not available to the first responders the electronic personal dosimeters (EPDs) issued to fire and rescue services through the National Resilience Assurance Team (NRAT) provide a basic dose rate measuring capability.

If the survey meter indicates normal background readings, the appliances may be moved closer if this is desirable. If the survey meter indicates elevated gamma dose rates the appliances should be withdrawn, ideally to a point where normal background readings are obtained. This should be balanced against the need to provide an effective response and may require specialist advice.

The incident commander should liaise with a responsible person on-site, if available. This may be a radiation protection supervisor (RPS) or radiation protection adviser (RPA) at a fixed installation or possibly the driver of the vehicle if in transit. At a licensed site there may be a written emergency plan. At a transport incident there should be documentation that will describe the type and size of sources being carried. The class of sign on packaging should also give information about the likely dose rates.

- The incident commander should carry out a risk assessment after attempting to determine:
- Is radioactivity the reason for the incident or is it a secondary issue that happens to be present?
- What type of source is involved? What nuclide is involved?
- Is it sealed or unsealed (i.e. is there an irradiation or contamination risk)?
- What is the size of the source (activity) in Bq? Which types of radiation are emitted? Most sources will emit more than one type of radiation.
- What is the exact location of the source within a building? Is this the same as the location of

the incident or is it likely to become involved in the incident?

Consider contacting [RADSAFE](#) in the event of a transport incident to gain expert advice and support.

If no responsible person is available and the premises/vehicle/source is not secure, the assistance of the police should be sought in order to secure it.

The relevant environmental agency should be informed whenever a registered radioactive source is involved in an incident. This is particularly important if any contamination is released into the environment, such as from water run off.

The local water undertakers should be informed if it is believed that radioactive contamination has entered a sewer or water course.

Assistance and liaison

RADSAFE

RADSAFE is a consortium of organisations that have come together to provide mutual assistance in the event of a transport accident involving radioactive materials belonging to a RADSAFE member. RADSAFE is designed to ensure the early provision of advice and support to the emergency services. It is activated by calling 0800 834153. Further information is available at www.radsafe.org

RADSAFE has three levels of response:

- Level 1: notification/communication service, provision of generic radiological protection advice provided by command and control centre (CCC)
- Level 2: provision of radiological advice/support at the incident scene
- Level 3: consignment owner response and clean up

National Arrangements for Incidents involving Radioactivity (NAIR)

The National Arrangements for Incidents involving Radioactivity (NAIR) scheme exists to provide protection to the public in the event of incidents involving radioactivity in cases where no specific plans are available or existing plans fail to operate effectively.

NAIR provides the emergency services with expert advice where the public might be at risk and acts as a long stop to other emergency plans.

The fire and rescue service may call on NAIR assistance through the police service, who should call **0800 834153** (same number as RADSAFE).

NAIR response is provided in two stages:

- Stage 1: provided by a radiation expert equipped with simple monitoring and protective equipment. They can quickly advise whether a radiological hazard exists. They are not equipped to deal with larger incidents. In such events they will advise the police to initiate the stage 2 response.

- Stage 2: provided by a well equipped team from a nuclear establishment with facilities to deal with larger incidents

NAIR will not organise substantial recovery operations or carry out large scale decontamination.



Radiation dose management

- Dose limit: under the IRR the maximum annual dose to firefighters is 20 mSv. There is an additional limit on women of reproductive capacity of 13 mSv in any three-month period.
- Dose constraint: it is recommended that a dose constraint of 5 mSv per incident is introduced at operational incidents involving radiation.
- Emergency exposure: at a licensed nuclear site or at an incident involving transport by rail the legal dose limit can be exceeded if in doing so it might be possible to save life or maintain critical infrastructure. In these instances an informed volunteer may be exposed to a dose of up to 100 mSv. The authorisation of emergency exposure must only be given by an officer or manager within the fire and rescue service who has received appropriate training

It is not sufficient just to avoid exceeding dose constraints or dose limits. The fire and rescue service must take active measures to ensure that all doses received are as low as reasonably practicable.

The incident commander must ensure that a full risk assessment is carried out before personnel are deployed, to develop an appropriate and proportionate response plan.

The incident commander, in conjunction with the hazardous materials adviser should determine the tasks to be undertaken. Consideration should be given to:

- The need to deploy crews
- If it is deemed necessary, determining whether the risk involves a sealed source, in which case the only hazard is likely to be irradiation, or an unsealed source, in which case the main hazard is likely to be contamination
- If the hazard is irradiation only (i.e. a sealed source), structural firefighting PPE with breathing apparatus is an appropriate level of personal protective equipment.
- If the hazard is contamination, chemical protection clothing with BA is often an appropriate level of PPE. If it is not known whether sealed or unsealed sources are involved, chemical protective clothing should be worn.
- The type of source and the type of radiation emitted. Determining the type of radiation is secondary to the need to determine whether the risk is from irradiation or contamination or both. Be aware that the majority of radioactive sources will emit more than one type of radiation.

- Be clear about the objective in committing crews e.g. fire fighting, search and rescue, maintaining critical infrastructure
- Brief the crews thoroughly about their task and emphasise the need to enter, carry out specific task then leave.

Remind crews that personal protective equipment will protect them fully from the effects of contamination and the principles of time, distance and shielding will protect them from the effects of irradiation. Spend as little time as possible in the proximity of the source, keeping as far away from the source as possible (survey meter readings will assist in this), make use of any available shielding (concrete, metallic structures water tanks, etc.)

Using a survey meter will help manage any possible dose to an acceptable level.

Dosimeters will record the personal dose received by each firefighter and the reading for each firefighter will need to be recorded robustly for future reference.

Electronic personal dosimeters issued to fire and rescue services through the National Resilience Assurance Team (NRAT) provide an audible alarm that should prompt the wearer's withdrawal from the hazard zone before any significant doses are received.

Three-stage alarm

It is essential that crews are aware of the three stages of the EPD alarm and the associated warning tones.

The first alarm is a dose rate alarm that gives a warning the wearer is entering an area affected by radiation. This can, and should, be cancelled by the wearer. Temporary shielding could cause this alarm to sound more than once during a deployment.

The second alarm will operate when the total accumulated dose reaches 5 mSv; crews would normally withdraw at this point – this alarm can be cancelled by the wearer. (If only one person's alarm sounds, the whole crew should withdraw). A new crew should then be committed if there are further objectives to be completed.

The third alarm which would only ever operate if an emergency intervention was being made, and will operate at 100 mSv. This must not be ignored; wearers must aim to leave the inner cordon before it sounds. This alarm cannot be cancelled by the wearer.



Classified persons

Classified persons are those who regularly work with radiation in regulated areas. It is unlikely that

any firefighters would ever need to become classified workers. However, a situation could arise with part-time or retained duty system firefighters where their primary employment might be in an organisation where they are exposed to ionising radiations; by virtue of this they would be classified workers.

This situation could arise where retained firefighters are recruited from an area where a licensed nuclear site is a major employer. Under these circumstances, the fire and rescue service would have a duty, under the Ionising Radiation Regulations, to have a system whereby the annual doses received by individual retained staff from their other employment is captured so that they do not exceed any applicable dose limit.

most convenient way of addressing this might be to issue each of the relevant members of staff with a radiation passbook. This is a recognised scheme within the nuclear industry where staff who may have to visit many sites during a year have their dose monitored by the Health Physics department of each site in question. This dose is then entered into the book issued on a personal basis. classified person then takes it with them from site to site and the running total is noted to ensure that dose limits and constraints are not exceeded.

It is recommended that if this is identified as an issue for any fire and rescue service, contact is made with the RPA at the main licensed nuclear site to arrange for such a scheme to be implemented.



Designated areas

Restricted and controlled areas are specially-marked areas where radiation dose rates in excess of prescribed limits (6 mSv per year or three-tenths of any other relevant dose limit) are likely to be encountered. Fire and rescue service personnel shall only enter a radiation controlled area (RCA) at a licensed site under the supervision of the site radiation protection supervisor (RPS), and shall wear any additional dosimetry equipment required by the site. If the incident occurs at an unregulated location, establishing the inner cordon and entry controls would satisfy this requirement.



Local rules for working with radioactive materials

The radiation employer (i.e. the fire and rescue service) must produce a set of written local rules which set out the procedure to be followed when working with radioactive materials. In most cases this fire and rescue service operational guidance would form the basis for fulfilling this requirement, amended by local risk assessments and standard operating procedures.



Radiation protection adviser and radiation protection supervisor

The fire and rescue service should consult a radiation protection adviser (RPA) if it considers it needs advice on compliance with IRR.

Appointing a radiation protection supervisor (RPS) within the fire and rescue service is useful in helping to ensure adherence to the operational procedures for radiation incidents. The RPS must:

- Understand the requirements of the local procedures within the fire and rescue service
- Command sufficient authority to be able to supervise the radiation protection aspects of incident
- Understand the necessary precautions to be taken to restrict exposures
- Understand the procedures to follow in the event of an emergency

The hazardous materials adviser (HMA) position should be considered suitable for the RPS role.



Prior risk assessment

A prior risk assessment must be carried out for all work involving radioactivity.



Dosimetry and record keeping

All staff who enter an area designated by the fire and rescue service as potentially containing a radiation hazard should be issued with a dosimeter or other suitable dose-recording equipment to record the external dose received. The fire and rescue service should have a system to capture this information and to store the dose record for up to 50 years.

The requirement to keep records only applies once a firefighter has received a radiation dose other than from normal background radiation. If, after being worn, the dosimeter is only displaying the normal background level of accumulated dose then there is no requirement to keep this record.



Medical surveillance

If firefighters receive significant exposure to radiation they must be referred to a suitably qualified employment medical adviser to conduct medical surveillance. Fire and rescue services should consider making provision in their occupational health arrangements for this service to commence should the need arise. This may also include the provision of bioassay services in the event of suspected internal exposure.

It is possible that the Health Physics departments of a local hospital or licensed nuclear site may be willing to provide this service locally, and liaison with the site RPA is therefore recommended.



Equipment maintenance and calibration

This guidance places reliance on the ability to accurately measure the dose and dose rates to which firefighters are exposed. It is therefore essential that equipment is properly maintained and subject to annual calibration tests.



Training

All staff expected to encounter radiation should be properly trained to undertake the tasks expected of them. The fire and rescue service should arrange for role-appropriate training (including acquisition, application and maintenance of competence) for personnel. This should be reinforced by exercises, both at specific locations of radiation risks and of general radiation procedures.



Emergency incident plans for radioactive materials

For planning purposes only, the following table may be useful in estimating the likely realistic working times for various dose rates and separation distances before the recommended dose constraint level of 5 mSv (fire and rescue service national resilience EPD standard alarm) and the emergency exposure limit of 100 mSv (EPD emergency alarm) are reached.

Radiation Incidents Approximate firefighter duration periods								
EPD Dose constraint alarm set at 5 milliSieverts								
Emergency dose for life saving or prevention of catastrophic escalation 100 mSv								
Red boxes indicate situations where maximum dose may be exceeded during normal wear of PPE								
Yellow box indicates situation where dose may be exceeded during prolonged incident								
Green boxes indicate situation where maximum dose is unlikely to be exceeded								
Typical Activity	Gamma Dose		Time to reach dose at		Time to reach dose at		Time to reach dose at	
Co-60	Cs-137	Rate at 1m	5mSv	100mSv	5mSv	100mSv	5mSv	100mSv
3.3 TBq	12 TBq	1000 mSv/hr	10 s	5 min	30 min	10 hr	13 hr	10 day
1.6 TBq	6 TBq	500 mSv/hr	30 s	12 min	1 hr	20 hr	1 day	21 day
330 GBq	1.2 TBq	100 mSv/hr	1 min	1 hr	5 hr	4 day	5 day	104 day
150 GBq	600 GBq	50 mSv/hr	5 min	2 hr	10 hr	8 day	10 day	208 day
33 GBq	120 GBq	10 mSv/hr	30 min	10 hr	2 day	42 day	52 day	More than 1 year
3.3 GBq	12 GBq	1 mSv/hr	5 hour	4 day	21 day	More than 1 year	More than 1 year	More than 1 year
1.6 GBq	6 GBq	500 µSv/hr	10 hour	8 day	42 day	More than 1 year	More than 1 year	More than 1 year
330 MBq	1.2 GBq	100 µSv/hr	2 day	40 day	208 day	More than 1 year	More than 1 year	More than 1 year
33 MBq	120 kBq	10 µSv/hr	20 day	More than 1 year	More than 1 year	More than 1 year	More than 1 year	More than 1 year

Table 53 Radiation incidents, approximate firefighter duration periods

This table assumes that there is no shielding between the source and the firefighter and that the source is a point source (i.e. very small in relation to the size of the firefighter). It has been calculated for two very common sources and it is important to be aware that the same activity from different sources can give rise to very different dose rates. This is useful for initial planning, but real dose rate information needs to be gathered at an actual incident using radiation detection and monitoring equipment. The figures shown should be treated with caution and be regarded as approximations only.

If fire and rescue services have significant radiation risks in their area they should arrange joint

exercises with the facility concerned. This is especially important if there is a licensed nuclear site within their turn-out area. Early contact with the radiation protection adviser (RPA) or the head of RPA services would enable both the facility and the fire and rescue service to understand each other's role in an emergency and what would be expected of the fire and rescue service. Licensed sites often operate their own fire brigade and are usually very helpful to the local authority fire and rescue service.

The safety of nuclear installations in the UK is the responsibility of holders of nuclear site licences granted by the Health and Safety Executive (HSE) under the Nuclear Installations Act 1965. The nuclear site licence, which permits the use of the site for certain specified activities, contains a number of standard licence conditions. Licence condition 11 (emergency arrangements) requires the licensee to ensure that adequate arrangements are in place to respond effectively to any incident ranging from a minor on-site event to a significant release of radioactive material. In the event of a fire at a nuclear installation, the fire and rescue service would be required to support. For this reason, it is recommended that fire and rescue services with a nuclear installation within their area should establish formal links with these installations and exercise the emergency response arrangements.

Licensed nuclear sites are typically nuclear power stations, facilities for the manufacture or reprocessing of nuclear fuel, production and maintenance of nuclear weapons and sites operating a nuclear reactor.

The Nuclear Emergency Planning Liaison Group (NEPLG) is a forum that brings together a wide range of organisations, including CFA, with interests in off-site civil nuclear emergency planning. NEPLG issues [consolidated guidance](#) on planning.

Informative messages to fire control rooms should state 'RADIATION SUSPECTED' when involvement is suspected but not yet confirmed, and 'RADIATION CONFIRMED' when radiation is known to be involved. On receipt of either of these messages, fire control rooms should inform all responders of the situation, it may also trigger other fire and rescue service's specific pre-determined attendances.

Radiation monitoring instruments should be switched on before reaching the incident.

Radioactive materials may be involved in incidents at premises or during transport. Their involvement may be suspected in the following cases:

There is knowledge or intelligence from operational information sources that radioactive materials are in a building (e.g. 7(2)d visits, agency notifications, fire safety inspections/assessments, etc.)

- A radioactivity warning placard on a vehicle or package
- A caller may state that radioactive materials are present
- An electronic personal dosimeter (EPD) alarm actuates
- A survey meter shows a dose rate above background
- There have been terrorist or other malicious acts



Assistance and liaison

RADSAFE

RADSAFE is a consortium of organisations that have come together to provide mutual assistance in the event of a transport accident involving radioactive materials belonging to a RADSAFE member. RADSAFE is designed to ensure the early provision of advice and support to the emergency services. It is activated by calling 0800 834153. Further information is available at www.radsafe.org

RADSAFE has three levels of response:

- Level 1: notification/communication service, provision of generic radiological protection advice provided by command and control centre (CCC)
- Level 2: provision of radiological advice/support at the incident scene
- Level 3: consignment owner response and clean up

National Arrangements for Incidents involving Radioactivity (NAIR)

The National Arrangements for Incidents involving Radioactivity (NAIR) scheme exists to provide protection to the public in the event of incidents involving radioactivity in cases where no specific plans are available or existing plans fail to operate effectively.

NAIR provides the emergency services with expert advice where the public might be at risk and acts as a long stop to other emergency plans.

The fire and rescue service may call on NAIR assistance through the police service, who should call **0800 834153** (same number as RADSAFE).

NAIR response is provided in two stages:

- Stage 1: provided by a radiation expert equipped with simple monitoring and protective equipment. They can quickly advise whether a radiological hazard exists. They are not equipped to deal with larger incidents. In such events they will advise the police to initiate the stage 2 response.
- Stage 2: provided by a well equipped team from a nuclear establishment with facilities to deal with larger incidents

NAIR will not organise substantial recovery operations or carry out large scale decontamination.

Establish and mark an inner cordon. Set up a breathing apparatus (BA) entry control point as its 'gateway'. The cordon boundary should be at a point where the background dose rate is about

normal for the area (Normal background in most parts of the UK will vary from approximately 0.04 to 0.2 microsieverts per hour ($\mu\text{Sv/hr}$)).

In certain circumstances, where a qualified radiological assessor has assessed the entire radiological hazard, the inner cordon may be set at a level slightly higher than background.

The incident commander should assign staff with survey meters to monitor the boundary to ensure that the situation does not change during the incident.

Gamma radiation will radiate outwards in all directions so monitoring all around the perimeter of the cordon should be considered, remembering that differences in shielding of the source may mean that the hazard zone is not circular in shape.

If an outer cordon is required, establish this at an appropriate position. The space between the inner and outer cordons should be unaffected by radiation from the incident.

Set up a decontamination area across the boundary of the inner cordon but slightly away from the BA entry control point. Maintain a clean path in and out of this area throughout the incident.

person passing through the BA entry control point and entering the hazard zone must be wearing a dosimeter. A system should be set up to record the displayed dose on entry and to record it again on exit. At the entry point, note the serial number of the dosimeter issued to each firefighter.

If chemical protective clothing is being worn and it becomes necessary to read the electronic personal dosimeter (EPD) display or to operate the unit, the wearer should withdraw their arm from the suit, unclip the EPD and pass it through the collar, if fitted within the suit, into the head compartment. The wearer may find it difficult to read their EPD due to the proximity to their eyes, but it is easily read by a companion outside the suit. It is therefore suggested that a buddy system is used to read EPDs when deployed in chemical protective clothing

Each crew entering the hazard zone should have a dedicated operator of a survey meter accompanying them. The purpose of the survey meter operator, who should be assigned no other task, is to monitor the dose rate of the whole crew and direct their pathway to ensure that all doses are kept as low as reasonably practicable. Using the survey meter is the primary means of ensuring external radiation safety.

The survey meter operator needs to be aware that the gamma radiation source may be located at any height, even on the floor above or the floor below, and should periodically move the meter vertically and horizontally to ascertain the direction from which the gamma radiation is coming. This information should be used to direct the crew away from the source as far as is practical and to take advantage of any available shielding.

When using a survey meter it is important to understand that, in some circumstances, gamma radiation beams may be highly collimated – they may be emitted in a narrow beam that may not impinge on the survey meter at hand height.

On exiting the incident, crews should be directed to the decontamination area. If there was originally no known risk of contamination (i.e. a sealed source) and the crews can confirm that they

encountered no other contamination risks, decontamination is not required and they should present their EPDs to the BA entry control officer for their personal dose record to be formally recorded.

If there is a contamination hazard crews should initially be checked with a contamination meter prior to disrobing. If the fire and rescue service does not have dedicated contamination meters, under some circumstances it may be acceptable to use a Rados 200 metre connected to the contamination probe (beta probe), but advice should be sought prior to undertaking this task. In the first instance, monitoring effort should be concentrated on the parts of the suit with the highest risk of becoming contaminated, usually the boots and the gloves, followed by knees and elbows.

Contamination meter readings of more than five counts per second (cps) above background level is usually taken as evidence of contamination. Licensed installations may have on-site emergency teams who could assist with contamination monitoring.

If no contamination is found (usually taken as five or less cps) the suits should be subject to appropriate cleaning following use in a radioactive environment. If found to be contaminated, it is recommended the suit is removed from the wearer using a safe undressing procedure (SUP) and is double bagged prior to disposal or decontamination by a specialist contractor. Keeping a record of where on the suit the contamination was detected will help in this process.

It is not generally regarded as good practice to use water/showers for decontamination of radioactive materials. The reason for avoiding using water is to prevent spread of contamination and prevent self-absorption of alpha radiation by water. But where large numbers of contaminated people require urgent mass decontamination wet-containment may be the most appropriate method.

Incident commanders should constantly evaluate the risk posed by radioactive materials and the effectiveness of radiation procedures and of specialist advice obtained. Evaluation is not a one-off process but should be continual throughout the incident as circumstances change or new information is gathered. After evaluation, the incident commander should review and adjust the response plan, amend or implement additional control measures and communicate the changes to all personnel.

Aside from the general considerations that would form part of the evaluation process for any incident, the incident commander should particularly check the dose readings as measured by the EPDs of crews committed and ensure that no limits or constraints have been exceeded and that all doses have been as low as reasonably practicable. The incident commander should also ensure that any issues relating to contaminated personnel or equipment leaving the hazard zone are being adequately managed.

The incident commander should consider the dose rates reported inside the hazard zone and the consequent need to deploy more crews. They should gather clear information regarding potential radioactive contamination within the building.

- At the end of the incident the following measures will need to be considered:
- If the source has been made safe or the affected area contained, it should be handed over to

the appropriate authority. In many cases this will be the owner of the source. If the incident has occurred at site registered under the Radioactive Substances Act a representative of the organisation should be on hand.

- 'Orphan sources' are radioactive sources with no traceable owner (e.g. lost, stolen etc.). If the incident has involved an orphan source the NAIR scheme should be implemented.
- Radiation exposure dose records should be collated and recorded of for all committed personnel. These need to be transferred to a robust recording system and need to be kept until the person whom the record relates has or would have reached the age of 75 but in any event for at least 30 years from the date of the relevant entry
- Medical surveillance for significantly exposed firefighters should be introduced
- Crews should be debriefed
- Firefighters should receive advice and reassurance on the nature of risks from radiation – enlist the help of a specialist adviser
- Engaging with the media and public relations issues – radiation incidents will attract a great deal of interest and it is usually advisable to keep the media well informed
- Conducting a formal investigation if the level of 6 mSv whole body dose has been exceeded by any personnel



Additional operational considerations when involved in fire

Defensive firefighting tactics should be considered, making every effort to minimise the use of water and take active measures to prevent contaminated run off from entering watercourses. If the sources are in a complex building (e.g. a hospital or university) and the fire does not initially affect the radiation sources, deploying resources specifically to protect radiation stores or sources could be considered.

The effect on dose rate if lead shielding were to melt (the melting point of lead is 327 degrees Celsius) and be lost as a result of heat from a fire should be considered. It may be necessary to adjust firefighting tactics to protect stores of radioactive substance.