BS 5908-1:2012

BSI Standards Publication

Fire and explosion precautions at premises handling flammable gases, liquids and dusts —

Part 1: Code of practice for precautions against fire and explosion in chemical plants, chemical storage and similar premises

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Contents

Summary of pages

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Foreword

Publishing information

This part of BS 5908 is published by BSI Standards Limited, under licence from The British Standards Institution, and came into effect on 31 December 2012. It was prepared by Technical Committee EXL/23, *Explosion and fire precautions in industrial and chemical plant*. A list of organizations represented on this committee can be obtained on request to its secretary.

Supersession

BS 5908-1:2012 supersedes BS 5908:1990, *Code of practice for fire precautions in the chemical and allied industries*, which is withdrawn.

Relationship with other documents

This part of BS 5908 is intended to be used with BS 5908-2, which gives guidance on the legislation and standards applicable to onshore industrial premises that handle significant quantities of flammable gases, liquids or dusts.

Presentational conventions

As a code of practice, this British Standard takes the form of guidance and recommendations. It should not be quoted as if it were a specification and particular care should be taken to ensure that claims of compliance are not misleading.

Any user claiming compliance with this British Standard is expected to be able to justify any course of action that deviates from its recommendations.

Contractual and legal considerations

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

Compliance with a British Standard cannot confer immunity from legal obligations.

1 Scope

This British Standard gives recommendations and guidance for the control of fire and explosion risks on sites at which chemicals are stored or processed in significant quantities.

NOTE 1 These precautions may extend well beyond those required under the fire safety legislation applicable to places of work, because of the wider range of risks. Additional legal requirements arise largely from the Dangerous Substances and Explosive Atmospheres Regulations (DSEAR) [1, 2], and the Health and Safety at Work legislation [3, 4].

NOTE 2 Annex A gives guidance on the classification of chemicals, while Annex B discusses ignition sources and Annex C covers hazards from smoke. Annex D gives guidance on the approaches to hazardous area classification.

The precautions recommended by this British Standard also address risks on and off site, within and external to buildings, that arise from the release of toxic materials, ejection of chemical containers from a fire, flowing fires where liquid products are handled, and special firefighting techniques.

The recommendations of his code of practice cover location, plant layout and design, separation distances, particular types of plant and facility with special fire hazards and other issues. Particular precautions might be relevant to preserving life safety or the health of persons on or off site; to property protection; and to protection of the environment.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

BS 799-5, *Oil burning equipment*

BS 5908-2, *Fire and explosion precautions at premises handling flammable gases, liquids and dusts – Part 2: Guide to applicable standards and regulations*

BS 9999:2008, *Code of practice for fire safety in the design, management and use of buildings*

BS EN 54-2, *Fire detection and fire alarm systems – Part 2: Control and indicating equipment*

BS EN 671, *Fixed fire fighting systems – Hose systems*

BE EN 976-1, *Underground tanks of glass-reinforced plastics (GRP) – Horizontal cylindrical tanks for the non-pressure storage of liquid petroleum based fuels – Part 1: Requirements and test methods for single wall tanks*

BS EN 1012-1, *Compressors and vacuum pumps – Safety requirements – Part 1: Air compressors*

BS EN 1127-1, *Explosive atmospheres – Explosion prevention and protection – Part 1: Basic concepts and methodology*

BS EN 1539, *Dryers and ovens, in which flammable substances are released – Safety requirements*

BS EN 1598, *Health and safety in welding and allied processes – Transparent welding curtains, strips and screens for arc welding processes*

BS EN 1991-1-2, *UK National Annex to Eurocode 1: Actions on structures – Part 1-2: General actions – Actions on structures exposed to fire*

BS EN 12094, *Fixed firefighting systems – Components for gas extinguishing systems* (all parts)

BS EN 12259, *Fixed firefighting systems – Components for sprinkler and water spray systems* (all parts)

BS EN 12285-1, *Workshop fabricated steel tanks – Part 1: Horizontal cylindrical single skin and double skin tanks for the underground storage of flammable and non-flammable water polluting liquids*

BS EN 12285-2, *Workshop fabricated steel tanks – Part 2: Horizontal cylindrical single skin and double skin tanks for the aboveground storage of flammable and non-flammable water polluting liquids*

BS EN 12416, *Fixed firefighting systems – Powder systems*

BS EN 12845, *Fixed firefighting systems – Automatic sprinkler systems* (all parts)

BS EN 12573, *Welded static non-pressurized thermoplastic tanks*

BS EN 12921-3, *Machines for surface cleaning and pre-treatment of industrial items using liquids or vapours – Part 3: Safety of machines using flammable cleaning liquids*

BS EN 13463-1, *Non-electrical equipment for use in potentially explosive atmospheres – Part 1: Basic method and requirements*

BS EN 13463-5, *Non-electrical equipment intended for use in potentially explosive atmospheres – Part 5: Protection by constructional safety 'c'*

BS EN 13480, *Metallic industrial piping* (all parts)

BS EN 13565-1, *Fixed firefighting systems – Foam systems – Part 1: Requirements and test methods for components*

BS EN 13565-2, *Fixed firefighting systems – Foam systems – Part 2: Design, construction and maintenance*

BS EN 13575, *Static thermoplastic tanks for the above ground storage of chemicals – Blow moulded or rotationally moulded polyethylene tanks – Requirements and test methods*

BS EN 14015, *Environmental management – Environmental assessment of sites and organizations*

BS EN 14122, *Safety of machinery – Permanent means of access to machinery*

BS EN 14491, *Dust explosion venting protective systems*

BS EN 14797, *Explosion venting devices*

BS EN 14994, *Gas explosion venting protective systems*

BS EN 15004, *Fixed firefighting systems – Gas extinguishing systems*

BS EN 61511-1, *Functional safety – Safety instrumented systems for the process industry sector – Part 1: Framework, definitions, system, hardware and software requirements*

BS EN 61511-2, *Functional safety – Safety instrumented systems for the process industry sector – Part 2: Guidelines for the application of IEC 61511-1*

DD CEN/TS 14816, *Fixed firefighting systems – Water spray systems – Design and installation*

API 620, *Design and Construction of Large, Welded, Low-Pressure Storage Tanks*

API 650, *Welded Tanks for Oil Storage*

API 2000, *Venting Atmospheric and Low-Pressure Storage Tanks: Nonrefrigerated and Refrigerated*

API RP 2021, *Management of Atmospheric Storage Tank Fires*

OFS T200, *OFTEC standard for steel storage tanks*

3 Terms, definitions and abbreviations

3.1 Terms and definitions

For the purposes of this British Standard, the following terms and definitions apply.

3.1.1 boiling liquid vapour cloud explosion (BLEVE)

event that follows the sudden failure of a vessel containing a liquefied gas under pressure after fire engulfment

NOTE A fireball and associated pressure wave occur.

3.1.2 dangerous goods

articles or materials capable of posing significant risk to people, health, property or environment when transported in quantity

NOTE This term is defined in the European Agreement concerning the International Carriage of Dangerous Goods by Road (ADR) [5] and other international transport legislation, and goods are classified as dangerous depending on results from tests set out in the legislation.

3.1.3 dangerous substance

a) substance or preparation which meets the criteria in the approved classification and labelling guide for classification as a substance or preparation which is explosive, oxidizing, extremely flammable, highly flammable or flammable, whether or not that substance or preparation is classified under the Chemicals (Hazard Information and Packaging for Supply) (CHIP) Regulations [6, 7]; or

b) substance or preparation which because of its physico-chemical or chemical properties and the way it is used or is present at the workplace creates a hazard, not being a substance or preparation falling within a); or

c) dust, whether in the form of solid particles or fibrous materials or otherwise, which can form an explosive mixture with air or an explosive atmosphere, not being a substance or preparation falling within a) or b)

(adapted from Dangerous Substances and Explosive Atmospheres Regulations 2002 [1, 2])

3.1.4 deluge system

system of fixed fire protection designed to release water from a large number of nozzles at the same time in response to manual or automatic activation in the event of fire

3.1.5 explosible

capable of being exploded or liable to explode

NOTE This term is used to describe a dust that is capable of creating an explosion if a dense cloud in air is ignited. It distinguishes dust which requires air for combustion from explosive materials, which can decompose rapidly and violently in the absence of air.

3.1.6 fire-resisting construction
ability of an element of construction to maintain its load-bearing capability, or provide a barrier to the passage of smoke, heat or flames for a stated period

*NOTE This term comes from the Building Regulations [8, 9, 10]. In the context of premises which store and use chemical products with a range of special properties, the usual construction methods might not provide the anticipated fire-resistance time (see Clause **14**).*

3.1.7 hazardous area
site in which an explosive atmosphere might occur in such a quantity as to require special precautions to protect the health and safety of the workers

NOTE This definition is taken from DSEAR [1, 2], but hazardous areas may also be assigned where the occupancy is very low but the risk from fires or explosions is significant.

3.1.8 hazard and operability studies (HAZOP)
technique for analysis of hazards used in process plants

3.1.9 means of escape
safe route by which persons can travel from any point in the plant or building to a place of reasonable or ultimate safety in the event of fire

3.1.10 non-combustible
not capable of undergoing combustion under specified conditions

[BS EN ISO 13943]

3.2 Abbreviations

ADR	European Agreement concerning the International Carriage of Dangerous Goods by Road [5]
API	American Petroleum Institute
ATEX	Atmosphères Explosive (ATEX Directive 94/9/EC [11])
BLEVE	boiling liquid vapour cloud explosion
DSEAR	Dangerous Substances and Explosive Atmospheres Regulations
FIBC	flexible intermediate bulks containers
HAZOP	hazard and operability studies
HSE	Health and Safety Executive
IBC	intermediate bulk containers
LEL	lower explosion limit
LPG	liquid petroleum gas
NFPA	National Fire Protection Association (USA-based)
PRV	pressure-relief valve
SHEVS	smoke and heat exhaust ventilation systems
VCE	vapour cloud explosion

Section 1: Fire risk assessments

4 Fire risk assessment and fire precautions

Fire precautions should be implemented on sites handling chemical products to ensure the safety of people on site in the event of fire and to:

a) limit any off-site risk to people in the surrounding area;

b) facilitate firefighting by professional firefighters;

c) limit the potential damage to the environment from release of chemicals;

d) limit the potential loss of plant, equipment and inventory of products and raw materials;

e) limit the consequential losses from loss of production;

f) limit the risk of a fire starting;

g) limit the rate of growth or fire spread; and

h) prevent explosions.

NOTE 1 In England and Wales, a distinction is made between general fire precautions and process fire precautions by the fire safety legislation [12, 13, 14, 15]. In most circumstances, enforcement of requirements relating to general fire precautions is through the local fire authority, while process fire precautions are enforced by HSE, or its equivalent in Northern Ireland. This standard addresses precautions for all the purposes in a) to h), whether they are required under general fire precautions or process fire precautions, or for environmental protection.

The fire precautions to be implemented on site should be informed by a fire risk assessment, which should identify the various risks from processing or storing chemicals on site, including:

1) sources of ignition;

   NOTE 2 A list of potential ignition sources is given in Annex B.

2) the hazards likely to arise from smoke, e.g. density and toxicity (see Annex C); and

3) the potential for an explosion to be initiated by fire or for a fire to result from the explosion, including the mechanisms that create explosions with different characteristics, for which different precautions and controls are needed.

The fire risk assessment should categorize the chemicals handled on site, including the fire hazards of solids which melt, products which are stored or processed well above ambient temperature, products which are both flammable and toxic, and dusts which can explode when dispersed as a cloud, but burn only slowly if exposed to a flame, and in many cases how the packaging influences the rate of fire growth (see Annex A).

An assessment of the fire hazard of flammable solids, for example, should consider the following.

i) The surface area that would be exposed in the early stages of a fire.

ii) The vertical extent of any surface across which fire could spread. Flame spread is always more rapid vertically than horizontally.

iii) Whether a material would melt, soften or char when exposed to flames or intense heat.

iv) The thickness of the material. A thin section of textile material burns in a different way from a tight roll.

v) How quickly any packaging is likely to fail. Cardboard boxes and plastic sacks release their contents more rapidly than a metal bin.

vi) The toxicity of any materials present, and whether this would change as a consequence of combustion (most organic products) or remain after a fire (e.g. products with a toxic metal content).

NOTE 3 To some degree these issues are common to all buildings, but chemical plants can have very large quantities of materials with specific properties that would determine fire development.

These inputs should be used to develop an understanding of possible fire scenarios in the early stages following ignition. From this the adequacy of the means of escape should be assessed, the need and form of any fixed fire protection established, and arrangements for firefighting agreed with the fire and rescue service.

NOTE 4 The conclusions may also influence the type of packaging used, the maximum height of any stockpile, separation of products with different fire hazards (see ***30.8.4****), and the maximum quantities in a given location.*

Section 2: Site layout and design

5 Selection of site and layout

The location selected for a site for processing or storing chemicals should have:

a) sufficient clear space from boundaries, plant buildings and other combustible storage that might create a fire exposure hazard;

b) adequate clearance from public highways and railways;

c) good access by all-weather roads;

d) no risk of flooding;

e) no gradient variations likely to cause hazards;

f) subsoil capable of supporting anticipated loads;

g) no underground piping or drainage that might create a hazard;

h) no overhead power cables;

i) adequate means to prevent unauthorized access;

j) sufficient area to provide safe segregation of different types of chemicals;

k) adequate water supplies for firefighting; and

l) means to control the flow of potential spillages, to limit environmental damage on or off site.

Within a site that has both process units and storage, the layout should be designed to minimize the potential for escalation of a fire. This should involve, as necessary, minimum separation between blocks of process plant, adequate separation within a tank farm, and between a tank farm and process plant, suitable location of occupied buildings, and separation of areas with major chemical inventories from activities creating a permanent fire hazard (boiler houses, flare stacks and facilities for use of welding/hot work).

NOTE Advice on the location and design of occupied buildings on chemical sites is given in the Chemical Industries Association Guide [16]. The particular issues of location of temporary or portable buildings on chemical sites are covered in code API 753 RP.

High-level design considerations for creating safer plant layouts was one of the objectives of the Mond Fire, Explosion and Toxicity index developed by ICI in the 1970s and 1980s. This used as primary inputs material properties, and inventories, and how the plant was or was intended to be subdivided. The subdivisions are intended to represent boundaries across which fire spread could be prevented by effective firefighting. Particular material properties included heat of combustion, flash point, potential for polymerization or dense phase explosion, ignition sensitivity, operating pressure, toxicity and aerial explosion hazards.

The calculated index does not give any indication of the frequency of possible events or take account of control measures of any sort. Instead, its value comes from setting a baseline for the inherent safety of an outline process design and site layout, and the ability to compare alternatives.

Details of the Mond Index were published mainly in the form of conference papers.

6 Access for firefighting

Roads or access over firm ground should be provided to allow fire appliances to approach within reasonable distance (generally 45 m) of all main fire hazards on site. Where practical, approach should be possible from two directions to major fire hazards. Access roads required for emergency use should be kept clear of parked vehicles, including disconnected trailers, and any other items that would create an obstruction, e.g. drums awaiting loading.

The advice given in BS 9999 on road widths, turning circles and load-carrying capacity for fire service vehicles should be followed.

NOTE 1 Because the weight of high-reach appliances, for example, is distributed over a number of axles, it is considered that their infrequent use of a carriageway or route designed to 12.5 tonnes is not likely to cause damage. It would therefore be reasonable to design the road base to 12.5 tonnes, although structures such as bridges ought to have the full 17 tonnes capacity.

For a large site, at least two points of access to the public road network should be provided.

Cul-de-sacs in internal road networks should be provided with sufficient space in which to turn a fire appliance.

NOTE 2 Requirements for access to buildings are set out in Approved Document B to the Building Regulations [17], Technical Handbook 2 to the Building (Scotland) Regulations 2004 [18] and Technical Booklet E to the Building (Northern Ireland) Regulations 2012 [19].

Where tall process plant or plant buildings are present on site, space should be provided for the operation of a turntable ladder or hydraulic platform.

Where open water sources might be needed for supplementary firefighting supplies, a hard standing should be provided beside each source.

7 Water supplies

NOTE Water is needed for the operation of any fixed sprinkler or drencher systems, for manual firefighting and for cooling plant, and equipment threatened by a nearby fire. The quantities needed might be very large, over an extended period.

Major chemical sites should consult their water supplier about the maximum flow rates that would be available immediately in an emergency, and how these could be augmented. Supplementary supplies, e.g. rivers, canals and lakes, might be available and should be considered as part of emergency planning.

Water as a jet should not be used for fighting fires involving the following.

a) Chemicals that react with water.

b) Flammable gases and liquefied flammable gases, for which water is generally ineffective and for which the risk continues if the flames are extinguished but the leak continues.

c) Situations in which the application of water could spread toxic material into water courses or the environment.

d) Flammable liquid, if the liquid is immiscible and lighter than water, and could be spread by the application of water jets.

e) Dusts, if a water jet would raise burning material into a cloud and cause an explosion hazard.

Fine sprays, water fog nozzles or foam should be used in the situations described in items b) to e). In the case of an ignited gas release, the priority should be to switch off the gas supply.

Site operators should obtain information about the appropriate means of fighting fires involving the chemical products on site. Discussions should be held with the local fire authority.

Water supplies within a small site may be provided by hydrants at the site boundary, but on a larger site a ring main with hydrants at appropriate locations should be provided. Hard-standings should be provided beside each hydrant to allow a fire service vehicle or mobile pump to make a connection.

Any ring main should have an adequate number of isolation valves, and be maintained under pressure by a jockey pump. Any fixed fire pumps used to maintain the pressure in the ring main during operation, or to draw water from a supplementary source, should be located where they are not likely to be affected by any fire on site. To maintain availability at all times, a minimum of two pumps should be provided. Electric pumps should be fed by separate power supplies. Where the pressure in a fire main drops and cannot be restored by the jockey pump, the main fire pump should start automatically, with a signal indicating this condition sent to a permanently staffed location.

Mobile pumps should be provided, if necessary, to boost the water pressure delivered to fire hoses or the pressure in fire mains.

Plans showing the layout of the system, including hydrants and isolation valves, should be available for use by the fire and rescue service.

Fire pumps should be tested at a frequency not greater than six months.

8 Drainage and pollution control

NOTE 1 Environmental protection legislation imposes strict controls on:

a) the deliberate release of liquid effluents that contain chemicals;

b) the accidental release from storage, transfer or processing activities;

c) chemicals released as a consequence of fire, including foam making compounds.

Where large volumes of water used to fight fires involving chemical products stored or processed on site could result in quantities of potentially contaminated water flowing away from the site, the site operator should:

1) identify the environmental hazards that would arise from the release into drains or water courses of the products processed or stored on site;

   NOTE 2 At sites where many chemical products are present, the chemical components in the water might be unknown.

2) ensure they understand the layout and capacity of normal drainage systems on site;

3) identify the likely direction of flow if the normal drainage systems cannot handle the water flows generated during firefighting activities;

4) identify the general direction that the drainage takes off site, including the location of any downstream sites that would be particularly sensitive to pollution;

5) determine the need for emergency containment systems;

6) discuss with the local fire authority the tactics to be used to tackle a major fire while minimizing the risk of pollution; and

7) if necessary, provide interceptors, permanent fixed tanks or emergency retention/containment systems to prevent the uncontrolled flow of potentially contaminated fire water off site.

NOTE 3 The quantities of water involved are likely to quickly overwhelm any drainage or interceptor system designed to capture or retain spills or leaks of product.

NOTE 4 Emergency containment systems may use temporary bunding and ground contours, together with areas impervious to water, such as roads or car parks, to create temporary lagoons.

The costs of retention facilities for fire water are likely to be high, and discussions should be held with the relevant authority [Environment Agency (EA) in England and Wales, Scottish Environment Protection Agency (SEPA) in Scotland, Northern Ireland Environment Agency in Northern Ireland] about the facilities required before committing to such expenditure.

NOTE 5 See also SEPA/EA guidance PPG18 [20].

9 Prevention of escalation

The plant design should limit the potential for fire growth by incorporating one or more of the following techniques for limiting escalation.

a) Limiting the quantity of combustible material within a process.

b) Separating process areas from storage areas.

c) Subdividing storage areas where inventories are inevitably large.

d) Design of open air plant to limit the potential for vapour cloud explosions (VCEs) in congested structures.

e) Providing fixed fire protection to major storage units.

f) Providing facilities for emergency isolation of large inventories and, where appropriate, depressurization.

Section 3: Buildings and structures

10 Fire resistance

Fire resistance should be built into the structure of buildings/structures to:

a) minimize the risk to the occupants during evacuation;

b) minimize the risk to firefighters engaged in search and rescue operations; and

c) reduce the danger to people in the vicinity from collapsing structures.

NOTE Guidance on periods of fire resistance for elements of a structure is given in BS 9999 and the supporting guidance documents to the Building Regulations, e.g. Approved Document B [17], including minimum periods of fire resistance for industrial buildings. Chemical plant includes many structures that are not considered buildings. In these cases, fire-resistant structures might be required to prevent escalation by premature collapse of the main load-bearing structure.

The hydrocarbon heating curve specified in BS EN 1991-1-2 should be used for the design of fire-resistant structures, when consideration of the plant and its inventory indicates it is more applicable.

11 Compartmentation

Compartmentation should be provided to:

a) prevent rapid fire spread if this could trap the occupants of a building;

b) reduce the risk of very large fires, which are difficult and dangerous to extinguish; and

c) where necessary:

    1) reduce the risk of release of toxic materials that are not initially involved in the fire;

    2) prevent the mixing of hazardous combinations of chemicals;

    3) make fixed fire protection systems effective;

    4) protect control rooms that cannot be immediately evacuated; and

    5) provide protection to electronic control equipment or power supplies that are important for the safety of the plant.

Internal doors in compartment walls generally permit the flow of spilt liquids to pass underneath. If the liquid is burning, fire is likely to spread in this way. Fire door sets are not tested against this risk. Where the spread of fire by flowing flammable liquids is possible, and needs to be prevented, a raised threshold or similar means to prevent or control the flow of liquid under a door should be provided.

Compartmentation requirements should be discussed with the insurers of the premises.

NOTE 1 Guidance for the sizing of compartments is given in Approved Document B to the Building Regulations [17], Technical Handbook 2 to the Building (Scotland) Regulations 2004 [18] and Technical Booklet E to the Building (Northern Ireland) Regulations 2012 [19]. Compartmentation requirements under Building Regulations [8, 9, 10] are intended to prevent rapid fire spread which could trap occupants, and to reduce the risks of very large fires to fire and rescue service personnel and persons in the vicinity. They are not intended to reduce the financial risk to occupiers in the event of fire.

NOTE 2 The size and intensity of a fire is strongly influenced by the ease with which materials can be ignited (assessed by flash point and other factors) and the potential speed of fire growth (influenced by the disposition of chemicals, the type of processes used and other factors).

Where the fire hazard arising from the chemicals stored or handled is high, the following maximum compartment sizes taken from the Scottish Technical Handbook [18] are recommended by this standard. In England and Wales the maximum compartment size in Approved Document B [17] takes no specific account of the fire hazard of materials present.

a) Factory buildings 33 000m^2.

b) Storage buildings 1 000m^2.

These figures may be increased where a suitable fixed fire suppression system is provided.

A review of the benefits of compartmentation in chemical warehouses is provided in HSE Contract Research Report RR 152 [21].

12 Fire detection and fire alarm systems

Automatic fire detection and fire alarm systems designed to BS 5839-1 should be provided to a category M standard for all occupied buildings, unless the fire risk assessment indicates otherwise, e.g. in a small building it might not be necessary to provide such a system as occupants would be immediately aware of a fire and could shout to alert others.

Automatic fire detection (category L system) might also be necessary, particularly where an undetected fire could jeopardize the ability of people to escape, but the extent of such protection should be determined by a fire risk assessment.

NOTE 1 Chemical plants frequently include buildings with unusual characteristics, structures that are not fully enclosed, enclosed structures linked to open air process plant at multiple levels, tall or extended open air plant and tank farms, and less frequently cable tunnels or other structures below ground that might not be considered a building. Examples of unusual characteristics include process buildings with little or no internal fire compartmentation, buildings where there is a risk of explosion as well as fire, buildings where the fire hazard is very low because the fire load is minimal, and warehouses where all or most of the occupants are driving lift trucks for most of the working day.

Buildings on chemical sites are often also characterized by very low occupancy levels, areas where there might be a significant fire hazard, but which are normally unoccupied and only accessed under a permit to work system.

In large sites or open areas, there might be a general need to ensure all persons on site are aware of a fire or other developing problem, but the immediate risk to life from fire is low. Site wide alarms may be provided to warn staff of other dangers, such as the release of toxic gases.

Property protection considerations might dictate a higher level of automatic fire detection.

The fire risk assessment should cover all parts of the premises, specifically means of detection and escape, to determine:

a) how fire would be detected (smoke, heat);

b) what type of detection (e.g. point detection, beam detector or aspirating system) is best suited to each area and the most effective evacuation strategy for that area (simultaneous, phased or progressive horizontal);

c) how quickly a fire would cause a hazard to persons in the area;

d) how the alarm could be raised (bell sounder, beacons, voice);

e) where the alarm needs to be heard (or seen); and

f) the action to be taken by staff in response to a fire at any location across the site, e.g. if fire breaks out in an area where it creates no immediate hazard to life safety, the required response may not be evacuation; instead an emergency plan could be prepared, containing emergency procedures (see Clause **41**) and the actions required.

As an alternative to fixed alarm call points, radios may be used both to raise the alarm and to alert staff with specific responsibilities in case of fire. Any such radio system used should be suitable for any hazardous areas in which they may be taken, and locations where a weak signal could cause them to be ineffective should be identified. Sufficient radios and spares should be available for all staff who need one. Mobile radio systems using the national networks are not recommended as a means of raising the alarm within a single site.

NOTE 2 Before major maintenance or other activities which significantly increase the numbers of persons present on site, the fire risk assessment ought to be reviewed. Temporary electric fire detection and fire alarm systems might be required and, where certain maintenance activities could trigger a detector, the temporary shutdown of part of the detection system might be necessary so as not to trigger a false alarm, e.g. welding activities could trigger an aspirated detection system.

13 Open air and unenclosed plant

NOTE 1 The structures found on chemical plants vary from conventional buildings with complete external walls and roof, together with solid internal floors, to plant that has no form of enclosure or weather protection. Sometimes a complete side of a building is open, or very large ventilation louvres are provided on more than one external wall. Some compressor houses have no wall at low level, but extensive enclosure at higher levels.

Frequently, internal floors are either of open-mesh construction or have large gaps where process vessels extend through more than one level. Sometimes structures are designed to prevent a liquid spill at one level from flowing down through the building; in other cases there is little to prevent this. Walkways and routes are commonly provided at one or more levels above ground between adjacent open air plant and enclosed buildings. Buildings or structures might need to be designed to provide some protection against explosion hazards. Fire loadings might be extremely high, but concentrated in distinct vessels or items of equipment.

Normal controls for fire growth and fire spread within buildings are therefore not applicable, e.g. compartmentation to limit the speed and extent of fire growth or the movement of smoke might be impractical.

When designing buildings or partial buildings, the following should be determined.

a) The types and quantities of combustible process materials present.

b) The characteristics of a fire involving these materials.

c) In the event of a fire, how much smoke would be produced and how toxic or irritating it would be.

d) How these materials would spread around the building if released.

e) Whether the products would create the risk of an explosion, as well as a fire.

The following factors should be provided, where appropriate, as inputs to the initial risk assessment.

1) Whether open mesh floors and/or large opening vents in external walls (or incomplete walls) could prevent smoke logging, improving visibility, which might otherwise be poor.
2) Whether escape routes are to be provided to a place of comparative safety outside the building at levels above the ground, from which there is an open air route to ground level.
3) Whether ventilation capable of dispersing small leaks and minimizing the risk of an extensive explosive atmosphere forming is to be provided.

NOTE 2 Where large openings in external walls are provided fire is not likely to reach ventilation controlled burning rate, a state where smoke production typically increases sharply.

Buildings in which there is a risk of an internal explosion from the release of gas or dust should not have load-bearing masonry walls, as a small overpressure could cause disproportionate collapse.

Buildings with access levels higher than 20 m above the ground should either have a fire enclosed external stairway leading directly at ground level to a place of safety, or access routes to adjacent open-air structures.

Storage of flammable raw materials, intermediates or finished products within a process or reactor building should be minimized where practical.

In multilevel buildings, provision should be made to prevent the unintended release of flammable liquids at an upper level from flowing down through the building.

Where flammable bulk powders are discharged from flexible intermediate bulks containers (IBCs), the discharge point should be at ground level, or enclosed to prevent any spillage from forming a large dust cloud that descends through the building.

Control rooms should be at or close to ground level, with a short direct route to a place of safety, or ideally located in a separate building from the process if the risk of a fire/explosion is deemed sufficiently high.

Combustion plant, such as boiler houses, should be installed in separate structures from chemical process plant, with sufficient space separation to control the risk of fire spread between the two.

Separate rooms should be provided to house electrical distribution and control equipment, and these should be given a degree of fire compartmentation. The fire load within these rooms should be kept low.

The effect on the building of an external fire in adjacent process plant should be determined by calculating the radiant heat effect (kW/m^2) on the building.

Fire protection of steelwork supporting main process vessels containing hazardous materials should be provided as appropriate.

14 Materials of construction

Process and storage buildings should normally be constructed with steel or concrete frames. Where chemicals used in the process are liable to cause corrosion or degradation, special protective coatings should be applied.

Where there is any risk of explosion, masonry should not be used in the construction of load-bearing walls.

The selection of materials for external cladding should take into account any fire resistance and external fire spread needed to prevent fire spread to adjacent or higher level plant and equipment. Thin metal-profiled sheet provides little insulation, and masonry or blockwork should be preferred.

Combustible materials, such as insulating cladding with combustible cores (sandwich panels), should not be used for the construction of buildings for chemical plants.

Internal compartment walls that require a high level of fire resistance should be made from one of the proprietary systems of fire-protective boards.

Many process buildings require pipework and cabling to run through internal compartment walls, and this can negate any protection they provide. Proprietary systems for maintaining fire resistance should be used for cable penetrations where plastic pipe passes through walls.

NOTE As metal pipe conducts heat, it is not practical to prevent fire attack on one side of a wall generating high temperatures in metal pipes on the other side.

15 Ventilation

The objective of any ventilation provided should be established, together with any risks this introduces.

The number and size of ventilation openings should be specified to permit dispersal of small releases and prevent the formation of an explosive atmosphere. Good natural high- and low-level ventilation should be provided where there are potential sources of release of flammable vapours or gases. Mechanical ventilation may be provided for the same purposes, or to limit the extent of a hazardous area or reduce the hazard expressed by the zone number.

NOTE 1 Mechanical extraction ventilation is often provided close to sources of release, resulting in duct work that runs for extended lengths. This may be provided mainly for occupational health reasons, or to capture dust releases to prevent them forming dust layers around the building. Deposits that collect within such duct work might provide a route for rapid fire spread, so fire dampers might be required to act as a barrier.

The following ventilation should be installed as necessary.

a) Large ventilation openings to allow waste heat from the process to be dispersed or to provide an air supply for a combustion process.

b) Pressurization ventilation to prevent smoke flow into a room housing electronic control equipment, or a process control room.

NOTE 2 Additional air movements not designed as ventilation can be generated by flows of process materials, particularly conveying systems for bulk powders or solids.

Mechanical ventilation systems are likely to affect the movement of smoke or heat within a building in case of fire. Ductwork should not run through fire compartment walls if this can be avoided. Alternatively, fire dampers may be provided. If ventilation systems or bulk conveying systems are likely to be a route for fire spread, they should shut down in the event of fire, and should be interlinked with the fire alarm or automatic fire detection systems.

16 Means of escape

Means of escape from process buildings and open-air structures should be provided in accordance with BS 9999:2008, Annex F, including the recommended maximum travel distances for different risk profiles, consideration of the different rates of fire growth to be expected in buildings with different inventories, and the occupancy levels at different times.

Where a site incorporates large machines with requirements for fixed access arrangements, these should conform to BS EN 14122.

Staff do not necessarily evacuate in response to an alarm. Where the response to an alarm is other than immediate evacuation, the following should be taken into consideration for process plant.

a) The case where fire is external to any building, and the building is designed to provide a degree of protection from heat radiation.

b) Preplanned shut-down actions by the operators are required to make the plant safe.

c) An automatic fire detection system reports a fire or overheating from an unoccupied location and the preplanned response requires someone to go to the area to investigate the circumstances.

For these circumstances, emergency plans should be developed which do not require any individual to take more than a few actions in a short period in response to fire or conditions giving rise to an increased risk of fire.

17 Lighting

Permanent lighting should be provided in external areas where work during the hours of darkness is regularly required, particularly areas trafficked by lift trucks or road vehicles carrying chemical products, and external process plant. Where there are infrequently visited areas, the lighting may be turned on and off by an operator as needed, but all relevant staff should be made aware of the location of the switches.

Often, lighting at high level is located above any hazardous areas, but it should also be located away from process vents or pressure relief valves if these could release flammable gases.

Luminaires and associated light switches installed inside buildings should be suitable for any hazardous areas which have been designated.

The provision of emergency lighting for buildings should take account of the actions required of operators in the event of fire or loss of power on site. If operators are required under some circumstances to remain in the control room after normal lighting has been lost, the duration of operation of the emergency lighting supplied should be extended.

Hand-held battery-powered lighting might be needed for specific activities. Where there are hazardous areas on site, all such torches used should be suitable for any location in which they are to be used. Lighting should not be lowered into process vessels, storage tanks pits, drains or silos unless these have been made gas/dust-free.

Mains-powered portable lighting on flexible leads is a particular ignition hazard, as it is easily damaged. It should be visually inspected each time before use.

18 Space heating

In hazardous areas, or locations where any fire constitutes a high risk because of the presence of dangerous chemicals, space heating should be selected from a type that creates no fire hazard, such as steam or hot water radiators.

NOTE 1 This includes offices attached to warehouse areas or process plants.

Site-wide rules should emphasize that no temporary space heating is permitted without a review of the additional fire hazards it could generate and specific controls over its location.

NOTE 2 Gas-fired heaters may be installed at high level above storage racking and above any defined hazardous areas, though this creates access problems for maintenance and inspection.

*NOTE 3 See Clause **45** concerning area classification and gas installation pipework.*

Boilers for space heating should be located where no flammable materials are likely to be drawn into the burner air intake.

Section 4: Precautions against ignition followed by an explosion

19 General

Separately from the fire risk assessment (see Section 1), where flammable gases, liquids or dusts are handled, the risk of an explosion within process equipment, within a process building or in the open air should be assessed. The appropriate precautions should be implemented in accordance with Clause **20** to Clause **28**.

20 Prevention of bursting of a pressure vessel caused by excess internal pressure

Where pressure vessels can burst as a result of overheating, particularly where pressure-relief systems designed for protection of the vessel against other causes of pressure rise might not be adequate to protect the vessel (e.g. BLEVE), protective measures should be designed to minimize the risk of fire engulfing the vessel, to keep the vessel cool when exposed to fire, or to provide supplementary pressure relief areas.

21 Prevention of bursting of process equipment caused by a chemical reaction

Where chemical reactions can cause a pressure rise by:

a) releasing gas into a system that does not have adequate capacity for venting the gas;

b) causing the reaction vessel to become liquid full; or

c) generating temperatures sufficient to weaken the vessel,

precautionary measures should be informed by a full understanding of the chemical kinetics, and involve avoidance of batch reactions from which a large amount of heat has to be removed and recognition of the risks from chemical processes where the kinetics are controlled by mixing in multiphase mixtures.

NOTE See Designing and operating safe chemical reaction processes HSG 143 [22].

22 Prevention of ignition of a mixture of air and gas or vapour inside process equipment or a storage vessel

Where practicable, chemical processes should be designed to avoid the generation of a gas or vapour/air mixture within the explosive range inside the system.

NOTE 1 In this way, explosion prevention does not depend on the avoidance of ignition sources alone. This option is not always possible, so that an explosive mixture can occur inside a vessel filled with air, during transfer in of a highly flammable liquid, or in the cold end of a condenser system during distillation of a flammable liquid at atmospheric pressure.

Where static discharges or other sources of ignition cannot be eliminated, the system should be inerted (see PD CEN/TR 15281).

Exceptionally, process vessels may be designed to withstand the full pressure of an explosion when this can be predicted.

*NOTE 2 See also **30.2** for precautions relating to bulk tanks.*

23 Prevention of ignition of a cloud of dust suspended in air inside process equipment or a storage vessel

Where ignition sources cannot be completely excluded from a dust-handling process that generates a dust cloud, one or more of the following precautions should be adopted, unless the system is so small that the risks are considered acceptable, e.g. in an area of low occupancy.

a) Explosion venting.

b) Explosion suppression.

c) Inerting.

d) Containment, i.e. building the plant strong enough to take the full explosion pressure.

NOTE 1 See Dust explosion Prevention and Protection: A practical guide [23] and BS EN 1127-1.

Explosion venting should be designed to release pressure to a safe place in the open air by vent ducts, in accordance with BS EN 1127-1, BS EN 14797, BS EN 14491 and BS EN 14994.

NOTE 2 Flameless venting devices may also be installed (see BS EN 16009).

If explosion relief is not installed, and there are extensive deposits of dusts on surfaces within the building, any dust explosion within the process could release burning and unburnt dust into the building, and raise further dust clouds. A secondary explosion is then possible, which is likely to be far more destructive than the primary explosion. Any outward loading on heavy load bearing walls is liable to cause serious collapse. Where process plants create dust hazards, buildings should be designed with lightweight walls and a framework not vulnerable to collapse if exposed to the explosion forces.

Another protective measure is the provision of a deliberate area of weakness on the process equipment. Where explosion relief panels are to be provided on buildings, these should be designed using the design equations for the size and opening pressures BS EN 14491. The panels used should be considered as ATEX explosion protection systems, and certified accordingly.

24 Prevention of ignition of a mixture of air and gas/vapour released from a process into a building

The process should be designed to minimize the potential for a major release of fuel or flammable process materials into a building, which would generate the risk of an explosion within the building.

NOTE This is most likely to occur where the flammable material released is in the form of a gas or vapour.

25 Prevention of ignition of a cloud of dust raised into suspension within a building, following some initiating primary explosion

Good housekeeping should be implemented to remove dust deposits and thereby control secondary explosion risks, but explosion prevention measures should also be implemented to prevent the release of burning material into a building following ignition inside the process.

26 Prevention of ignition of a mixture of air and gas/vapour into a partially confined (congested) area of a process plant

At an early stage of design, the layout should be reviewed for any areas where congested plant could cause any ignition of a gas cloud to create greater overpressures than would occur in an uncongested location. If the calculated explosion overpressures are likely to create an unacceptable risk to people and buildings the layout should be amended, or the buildings relocated or strengthened.

27 Prevention of ignition of a mixture of air and gas in the open air

NOTE Releases of gas/vapours in the open air in an unconfined location are normally dispersed quickly below the lower explosive limits due to the good natural ventilation present. However, if a major release occurs with delayed ignition, then the consequence might be a fireball, or a vapour cloud explosion. A fireball effect could cause injuries from the radiant heat and/or initiate a fire in other materials or buildings. Where large quantities can be released, a vapour cloud explosion can result, causing severe danger to people, and potential damage to buildings and process plant from the pressure effects. The minimum quantity of material which can generate a vapour cloud explosion depends on factors including the reactivity of the product, the turbulence of the gas cloud, the height of the release source above the ground and the gas concentration through the cloud at the time of ignition.

Where there is a risk of release of tonnage quantities of material, computer modelling should be carried out to assess the possible consequences.

External ignition sources should be controlled through hazardous area classification, and the selection of ATEX equipment. Processes should be designed so that any major leak can be detected quickly, and emergency precautions taken to limit the consequences. In particular, processes should be designed so that a foreseeable release is not likely to generate an explosive atmosphere outside the site boundary.

28 Prevention of bursting of a pressure vessel holding flammable liquids or liquefied gases, followed by sudden ignition of the released material

Sudden failure of pressure systems without external fire is relatively rare, but appropriate design and inspection regimes should be implemented to control this.

NOTE This risk has little direct link to fire precautions.

Section 5: Storage and movement of chemicals

29 General

NOTE Safe handling of chemicals requires an understanding of the hazards associated with individual products, how they might disperse if released from storage of process, and any particular hazards from combinations of materials.

The transport labelling should be checked to identify the primary hazard, one of the nine hazard classes, which with subdivisions are shown as a coloured diamond on the packaging. Any subsidiary hazards associated with chemical products should be identified from the material safety data sheet (MSDS) and taken into account, for example materials might be both flammable and corrosive or toxic. The information should be retained in a central location for reference purposes, and safety data made easily accessible to staff handling specific materials.

The influence on the fire hazard of the physical form of the chemical should be taken into account in any assessment of the risks.

EXAMPLES

Fine dusts can create a dust explosion hazard, even when the same material in granular form would not explode.

Viscous materials, such as paint resins dispersed in a solvent, flow more slowly out of any container that is damaged than the same solvent as a pure material.

Materials which are solids at room temperature might be liquids or even vapours within the process, and disperse very differently if released.

30 Storage of chemicals

30.1 Packaged goods external: separation distances

Many types of chemicals, including flammable liquids and some flammable solids, are transported and kept in containers such as rigid IBCs, steel or plastic 200 L drums, and smaller containers. These should be stored in the open air to provide good ventilation and prevent accumulation of vapour from small leaks.

The fire hazards that should be controlled include the following.

a) Fire involving a drum stack generating high levels of radiant heat, affecting nearby buildings, neighbouring premises or process plant. A stack fire can also create missiles from containers which burst when overheated. They carry with them residual flammable material if the top seam fails before the bottom.

b) Small releases from a damaged containers spreading beyond the storage area, which can be ignited readily.

c) Fire in adjacent premises overheating containers, causing them to fail violently.

d) Liquid from failing drums flowing into drains and spreading off site or causing fire, explosion and pollution risks well away from the storage area.

Items a), b) and c) should be addressed by adopting separation distances of drum stacks from boundaries, buildings and fixed sources of ignition. The distances should be based on the quantities of material stored, as this controls the radiation at the boundary in the case of a fire involving the full inventory.

Small releases of vapour disperse readily from well-ventilated sites. To ensure this occurs, external storage sites should be open to the appropriate separation distance on at least two sides, and preferably three. Where the full separation distance cannot be achieved, a fire wall should be provided along one side to provide some protection from radiant heat from a stack fire or off-site fire, and prevent vapour reaching sources of ignition before it has been diluted below the lower flammable limit.

Storage sites should be impervious, have no gullies or drains where liquid could collect or flow off site, and have a raised kerb or edging sufficient to retain the contents of a single container of the largest size within the storage area.

NOTE Detailed guidelines for open air storage are given in HSG 51 [24].

30.2 Bulk liquids tanks for flammable liquids

30.2.1 General

Bulk liquids may be stored in tanks ranging in size from 1 m^3 to 2 m^3, commonly used for diesel fuel for space heating up to 5 000 m^3 or greater as found on refinery sites and major distribution depots.

NOTE 1 Atmospheric storage tanks can be located underground or above ground. Smaller factory-built above-ground tanks are commonly horizontal cylindrical in form. Large site-built tanks are commonly vertical cylinders, and may have a fixed cone roof, a floating roof or an internal floating roof.

From the perspective of fire protection, each design has positive and negative features.

Underground tanks should be used where space is limited, and to avoid the possibility of external fire attack following any release.

NOTE 2 These are almost universally used at petrol filling stations and typically need vents which extend well above ground level, as vapours are released during filling.

Precautions should be implemented to control the following hazards.

a) Above-ground tanks require bunding to control the flow of any major release. A bund fire involving a major spillage quickly heats the external shell of a tank and generates a flow of vapours from the vent.

b) Where low flash point products are stored, the space above the liquid level might be permanently in the explosive range, creating the potential for an explosion if this ignites. Flame arrestors should be fitted or tanks may be inerted to reduce this hazard.

c) Comparatively large volumes of vapour are released during tank filling.

Floating roof tanks should be used for the larger sizes, as these prevent the formation of a large volume of an explosive vapour/air mixture and reduce the losses through the vent. The danger from rim seal fires should be considered.

NOTE 3 If the floating roof sinks, a very large fire might spread across the whole surface of the liquid. At the largest scale of operation, such fires are difficult to extinguish.

Tanks with internal floating roofs should be ventilated to avoid the formation of an explosive atmosphere above the floating roof in normal operation, but the design considerations for fire engulfment are more complex to control.

30.2.2 Tank design

Tanks should be designed in accordance with the following standards, as applicable.

- BS 799-5 (carbon steel oil storage tanks).
- BE EN 976-1 (horizontal cylindrical underground GRP tanks).
- BS EN 12285-1 (horizontal cylindrical workshop fabricated below ground).
- BS EN 12285-2 (horizontal cylindrical workshop fabricated above ground).
- BS EN 12573 (welded, static, non-pressurized thermoplastic tanks).
- BS EN 13575 (thermoplastic tanks for storage of chemicals).
- BS EN 14015 (vertical cylindrical site built above ground flat bottomed).
- API 620 (large low pressure storage tanks).
- API 650 (welded steel tanks for oil storage).
- API 2000 (venting atmospheric and low pressure storage tanks).
- API RP 2021 (management of atmospheric storage tank fires).
- OFS T200 (steel storage tanks).

When tanks are being selected, their intended use should fall within the scope of the design standard. Moreover, where an existing tank is to be reused for an alternative purpose, where practical the original design standard should be consulted.

30.2.3 Location

Tank location should address the following hazards by incorporating the separation distances in HSG 176 [25].

a) A fire at the tank or in the bund that threatens neighbouring plant, property or adjacent premises.

b) A nearby fire that subjects the tank to excessive heat.

c) The vulnerability of the tank to impact from vehicle movement, leading to a major spill.

d) Limited control over sources of ignition within an adequate range around the tank.

NOTE Tank spacing to prevent escalation depends on the available resources for tackling the original fire, and the availability of cooling water/foam and other resources to protect tanks not on fire. Times for fire spread can be calculated; these depend on weather conditions.

30.2.4 Bunding

Bunding should be designed to retain 110% of the liquid in the largest tank within the bund. Larger bund capacities should be provided if there is a risk of bund overtopping due to sudden failure of a tank that would otherwise lead to substantial loss of liquid over the bund wall.

NOTE 1 The form of bunding has an impact on control of fire risks. A large, wide bund with low retaining walls creates the hazard of a pool fire covering a large area, and if the bund contains more than one tank all might be quickly threatened by a bund fire. However, this type of arrangement promotes dispersion by the wind of any small releases of liquid or vapour.

A tall bund of small area closely surrounding a single tank creates a situation where vapour can accumulate, so that small liquid releases might be more difficult to identify during a walk-by inspection. However, the small surface area is likely to make firefighting operations simpler. The bund walls should not exceed 1.5 m in height.

Where a common bund encloses more than one tank, dwarf cross-walls should be provided to control the spread of a small release.

Provision should be made to remove or drain away surface water. Any pump used for this should be of a design that does not cause ignition of the stored product. Where this is achieved by manually opening drain valves, secure procedures should be provided to ensure the drain is not left open after the bund is emptied.

*NOTE 2 See Clause **8** for drainage.*

All bunds tend to accumulate rubbish, which can act like a wick so that liquids that cannot be ignited directly as a pool might support sustained burning.

The Oil Storage Regulations [26, 27, 28] require secondary retention for oil storage vessels of more than 200 L on commercial sites.

30.2.5 Overfill protection

Bunds should not be considered as a safety measure against overfilling tanks.

The primary prevention measure against overfilling a tank should be good operating procedures, but for the more hazardous products, larger scale operations or situations where a transfer is not continuously supervised, high-level alarms and trips should be provided.

30.2.6 Control of ignition sources

Where flammable liquids are stored, a hazardous area classification exercise should be carried out. All potential sources of release should be identified, including tank vents, sample points, connection points for flexible hoses and transfer pumps.

ATEX equipment suitable for the zone should be provided, but other sources of ignition should also be addressed. For example, tankers should be earthed prior to deliveries to prevent ignition by static electricity generated during transfer operations. Splash filling should be avoided by using dip pipes that extend inside the tank close to the base, and limiting pumping speeds (see BS PD CLC/TR 50404).

Precautions should be implemented to avoid ignition by lightning strikes, the most common ignition source for the largest, tall floating roof tanks.

Close control should be exercised over hot work in a defined area around the tanks.

30.2.7 Fixed fire protection

The provision of fixed fire protection should be based on a risk assessment, particularly at the largest scale of operation. Fixed foam application systems should be provided to protect the shell of a tank from external fire, and to extinguish bund fires. They can be affected by strong winds, so back-up systems for manual application of foam should be provided wherever a fixed foam system is installed.

30.2.8 Firefighting

Preplanning should be carried out to determine the quantities of water and foam compound likely to be required for firefighting.

NOTE Further information is available in HSE Contract Research Report RR 333 [29]. Guidance on dealing with tank fires at the largest scale is given in BP Process Safety Series and I Chem E publication, Liquid Hydrocarbon tank fires: Prevention and Response [30].

30.3 Tanks for LPG and similar

NOTE 1 Above-ground LPG tanks are a significant fire hazard. Fires might start following a leak during tank filling or discharge, or when gas is released from the pressure relief valve, following overfilling or exposure to fire nearby.

Facilities should be designed so that any release which does not immediately vapourize does not remain underneath the tank, and that leaks from a tanker during product transfer flow away from the fixed tank.

Larger tanks should be protected against failure following exposure to fire by, for example, a water deluge system or a form of thermal insulation designed to withstand exposure to a severe fire. Intumescent coatings may be applied.

NOTE 2 Intumescent coatings expand when exposed to heat, producing a foamed layer with durable insulating properties.

Separation distances for tanks from buildings, boundaries and fixed sources of ignition should be selected according to the size of the tanks.

NOTE 3 Detailed requirements for all aspects of a facility comprising one or more fixed LPG tanks are set out in UKLPG Code of Practice 1: Bulk LPG storage at fixed installations [31].

30.4 High-pressure gases, cylinders or larger static containers

NOTE Most LPG cylinders are fitted with pressure-relief valves which open if the cylinder is exposed to fire, but most other types of high-pressure cylinders have no pressure relief. If exposed to fire they are liable to burst violently after an unpredictable period.

Gas cylinders, including those containing non-hazardous gases, should be stored outside any building, in a well ventilated place. To control access, where necessary, a caged or wire-fenced locked compound should be provided.

All combustible material, such as packaging, pallets, flammable chemicals in drums and parked cars, should be kept well away from cylinders. Sources of ignition should be controlled in the area around cylinders containing flammable gases or oxygen.

Provision should be made for cooling the cylinders by applying water in the event of a fire.

NOTE See British Compressed Gases Association Guidance Note 2, Storage of Gas Cylinders in the Workplace [32].

30.5 Storage of powdered products in bulk

NOTE 1 Bulk quantities of granular or powered chemical products are commonly stored in bulk in cylindrical silos. Smaller quantities can be stored in FIBCs, in stacks or on racking. Many products react slowly with air at temperatures well below that required for flaming combustion, and some might decompose exothermically in the absence of air. As with most chemical reactions, the reaction rate increases greatly as the temperature increases.

In bulk powder storage there are no convection currents and the thermal conductivity is low. Any tendency to self-heat is then liable to cause an increase in temperature local to the point at which the process starts, and self-accelerate, unless limited by the supply of oxygen.

To specify storage conditions that prevent self-ignition, the thermal properties of a substance should be identified using a range of available tests. Small-scale tests, such as differential scanning calorimetry, may be used for screening purposes, while larger scale isothermal tests provide more precise information about onset temperatures.

Safe storage conditions depend particularly on the dimensions of the silo or stack, the temperature of product at the time it is bulked, and the storage time. The selection of silo capacities should take into account any calculated thermal onset temperature for a given volume (see BS EN 15188).

NOTE 2 Fire detection measures on individual silos are not generally required where the material has been adequately characterized, and the storage times and bulking temperatures can be reliably controlled.

Effective stock rotation is a key element in preventing fires from self-heating. Silos should not be left unemptied for extended periods simply because of a flow blockage. Where product needs to be kept for extended periods, a facility should be provided to recirculate this through a conveying system and prevent heat build-up, or to identify signs of overheating at an early stage.

Precautions against fire and explosion of powdered products stored in bulk should take account of the following.

a) Fire detection of a developing fire within the bulk cannot be achieved quickly using the normal techniques of point smoke or heat sensors. The most useful technique for early detection of a developing fire within the bulk container uses gas monitors to measure the concentration of chemical species formed in the gradual reaction. Carbon monoxide is the most common gas detected for this purpose, but others might be more suitable, depending on the particular product. A sensor located in the head space of the silo monitors the atmosphere continuously, and raises the alert either on a maximum level or where the measured level is increasing at a rate exceeding a given threshold.

b) Extinguishing a developing fire within the bulk is not straightforward, particularly as the precise location and size of fire at time of detection is not known. The options are usually limited to displacing air by an inert gas, e.g. nitrogen or carbon dioxide, or by emptying the silo if this can be done safely. The use of water is usually to be avoided, as it makes subsequent emptying of the silo much more difficult.

Where the risk of a fire starting inside the silo cannot be excluded, facilities such as a blanked-off nozzle with a valve should be provided for connecting up an inert gas supply close to the base.

NOTE 3 Fire extinguishing using an inert gas takes an extended time because the gas provides little cooling. In a large silo this might take several days.

Where the risk of fire cannot be excluded, facilities should be provided to allow the silo to be emptied to the open air, provided the product is not toxic or otherwise hazardous. It is usually impossible to be certain when a deep-seated fire is completely extinguished, and discharge of a silo on through the normal conveying system should be avoided.

NOTE 4 Self-heating is not the only cause of fires within silos, and fires might start because burning material is introduced from upstream in the process.

*NOTE 5 Section 4 recommends control measures for other sources of ignition. Clause **38** also recommends fire precautions specifically for dust-handling processes.*

NOTE 6 Where fine products are handled, a dust cloud capable of exploding is liable to form during silo filling, or when dust clinging to the upper walls and roof is dislodged. In most cases, precautions to control dust explosions are likely to be needed where explosible dusts are handled. The technical measures for this fall outside the scope of this standard. See Fires in Silos [33].

30.6 Underground storage

The benefits of buried tanks (commonly used for storing petrol, LPG and other products) in terms of fire protection should be balanced against increased risks of corrosion and difficulties of both detecting any leakage of liquid from an atmospheric tank, and periodic tank inspection for either atmospheric tanks for liquids or pressure vessels for LPG.

A buried tank has no exposed surface that can be exposed to fire, and no risk of a pool fire underneath or surrounding the tank. The connecting pipework and vents, however, should be designed to ensure safety of the facility in case of fire.

Tanks and their filling points should not be located underneath a building or process plant, though the guidelines for petrol storage set no minimum separation distance between a tank and a building.

Tank vents, including discharge points from pressure relief valves on large LPG tanks, should be extended vertically, to encourage dispersion of vapours that are released and to minimize the extent of any hazardous area at ground level. Tank vents on atmospheric tanks should be fitted with end-of-line flame arrestors.

Hose connection points should be located where they are convenient for connection to tankers. Any trench carrying pipework for flammable liquids should be in accordance with the Energy Institute's *Guidance for the Design, Construction, Modification and Maintenance of Petrol Filling Stations* [34] and the UKLPG Code of Practice, *Bulk LPG storage at fixed installations, buried and mounded storage vessels* [35].

30.7 Storage in buildings: flammable liquids

Flammable liquids in containers should only be stored in buildings or parts of buildings that are specially designed for the purpose. Stocks of flammable liquids in process should be limited to the amount needed for half a day's production.

Smaller quantities, in bottles or tins used in laboratories, should be stored in steel cupboards or bins designed to retain the contents if a leak occurs.

Storage buildings for flammable liquids should:

a) be of non-combustible construction;

b) be provided with good ventilation at high and low levels along at least two walls or be provided with mechanical ventilation;

c) have more than one exit, where the travel distance to the door exceeds 12 m;

d) be classified as zone 2 to a level at least 1 m above the highest stored container;

e) have a low sill or gully at access doors to prevent any leakage flowing out of the building;

f) be marked with the "Ex" symbol, indicating a hazardous area at entrances;

g) be fitted as necessary with non-opening windows with 30-minute fire-resisting glazing; and

h) be fitted with a lightweight roof.

In addition:

1) drums or containers should be stacked not more than three high, unless the drums are supported by racking;
2) any racking provided should be of metal construction;
3) no decanting or other activities liable to cause a significant spillage should be allowed within the building; and
4) access to the building should be limited to authorized persons

The same precautions should be implemented where a flammable liquid store room forms part of a larger building.

In addition, the store room should be separated from the remainder of the building by 30-minute fire-resisting construction, with no direct access into the remainder of the building.

NOTE It is difficult to meet the ventilation requirements by natural ventilation, unless the room is of small area or two external walls.

The building may be located on the boundary, where the wall facing the boundary is of fire-resisting construction.

Further details are set out in HSG 51 [24].

30.8 Chemical warehousing

30.8.1 Chemicals with diverse hazards

NOTE Chemicals in IBCs, drums or smaller containers are often stored inside a chemical warehouse.

Where a chemical warehouse stores multiple products with a diverse range of hazards, fire protection is not straightforward. Fires in chemical warehouses typically involve few direct casualties, but the potentially toxic nature of the smoke plume causes much alarm, and pollution from chemicals flowing off site might cause lasting damage. The damage to reputation and the costs of business interruption can be very high.

To identify suitable fire precautions in chemical warehouses the hazards of the materials in store, the consequences of their release into a burning building and how different types of chemical container behave in a fire situation should be established.

a) Chemical containers normally come to site with a hazard label showing the transport category, but intermediates used on site might not be labelled in this way. The transport diamond label (see Clause **29**) gives the primary classification, but not necessarily the secondary characteristics. For example, many flammable liquids also cause lasting pollution if released into water courses, many monomers which are flammable liquids polymerize uncontrollably if overheated during storage, and toxic materials create different problems if they are water soluble, insoluble or readily vaporized in a fire.
b) Steel drums might fail suddenly at the seam of the base or top to the walls, and part of the drum might be ejected from a stack. Plastic drums soften and burst, usually less violently. Pressurized gas cylinders fail very violently, unless they are fitted with pressure-relief valves. In this case overheating of an LPG cylinder opens the PRV and the escaping gas then creates a new jet flame, which might overheat other cylinders.

c) FIBCs holding powders and held on racking have been shown to melt in fires, releasing a flow of product from the bags, which can then burn more rapidly than a pile on the floor. Generally, the mechanisms for fire spread are not the same as those found in offices or other places where the main fuel for a fire is furniture and furnishings.

d) The consequences might be that fire growth is very rapid, and exploding containers can cause flying debris. In such circumstances, it is dangerous for the incoming fire and rescue service to tackle a fire from within the building, even in the early stages.

30.8.2 Fire prevention in chemical warehouses

A high standard of precautions should be adopted to prevent the outbreak of fire in a chemical warehouse.

The precautions for controlling ignition sources should include the following.

a) Where flammable liquids with a flash point below 32 °C are stored, a hazardous area study should be completed, and the area classified as zone 2.

b) All fixed electrical equipment should be selected according to the zone, and properly maintained.

c) Replacement of gas cylinders on LPG powered trucks and recharging of electrical lift trucks should take place outside the store.

d) Space heating should be selected that creates no ignition hazard.

e) All electrical equipment that does not need to be energized when the warehouse is unoccupied should be turned off.

f) Personal mains-powered electrical equipment (e.g. radios) should be excluded from the store.

g) Where attempts at arson are anticipated security measures should be implemented to detect potential intruders.

h) During normal working hours, it should not be possible for an unauthorized person to enter the store unchallenged.

i) Welfare facilities that include any equipment for heating food should be located external to the warehouse.

j) Lighting should be selected which cannot act as a heat source capable of igniting packaging by radiant heat.

k) Hot work should be excluded from the store as far as possible, and only carried out under permit to work after a substantial area has been cleared.

l) Rules against smoking should be rigorously enforced.

m) Normal road vehicles should not be allowed to enter the store. While parked adjacent to the warehouse for unloading, the engine of any such vehicle should be turned off, but the driver should remain on site where they can be contacted promptly if the vehicle needs to be moved.

30.8.3 Precautions to limit the availability of fuel

Combustible packaging should not be kept in the same compartment as hazardous chemicals.

Materials from drums or IBCs should not be transferred to smaller containers in the store.

Piles of pallets should not be kept in the store or stacked along the external wall of the building, unless this provides a minimum of one-hour fire resistance.

Chemicals should not be processed in the store.

Damaged containers should not be placed in the main store.

Facilities should be available for over-packing any container that starts to spill or leak.

30.8.4 Separation of chemicals with different hazard categories

A policy should be drawn up and implemented for the storage arrangements for products with different hazards.

The policy should emphasize the need to avoid combinations of chemical types that increase the fire risk if they are mixed, and to prevent a small fire growing to involve materials that have a low fire risk, but which create additional hazards if involved and dispersed by fire.

A second objective should be to simplify the options for fixed fire protection. Water-based systems are suitable for some chemical storage areas, but should be avoided if any of the chemicals stored would react with water.

Particular products requiring special conditions for storage or which are particularly high fire hazards should be separated.

NOTE Examples include materials that are prone to decompose at temperatures close to normal ambient, such as organic peroxides, and pyrophoric chemicals, e.g. yellow phosphorus. Recommendations relating to separation of different categories of chemicals are set out in HSG 71 [36].

30.8.5 Compartmentation

*NOTE Compartmentation is normally provided in a building to meet the Building Regulations requirements described in Clause **11**. However, there might be good reasons to provide additional compartmentation in chemical warehouses. Tall free-standing fire compartment walls are difficult and expensive to construct, and might be impractical in a high bay warehouse. If a small separate compartment is required for a particular category of chemicals, this might be best constructed as a small unit with its own fire-resisting ceiling, instead of a full height compartment wall.*

For the maximum security, compartment walls should have no openings. This arrangement, which implies additional entrances into the building, should be adopted to separate office accommodation from the chemical store and compartments for organic peroxides or pyrophoric materials from general storage

Some materials, such as high-pressure gas cylinders, should be stored external to a building where they can protected from sources of radiant heat and cooled safely if necessary.

LPG cylinders should be stored in the open whenever practicable, as small releases can create an explosive atmosphere over a wide area and, as the gas accumulates at low level, it is unlikely to be readily detected by smell.

30.8.6 Ventilation

Effective general ventilation should be provided for chemical warehouses, at low and high level. When the size of the building is moderate, this may be achieved by fixed ventilation openings in two or more external walls, but as the size of the building increases, the effective air exchange rate falls.

NOTE In principle, ventilation can be improved by a mechanical system, but in a large warehouse the scale of the system needed might be prohibitively expensive to install and run. It is also likely to be ineffective, if during the working day a large door is open for extended periods to allow movement of lift trucks in and out.

As an alternative, and provided no leakage is likely except during stock movement, all stock should be inspected for signs of damaged or deteriorating packages, and:

a) checks should be made by portable gas detection meters, if these are available for the particular substances in store; and
b) detailed procedures should be implemented for dealing with releases caused by damage during stock movement, including isolation of all electrical equipment if stock is moved through an area that is not classified as hazardous.

30.8.7 Waste materials

NOTE 1 Most chemical manufacturing plants generate waste products on site. Where these are produced in small quantities, e.g. from laboratory operations, various products may be bulked together to make a suitable quantity for disposal.

Waste products are often stored in recycled containers, which are labelled for the products they originally held.

To control the fire risks associated with waste materials, the following precautions should be adopted.

a) Waste materials should only be transferred into containers that are in good condition. Where containers are to be reused they should be individually inspected before filling.
b) Potential interactions of residues from earlier use with the waste material to be transferred should be identified by someone with adequate chemical knowledge.
c) Containers should be marked with an indication of their contents, and an indication that the product is waste.
d) The hazard category of the product should be indicated to ensure that a safe storage location can be assigned.
e) Containers should be securely closed, and any drum or container rejected if the closure is damaged.
f) Where mixtures of different chemicals are to be bulked, even on a laboratory scale, the potential for reactions that cause heating or gas evolution should be determined.

   NOTE 2 See Bretherick's Handbook of Reactive Chemical Hazards [37].
g) Waste awaiting disposal should be stored with the same precautions against fire hazards as new raw materials or finished products.
h) If waste materials are held for extended periods before disposal, the containers should be inspected periodically for signs of deterioration.

31 Delivery by road and rail

31.1 Tankers

NOTE Detailed rules for the design of road vehicles carrying dangerous goods are set out in the international agreements known as ADR [5].

Loading and unloading points for flammable products should be designed and laid out so that:

a) any spillage flows away from underneath the tanker;
b) spillages are retained in specially-designed drainage systems with an interceptor to prevent loss of product off site;

c) tanker stances are not inside any building and are well ventilated on at least two sides:

d) connecting points are provided for earthing the tanker to the facility;

e) lengths of flexible hose required are minimized;

f) where there are multiple connection points, these are properly labelled;

g) systems of work are in place to minimize the release of any liquid when hoses are disconnected;

h) the vehicle electrical systems are turned off;

i) the driver remains available so the vehicle can be moved in case of emergency;

j) control equipment and safe systems of work are provided to minimize the potential for spillage caused by overfilling;

k) during transfer, controls are in place over other vehicle movements nearby and other movable ignition sources;

l) suitable fire extinguishers are available for immediate use, including on the tanker;

m) fixed pumps provided for transfer are located in their own small bunded area, and not included in the main bund for a fixed tank.

Gas cylinders, flammable liquids in IBCs, drums or smaller containers and powdered flammable products in sacks or IBCs are normally delivered to sites by road vehicles. Safe systems of work should be implemented to minimize the risk of damage leading to loss of containment during any transfer of chemical products This should involve the use of lift trucks, though some gas cylinder supply vehicles are fitted with their own lifting equipment. Drums and cylinders should never be rolled down ramps or bounced onto a foam bed. Small items may be lifted manually.

Unloading activities should only be carried out where any spillage of liquid from a damaged container can be retained locally and prevented from flowing into drainage systems or off site.

Fixed lighting should be provided at the road vehicle stance where transfers are undertaken during hours of darkness.

Road vehicle standing points should be substantially level, except for any small camber or gradient designed to direct small spillages away from under the vehicle.

Unloading points should not be inside any building, but may be located under a roofed canopy at the front of a building.

Site-specific risk assessments should be carried out, taking into account the frequency of transfers, the risk of escalation of any incident, the numbers of people at risk, the particular fire hazards of the products to be handled and the total quantity of material in the area.

Where a risk assessment indicates that the risks are sufficiently low, a normal lift truck may be used. Where any aspect of the operation gives rise to a significant risk, a lift truck designed to ATEX category 3 should be used.

31.2 Rail

NOTE 1 The UK has adopted as the basis for rail transport within the UK the same design rules for rail vehicles as those which control international rail traffic. The design rules for rail tank cars, including those that operate under pressure, are set out in international agreements and the technical details in BS EN 12561. A summary of the requirements published by the European Chemical Transport Association is available at www.ecta.be

Loading and unloading of bulk liquid fuels, LPG or other flammable chemicals creates serious fire hazards. This subclause considers only transfer operations and does not consider the hazards that arise from the potential for release of chemical products from a train during transit on the national rail network.

The risks during loading and unloading are particularly large, because of the large quantities involved in a single train load, the common practice of filling or discharging multiple rail tank cars at the same time, the potential for trains to move during a transfer, the risk of a derailment or roll over when trains are moved on poor quality track or at excessive speeds, handling of large volumes of a flammable vapour air-mixture in the vapour recovery sections during tank car filling, the difficulty of providing secondary containment at many rail facilities, and the potential for trains to be moved before all the loading/unloading connections have been disconnected.

Fire precautions should be implemented to address hazards by ensuring the following.

a) Safe systems of work.

b) Close cooperation between the rail operators and staff at the transfer location.

c) Good controls to prevent spillage, overfilling, correct routing of product transfers.

d) Control over ignition sources, particularly electrostatic hazards and stray electrical currents through the rail track.

e) Preplanning for fire situations, including the potential for fire spread between adjacent tank cars.

The precautions should include the following.

1) Rail transfer loading and unloading facilities for flammable liquids should be subject to a hazardous area classification study, and the safe system of work should detail how ignition hazards are controlled in the hazardous area during train movements.

2) Overfill protection measures for rail tank cars should be implemented as a safety critical system and subjected to analysis using the methodology of BS EN 61511.

3) A human factors analysis of the procedural aspects should establish the risks that arise from omitting stages in the procedure, doing them in the incorrect order, failing to complete a task, routing product to the wrong tank, and incorrect information transfer between rail network staff, staff at the transfer point and staff at the tank farm.

4) Staff involved in the transfer process should be trained in the actions to be taken in the event of any spillage, small fire, overfill situation or other hazardous situations.

5) The risk to neighbouring premises and property from a fire involving one or more rail tanks cars should be considered.

6) The risk of an ignition from inside a vapour recovery system during product transfer should be determined.

7) Suitable access arrangements for firefighting from each side of the train should be provided.

NOTE 2 The particular issues arising from the introduction of vapour recovery systems are considered in the Energy Institute's Guidelines for the design and operation of gasoline vapour emission controls at distribution terminals [38].

Section 6: Design of process plant

32 Design of process plant to control ignition hazards

Process plant and unit operations should be designed to avoid ignition sources, such as the following, in hazardous areas around the plant and inside the process, wherever flammable materials are handled and air could be present.

a) Mixing processes, where the moving parts of the mixing machine could generate sparks or frictional heating.

b) Sieving processes for powders, where there is a potential for static discharges.

c) Addition of powders to highly flammable liquids in a reactor vessel, where static discharges are difficult to control.

d) Use of pumps of a type which can overheat if they run dry.

e) Drying processes that generate surfaces hot enough to initiate exothermic reactions or fire on prolonged contact.

In many cases such hazards can be controlled by inerting, typically with nitrogen, or by operating under vacuum.

To control the risk of ignition from electrostatic discharges, the following should be determined.

1) The processes that can generate charge.

2) Where charge can collect.

3) How charge can then form a spark.

4) Whether a spark would be capable of igniting the gas, vapour or dust that is present.

NOTE 1 Recommendations are given in BS PD CLC/TR 50404.

The potential for mechanical plant that does not generate ignition sources during normal operations to do so under fault conditions or when tramp metal enters the system should be determined, using the framework of an ignition hazard assessment set out in BS EN 13463-1.

*NOTE 2 See Clause **38** concerning powder-handling processes.*

Chemical reaction processes should be designed to prevent exothermic runaway conditions which can lead to loss of containment, following overpressurization of equipment, boil-over or directly to a fire if the reactants become hot enough.

NOTE 3 See HSG 143 [22].

Precautions should be implemented to address the consequences of loss of services, particularly electricity, cooling water, inert gas or compressed air for all but the simplest of operations. Where loss of cooling water could create a release, this should be monitored and an alarm raised on loss of flow.

Items of process equipment which could cause a serious release of flammable material if they failed as a result of gradual loss of strength or thickness due to corrosion or degradation should be identified. Such items should be included in a planned preventative maintenance regime.

NOTE 4 Process plant constructed from materials resistant to the chemicals it contains is subject to corrosion or degradation over time. Detailed rules apply to such plant where it forms part of a pressure system. A written scheme of examination is also applied, but other process plant might not be covered in this way.

Process vents that are designed to release flammable material should be extended to the outside of a building, normally at high level, but the implications of a long vent line for pressure drop and venting capacity should be determined. Flame arrestor elements traps should be provided on normally open vents, unless the nature of the chemicals in the process would make them prone to blockage from build-up of polymer or resinous material.

Polymeric parts of process plant such as flexible pipework are likely to melt or burn, leading to failure in the early stages of a fire. If this could lead to sudden fire growth from loss of containment, alternative materials should be considered.

*NOTE 5 Design tools useful in a systematic review of the hazards include the Mond index (see Note to Clause **5**) and HAZOP. See BS IEC 61882.*

33 Process vessels

Reaction processes can be vulnerable to overpressure, either from loss of control of the process or external fire attack. Floor grading and drainage should be designed such as to prevent a large pool of flammable material collecting under process vessels in case of spillage. Where emergency venting is provided, the design calculation should assign some pressure rating for the equipment to be protected, even if operation is normally at atmospheric pressure. This might require the use of pressure vessel specifications, such as PD 5500 or BS EN 13445.

Heat exchangers are high-risk items if they fail, particularly if one of the process fluids is above its auto-ignition temperature or an element will fail if liquid cover is lost. In these cases, accurate control of operating conditions should be linked to planned preventative maintenance.

Stirred reaction vessels incorporate a seal where the stirrer shaft passes through the shell, which could be the source of a leak into or out of the vessel, depending on the internal and external pressures. This creates the hazard of either a release of flammable material, within the building or an internal gas air mixture in the explosive range. The amount of heat generated in stuffing box seals is difficult to control, and these should not be used except in low-risk situations. Mechanical seals offering high integrity should be used, particularly the double type of seal, with a fluid circulated between the seals. The ignition hazards arising from stuffing box and mechanical seals should be addressed in accordance with BS EN 13463-5.

NOTE The application of the ATEX directive to seals is covered in the ATEX guidelines:

http://ec.europa.eu/enterprise/sectors/mechanical/files/atex/guide/atexguidelines-may2011_en.pdf

To ensure the required integrity of pipework for general safety, metal pipework should conform to BS EN 13480 (all parts), though other standards may be used for specific applications (e.g. ASME B31.3, IGEM/UP/2 [39] and UKLPG CoP22 [40]).

34 Pumps and heat transfer systems

NOTE Flammable oils are sometimes pumped around a plant to transmit power or motion (hydraulic oil systems) or heat (heat transfer systems). In each case there is a fire hazard potential.

34.1 Hydraulic oil systems

NOTE Mineral oils with closed cup flash points in the range 150 °C to 250 °C and auto-ignition temperatures of 315 °C to 425 °C are normally used. Operating pressures are often very high, in the order of several hundred bar, and all hydraulic systems are prone to leakage, especially where the pipes need to move. Although the temperature in the oil in a correctly operating system is usually less than 65 °C, considerably less than the flash point, leakage could give rise to a serious risk of fire. High-pressure leaks produce a fine mist which has been known to travel more than 10 m and can be readily ignited

If potential ignition sources cannot be eliminated, consideration should be given to the use of less hazardous “fire-resistant” hydraulic fluids, where applications permit. To minimize leakage, rigid pipes with swivel joints should be installed, rather than flexible hoses, but if flexible hoses cannot be avoided they should be of braided construction. Manifolding can reduce the number of potential leak points. Pipes should be well supported to prevent damage by vibration and movement. The pipes and joints may be fitted with a loose-fitting transparent plastic (PVC) hose to channel any leakage to a safe place.

Power packs should be sited well away from any potential fire hazard, and drip trays should be provided. Thermal cut-outs should be included in the system to shut down the system in the event of oil overheating.

To avoid the possibility of a massive leak of oil in the event of pipe breakage, excess flow shut-off valves should be fitted at strategic circuit locations, taking account of the most likely failure points. Quick-acting controlled shut-off valves should also be fitted.

34.2 Heat-transfer systems

NOTE Organic heat transfer oils are used up to approximately 425 °C, often at temperatures well above their flash point. The pressures are generally lower than for hydraulic systems but leaks can occur and, on ignition, a severe fire can result. If the oil leaks onto hot lagging and soaks into it, degradation and eventual spontaneous ignition can occur.

Potential leakage points should be carefully located so that any drips occur away from the lagging. At such points the lagging should have an outer casing impervious to oil. Valve glands are a common leakage point, so valve stems should be mounted horizontally. Shut-off valves should be provided to prevent massive oil leaks, similarly to those described for hydraulic oil (see **34.1**). The possibility of leakage within the heater unit and subsequent fire should be established.

35 Compressors

NOTE 1 Air compressors are hazardous if flammable vapours can be drawn into the machine. Internal fires or explosions are also possible if the wrong lubricant is used and deposits of degraded oil collect.

Air compressors should be installed in accordance with the safety requirements of BS EN 1012-1.

For compressors handling flammable gases, a complete duty specification and gas analysis, covering possible off-specification conditions, should be prepared by the user to inform the compressor manufacturer of all relevant parameters that would affect the design and operation of the compressor. In turn, the manufacturer should inform the user of those operational conditions that could lead to a hazardous situation, with particular attention being given to possible failure of services, e.g. cooling water and power.

The following should be considered in the design of compressors.

a) The materials of construction used should be resistant to the chemical and physical properties of the gas to prevent failure due to corrosion, erosion or brittle fracture. Attention should be given to the seal, bearing, valve and piston ring materials.

b) All stages of positive displacement compressors should be protected against an overpressure condition by fitting relief valves after each compression stage. Isolation valves should not be fitted between the cylinder and relief valves.

c) The compression ratios selected should avoid excessively high discharge temperatures. In the case of oil-lubricated air compressors, cylinder discharge temperatures should not exceed 140 °C to prevent possible decomposition of the oil used for lubrication, which could result in an explosion. Temperature alarms and trips should be fitted to the cylinder discharge manifolds of all compressors.

d) In the case of reciprocating compressors, to avoid excessive vibrations caused by flow pulsations, the suction and discharge pipework should be analysed and consideration given to the fitting of pulsation dampers.

e) Flammable and toxic vapours leaking past seals should be piped to a safe location. Alternatively, adequate ventilation and gas detection equipment should be provided. Such vapours should not be allowed to enter the crank case or vent directly into the compressor house.

f) Crank cases should be adequately ventilated.

g) Where free liquid can be present in any suction line to a compressor which is not capable of handling entrained liquid, a separator in the form of a catchpot should be provided, with means of detection for any liquid accumulation and facilities for its removal.

   NOTE 2 Liquid drawn into the suction line(s) of a gas compressor which is designed for dry suction conditions can cause severe mechanical damage and, in extreme conditions, fracture the casing.

h) The suction point for air compressors should be located such as to prevent the possible presence in the air of flammable, toxic or corrosive substances. Particular care should be given in this respect to the siting of the air intakes to compressors on air separation plants.

i) Lubricants and seal fluids in contact with the gas being compressed should be compatible and not react dangerously with any downstream process fluids. For example, air compressors on air separation plants should not have hydrocarbon oils in contact with the gas being compressed, as these could react explosively with oxygen enriched air present in the process.

j) Compressors should be protected by the fitting of temperature, pressure, vibration and overspeed alarms and trips at all appropriate points. In particular, the compressors should be protected against the failure of supply of cooling water, lubricant, electric power and other services. Precautions should be taken against surge. On critical duties, automatic monitoring systems should also be fitted.

k) Consideration should be given to the fitting of check valves in compressor discharge lines where the reverse flow of gas could create a hazard.

l) Remote stop buttons should be fitted to enable compressors to be shut down from safe locations.

m) Compressors handling flammable gases generate hot surfaces, and have a potential source of gas release mainly from the shaft seal. They might also be vulnerable to other types of mechanical failure that can cause a large gas release. Protection should be provided against these hazards by area classification, forced ventilation and monitoring of the condition of the compressor through temperature and vibration measurements.

NOTE 3 BS EN ISO 10439 and BS EN ISO 10440 specify requirements for, respectively, centrifugal and positive displacement machines.

36 Fired heaters

NOTE 1 Many types of chemical plant that operate at high temperatures require fired heaters to produce the heat. Oil refineries' processes in particular use temperatures up to 900 °C in cracking processes.

The principle hazards from such high temperature plant arise from:

a) a leak of fuel or process fluid that ignites on an external hot surface;

b) failure of a burner tube, which allows flow between the burner side and the process side;

c) leakage of fuel into the combustion chamber while the plant is shut down;

d) the presence of excess fuel inside the combustion chamber at the point of ignition, through delays in establishing a flame;

e) loss of flame when this is not intended, e.g. from fluctuations in the fuel supply;

f) excess fuel being drawn into the combustion chamber through the air intake;

g) incomplete combustion leading to high levels of carbon monoxide or other combustible materials in the exhaust; and

h) emission of sparks from the exhaust;

The area immediately around high temperature plant is not classed as a hazardous area, as hot surfaces cannot be avoided. Electrical burner controls are not generally built to ATEX standards.

To control the hazards associated with fired heaters, only those incorporating fully automated burner controls with the following features should be installed.

1) High standards of isolation valves for the fuel supply.

2) Timed purge of the system before start-up.

3) Controlled admission of fuel during the ignition sequence, and if flame is not established within a set time period, restarting the sequence.

4) Air intake drawn from an area where it is unlikely that any fuel is present.

5) Flame failure devices, with a high speed of response.

6) Monitoring of the fuel gas pressure, or liquid fuel flow rate.

7) Monitoring of the pressures/flow rate of combustion air.

8) Monitoring of the exhaust gas composition, although this is more likely to be provided for fuel economy or control of pollution than safety of the combustion process.

In addition, high standards of plant inspection should be instituted to minimize the risk of pipe failure inside the furnace, or in the fuel supply lines.

Where sparks are likely to be emitted from the exhaust of diesel engines spark arrestors should be provided if the exhaust does not open to a safe place.

NOTE 2 The reliability of modern control systems is such that explosion relief on large combustion plant is not generally provided. BS 5908-2 lists relevant standards for combustion plant.

37 Ovens and driers

NOTE 1 Ovens and driers are widely used in coating and printing processes, and in many types of plant where solids including powders are separated from a liquid phase. The processes are either continuous or batch, and the controls needed are different.

Fire and explosion hazards arise if:

a) the substrate is flammable (e.g. paper or textiles);

b) flammable liquids are evaporated during the drying process, e.g. some types of solvent evaporating plant incorporate a thermal oxidizer at the end of the process, which creates a potential ignition source downstream from the drying stages;

c) the solid material is capable of self-heating or decomposing exothermically;

d) the fuel used in the heaters accumulates in the drying chamber;

e) powder or residues accumulate in the exhaust ducting from the plant.

Among the most common drying processes for solids are spray drying and fluid bed drying, which generate dust clouds, so the risk of an explosion should be controlled as well as the risk of fire.

Where dust clouds could form inside a dryer, the normal explosion prevention techniques should be applied: inerting, venting or suppression.

A system for normal control and for high-temperature cut-out should be implemented as necessary to control temperatures.

NOTE 2 Often, this is done by measurement of the temperature of the heating medium (oil/hot air/steam pressure), though this might not be adequate if the product starts to self-heat, or the substrate in a coating process starts to char or burn. Systematic analysis of the hazards, using a HAZOP or similar type of study, might be useful.

Any coating process that evaporates flammable solvents should conform to BS EN 1539 or BS EN 12921-3, as applicable. The controls needed should be informed by the intended operating range, with the simplest controls applicable to plants designed to run under all conditions at less than 25% of the lower explosion limit (LEL) in the main atmosphere of the dryer.

Effective filter systems should be provided to reduce the risk of dust or droplets being carried from a drying process and accumulating downstream in duct work. Periodic inspection of the inside of ductwork should also be conducted. Openings in the downstream ductwork should be provided to allow this.

38 Dust-handling process plant

NOTE 1 Fires are most common in plants which either deliberately run at elevated temperatures, or where parts of the equipment inevitably get hot during operation, e.g. drying processes, milling processes, conveying processes where frictional heating is possible, and combustion processes burning powdered fuels. Ignition of a powder on a hot surface is time-dependent, and fire is most likely where a small quantity of powder remains in contact with a hot surface for an extended period. This can be the result of powder deposits sticking to a heated surface, a grinding unit stopping while full of product or ingress of dust into a bearing.

Fires also occur as a result of blowback from pulverized fuel combustion plants, and where flow blockages occur in mechanical conveyors, but the drive to the machine is not tripped off.

Where combustible powder is present, a fire risk assessment for the process should be carried out.

NOTE 2 An explosion risk assessment is also required to be undertaken to comply with DSEAR [1, 2].

The precautions against fire and explosion should be selected according to the cause and scale of the hazard.

Where the risk assessment indicates that burning or glowing fragments could be drawn into a pneumatic conveying system, spark detection and extinguishing systems should be provided, if they are needed to prevent explosions downstream.

NOTE 3 See NFPA 69 and NFPA 654.

The fire risks associated with milling plant should be controlled mainly through operating procedures, such as requirements for mills to be run to empty before planned stoppages, and specific procedures for dealing with unplanned stoppages of different time lengths.

Depending on the fire risk, provision for inerting the atmosphere of a mill during an unplanned stoppage or application of cooling water should be provided.

The risk from dust ingress into bearings or other parts should be addressed by appropriate selection of ATEX equipment rated for dust service (see BS 5908-2).

Dust deposits should be removed from all areas of a building as a precaution against secondary dust explosions. During cleaning work, priority should be given to the removal of dust deposits from the surfaces of electrical and other equipment that generates heat.

Mechanical conveying systems should be provided with suitable instrumentation to detect flow blockages, and/or trip the drive motors to conveyors if a blockage occurs.

39 Instrumentation

Many chemical process plants have control systems designed to prevent loss of control over chemical reactions, provide correct shut-down or loss of essential services or loss of containment through any cause. All of these have an impact on fire safety, as well as general safety for the workforce. The degree of automation and complexity of the control system should take into account the full range of risks from the operation, including the risk of fire and explosion.

Where the instrumentation and control system are essential for ensuring the safety of the plant, they should be designed in accordance with BS EN 61511-1 and BS EN 61511-2.

NOTE 1 Where instrumentation is to be installed in hazardous areas, even where it operates at low voltages, the individual components and the wiring of electrical parts of the system within the hazardous area have to meet the ATEX requirements for the zone. Often this requires the use of intrinsically safe equipment, "ia" in zone 0 or "ib" in zone 1.

Modern electronic control systems permit a large amount of information about a process to be recorded, accessed and displayed in different forms on one or more screens in a control room. BS EN 54-2 recognizes the potential need for control and indicating equipment for a fire alarm system to provide an output signal to other systems, and provides a specification for the information that should be available as an electronic signal.

NOTE 2 The use of video cameras, if appropriately specified, could provide useful information, not only to help early detection of a fire or major release, but also to provide information for post incident analysis. Thermal imaging cameras may be provided to monitor process plant to provide early information about some abnormal state that creates an increased risk of fire.

Fire detection and fire alarm systems, typically designed to BS 5839-1, are traditionally stand-alone, with any link limited to either a duplicate display at a permanently manned location, such as the gatehouse, a separate display board in the control room, or at sites that do not have 24-hour security, to a permanently staffed fire reporting centre.

The links that might be useful depend on the actions that are expected of the control room operators or others in the event of fire (see Clause **41**). Following any equipment failure, alarms may be raised quickly and sequentially from process control systems, gas detection systems, and then fire systems. Alarm flooding, where the control room staff are presented quickly with more alarms than they can respond to, should be avoided.

NOTE 3 Guidance on prioritization of alarms is available in EEMUA Code 191 Alarm Systems – A Guide to Design, Management and Procurement [41].

Section 7: Operation of process plant

40 Human factors

NOTE 1 Some sources of ignition are a direct consequence of the actions, deliberate or unintended, of a process operator, or during maintenance work. Other sources of ignition are faulty equipment or other causes not directly a result of plant operations.

To ensure high standards of fire prevention and protection it is necessary to recognize the human factors aspects which impact on the plant operations.

Recognition of the importance of fire safety should be demonstrated at all levels of the company. In particular, where flammable chemicals are handled there should be:

a) a safety policy that identifies fire safety as one of the key issues to control;

b) a clear system for the control of contractors and visitors to the plant areas;

c) a stated policy concerning handover of new plant;

d) a robust procedure for management of changes, either to the plant or to procedures;

e) a system of planned inspection, testing and maintenance for all equipment that is safety critical, including fire equipment not directly needed for production; and

f) a system for auditing that procedures are followed.

Many chemical plants operate with small numbers of staff, who divide their time between a control room and process areas. Where this is the case, a review should be conducted to determine the risk that staff could be expected to carry out an excessive number of actions within a short time in the event of plant emergency.

Regular auditing of fire precautions should include:

1) checks on means of escape, where these are irregularly used;

2) testing of the fire alarm system;

3) inspection and testing of fire extinguishers and hose reels; and

4) testing of any flammable gas detection equipment.

Basic training on fire safety should cover:

i) the hazards of the materials that are handled and the labelling systems for chemical containers and pipelines;

ii) the actions required in the event of spillage or fire;

iii) the reporting procedures for faulty equipment and near misses; and

iv) the system for plant evacuation and accounting for persons.

Written procedures for many aspects of both routine and non-routine activities should be provided, particularly where:

- there is the potential for spillage, or a release of a hazardous material, or a release from a system under pressure;
- activity requires access to an area where escape might be difficult (confined spaces require additional controls);

- activity requires routine actions to control ignition hazards (e.g. earthing of equipment); and
- new materials are being introduced to the process.

NOTE 2 DSEAR [1, 2] requires that those handling and using dangerous substances are given training appropriate to the operations being undertaken, i.e. it could be just DSEAR awareness or more complex if staff are undertaking their own fire/explosion risk assessments and hazardous area zoning exercises.

41 Emergency procedures

Emergency procedures should be developed for premises at which chemicals or other dangerous goods are processed or stored. These should cover events such as loss of containment, loss of essential services, fire or explosion.

The procedures should be linked to the potential for escalation of the event, particularly if there is any off-site risk, and the numbers of people likely to be on site at different times.

The COMAH Regulations [42, 43] contain specific provisions for the preparation of an emergency plan and liaison with the emergency services, but a simpler plan should be developed for sites with smaller or less hazardous inventories.

General activities that should be assigned as necessary include:

a) raising the on-site alarm;

b) contacting the fire and rescue service;

c) liaison with incoming emergency services, including providing information about the hazards of materials on site, the location of water supplies and other services they might need to use;

d) roll call and accounting for persons;

e) contacting the water utility company if chemicals could flow off site;

f) contacting senior management in the case of an "out of hours incident"; and

g) control of traffic on site particularly if spillage could present a fire hazard.

Where the numbers of people on site are adequate, some more proactive measures should be planned as necessary to deal with an incident, including:

1) spillage retention barriers;
2) shutting down plant or processes on site;
3) monitoring for flammable atmospheres, using hand-held equipment; and
4) alerting occupiers of adjacent property.

If only a very small number of people are going to be on site at particular times, they should not be expected to undertake an unrealistic number of actions in a short time during an emergency.

Staff expected to deal with spillages of flammable liquids should be instructed never to stand within a pool while it is being cleared.

Consideration should also be given to the actions required where an automatic fire detection system raises the alarm in an area in which no staff are present. Examples include electrical switchrooms, computer server rooms, tank farms, storage buildings locked out of hours, boiler houses. A response should be implemented, but this should not put the person attending at risk.

Where some staff members are expected to undertake specific actions in response to an emergency on site, e.g. first-aiders or fire team members, communication arrangements should be implemented to ensure they can be rapidly alerted.

Where fire or explosion hazards could endanger the primary assembly area, depending on wind direction, the chemicals involved or other circumstances, a secondary assembly area should be designated.

Section 8: Maintenance of process plant

42 Maintenance

42.1 General

Appropriate precautions should be implemented for inspection, testing, repair or replacement of all types of equipment, including process plant containing flammable chemicals, instrumentation, power supplies and emergency facilities, particularly where these:

a) require the opening or deliberate venting of a containment system for flammable chemical products;

b) could give rise to an unintended release during work on a containment system;

c) could result in major plant damage as a result of heavy lifting operations or manipulation of major items of process equipment;

d) require the removal or disconnection of control instrumentation, if this could increase the likelihood of a release;

e) create potential ignition sources in hazardous areas or other locations where they are normally excluded;

f) involve accessing areas where means of escape are restricted, e.g. tall columns, confined spaces, locations requiring scaffolding or other temporary access arrangements;

g) generate quantities of flammable waste, e.g. packaging, contaminated lagging; and

h) could result in communication failures, e.g. between maintenance and production or between permanent staff and short term contractors.

Where these situations exist, maintenance activities should be properly planned and risk assessed, as necessary, with written systems of work. In the case of higher risk activities a formal permit to work system should be adopted (see **42.4**).

The following activities should be closely controlled.

1) Plant/process equipment isolation and handback (see **42.2**).

2) Depressurization, purging, cleaning and gas-freeing of process equipment (see **42.3**).

3) Electrical isolations.

In addition, the introduction of flammable materials, including scaffold boards, scaffold sheeting, paints, flammable cleaning solvents and fuel gas cartridges/cylinders, to the process area should be limited.

Some maintenance activities might require scaffolding or similar temporary access to be provided. Where the maintenance activity creates a fire hazard, the adequacy of the means of escape should be specifically considered when the maintenance activity is being planned.

42.2 Plant isolation

Plant isolation should involve the isolation of power from individual items like compressors or pumps, or the isolation of sections of plant from the rest of an extended system, as necessary, so that parts might be depressurized, freed from process materials or otherwise made safe for maintenance activity. The act of isolation itself is a high-risk activity on plant that operates at high pressure, or where a joint in the containment system needs to be split to insert a blanking plate or other temporary isolation device. The isolation procedure should therefore be based on the potential hazards. The system of work should be based on a careful risk assessment and HAZOP study.

NOTE See HSG 253, The safe isolation of plant and equipment [44].

42.3 Gas-free testing

Where heat is to be applied to plant that has contained flammable chemicals, very high standards of isolation and checks should be implemented for the interior of the plant.

NOTE 1 Measurement of the atmosphere for the presence of flammable gas alone is not sufficient as deposits of products that are normally of low volatility can create flammable vapours when heated. A gas-free state might also have only limited validity of time, if there is any possibility that vapour could diffuse from deposits in the vessel or gases could pass from other parts of the plant due to inadequate isolation methods.

Plant that has contained granular or powder materials should be subject to thorough visual inspection for deposits that might remain after the plant is emptied.

NOTE 2 These can start smouldering fires that continue after any hot work has been completed, and cause a subsequent fire at the original location or elsewhere in the plant if burning material is carried through the process. See Cleaning and gas freeing of tanks containing flammable residues CS15 [45].

42.4 Permits to work

Activities that could create a release of flammable materials, ignition sources where these are normally excluded in hazardous areas and similar locations, or other increased danger from fire, should be controlled through a system of permits to work.

Site rules should:

a) clearly set out the type of activities and the locations for which a permit to work is required;

b) specify the contents of any permit;

c) specify who is authorized to issue a permit; and

d) specify whether and how the authorization can be extended beyond a single shift.

The site safety policy should set out the arrangements for auditing the effective operation of the permit to work system.

NOTE Further guidance on permit to work systems is given in DSEAR Guidance [46, 47, 48, 49, 50] and HSG 250 [51].

43 Hot work

Activities that involve naked flames or generate a fire hazard, often described as hot work, should be controlled by a permit to work system where there is any risk that the activity could cause a fire that could spread to involve stored chemicals or chemical plant. The extent of the area to be covered by specific controls over hot work should be clearly set out and form part of site rules.

NOTE Hot work permits might not be needed for, for example, soldering work on a water pipe in an office block or work on a road barrier at the site entrance.

The range of activities covered by the hot work rules should also be clear. Any activity involving naked flames and electric welding should always be included, and the use of angle grinders and powered saws should normally be included. The risk of ignition from small diameter drilling work or rust removal by a powered wire brush may be excluded, depending on the materials present on site and the risks from any possible fire.

Wherever practical, items requiring welding or hot cutting should be removed from an area where there is a risk of fire involving chemicals, and ideally moved to a specially prepared area.

Where hot work has to be carried out within a plant or storage area, all combustible material should be removed, so far as practical. This should include lagging, plastic pipework and plastic containers, even if these are clean and empty. Where heat has to be applied to a floor, wall, bulkhead or similar, both sides should be inspected before work starts. Protective sheets made from non-combustible material conforming to BS EN 1598 may be used to protect items that cannot be moved from stray sparks.

Empty drums should never be used as welding supports.

Where electric welding is carried out, the process plant and pipework should not be used as a current return path. A dedicated lead from the location of the work should be provided.

Where the hot work is to be conducted at an elevated level, the area to be cleared should be substantially extended as sparks could spread a considerable distance and remain hot enough to start a fire.

Suitable means to extinguish any small fire should be immediately available at the work site. A fire watcher should be present, separate from the person(s) doing the hot work. The area should be kept under observation for at least an hour after work has been completed.

Section 9: Fire prevention

44 General fire prevention

At sites where chemicals are used or stored, training and good working practices should emphasize that general fire safety is everyone's concern. Standing instructions should make clear who is responsible for standards of housekeeping in each part of the site. Good controls over waste materials should be maintained to keep the site clear from common, easily-ignited materials such as cardboard, plastic packaging, waste from meals and snacks, and discarded protective equipment such as gloves or disposable overalls.

Spillages of liquid or solid materials should be cleared up promptly, even if the material is not an immediate high fire risk. Where rags or absorbent granules are used to soak up liquid spills, a supply of empty metal containers with lids should be available to allow the absorbed waste to be cleared away promptly to a safe place.

Vacuum cleaners should be provided where deposits of dusts need to be removed regularly. Where a vacuum cleaner is used in an area classified as hazardous zone 21 or 22, it should have a suction hose that is antistatic.

NOTE Some metal powders generate particularly fierce fires, and special precautions are needed where these are handled.

Where dusts and flammable vapours might be present, dust removal with a vacuum cleaner should only take place after the area has been ventilated, and the atmosphere tested and gas/vapour levels have been shown to be less than 25% of the LEL.

Small drips and leaks should be reported to a responsible person, and the releases should not be allowed to accumulate.

45 Hazardous area classification study

45.1 Gases and vapours

Electrical equipment designed such that it does not create an ignition hazard to a surrounding explosive atmosphere should only be installed in a hazardous area for which it has been designed. A hazardous area classification study should therefore be conducted to identify which type of hazard an area presents, using the applicable zone classes defined by DSEAR [1, 2].

- **Zone 0** is an area in which an explosive atmosphere is present for long periods, or frequently, e.g. above the liquid level of a container used for highly flammable liquids, or inside some enclosed processes.
- **Zone 1** is an area in which an explosive atmosphere can form in normal operation, e.g. where highly flammable liquids are poured from one container to another, or very close to the nozzle of a spray gun.
- **Zone 2** is an area in which explosive atmospheres are not likely to occur in normal operation and, if they do occur, persist for a short period only, e.g. where perhaps a spillage is possible, or controls on some item of equipment are faulty, provided in both cases that the problem is detected reasonably promptly.

NOTE 1 These definitions take no regard of the consequences of an ignition.

The study should be informed by such issues as:

a) whether releases are expected as part of normal operation;

b) whether releases take the form of a liquid, gas or flashing liquid;

c) the properties of the flammable material, such as vapour density and flammable range;

d) how large such releases are expected to be;

e) how long releases are likely to continue, or how frequently;

f) failure modes of equipment;

g) how much material would be released following a failure;

h) how quickly the release source could be detected and isolated;

i) how the material would disperse; and

j) the influence of ventilation or atmospheric conditions on dispersal.

NOTE 2 Approaches to hazardous area classification are discussed in Annex D.

Hazardous areas are not generally assigned around low-pressure natural gas installation pipework. Such pipework, which might contain many joints, should be inspected annually for signs of deterioration or damage, and pressure-tested periodically.

NOTE 3 See for low pressure natural gas IGEM/UP/2 [38], IGEM/SR/25 [52] and the Energy Institute's Model Code of Safe Practice Part 15 – Area Classification Code for installations handling flammable fluids [53].

45.2 Dusts

Any area classification study for dust-handling plant should explicitly recognize that a prime objective is the prevention of fires, as well as explosions. Layers, deposits and piles of dust should be treated as any other source that can form an explosive atmosphere, so that an assessment should be made of the risk that a dust layer exists regularly and can be raised into a cloud dense enough to create an explosion hazard.

45.3 Equipment selection

NOTE Basic rules for selection of equipment to be installed in a hazardous area are set out in DSEAR [1, 2] (see BS 5908-2). Chemical sites need to recognize where the issues are not clear cut, and have a policy on how the risks are controlled on site. Specifically, on sites with very low occupancy levels, explosion-protected equipment may be used primarily with a view to avoiding equipment loss and damage caused by fire. In dust-handing plants, there may be locations where explosion-protected equipment is selected to avoid the risk of fire from dust layers, but explosions are unlikely because there is no credible means of creating a dust cloud. In addition, in many plants handing granular material containing dust, where product is conveyed through a system, the location of an initial fire and the location of an initial explosion are not the same. In these circumstances, explosion-protected equipment may be selected, even where the process stream is granular, with little dust content.

45.3.1 Low-powered, low-voltage battery equipment

Staff and visitors should be made aware of the site policy on low-powered battery equipment on site, e.g. hearing aids, car door remote controls, digital watches, mobile phones, digital (mp3) music players and small LED torches. If common items of this type are to be excluded from all process areas, safe storage for the items concerned should be provided.

45.3.2 Mechanical sparks

Use of hand tools can generate both single impact sparks and some degree of heating. Use of hammers, chisels, files and hand-held hacksaws is generally safe, but hazards might exist where particularly sensitive products are handled (hydrogen, nitrocellulose, sulfur) or there is potential for a thermite reaction between rusty ferrous metal and aluminium or similar light metals. "Low sparking" hand tools should be used as appropriate to reduce the number of mechanical sparks and the potential ignition hazard from these, provided the impact surfaces are kept clean and free from grit. They should not be seen as an alternative to other precautions designed to minimize the fuel available if ignition occurs and to ensure that the user of the tools can escape safely in the event of an ignition.

45.3.3 Vehicle movements

Road tankers and other delivery vehicles used on public roads might need to be driven into areas that are classed as hazardous, and some can only be discharged using their engine to drive the on-board pump. Tankers should only be permitted in such areas if they conform to ADR [5], which provides controls over electrical systems and ignition sources on vehicles handling flammable products but which are not certified as ATEX equipment.

Fire safety should be controlled by drawing up a safe system of work that includes checks to be made before transfer of flammable materials begins, requirements for supervision of transfers, checks to be made at the end of a transfer before the vehicle is restarted, and restrictions on other activities taking place in the same area at the same time.

The written safe system of work should be provided and explained to both site employees and vehicle drivers.

46 Static electricity

NOTE 1 Static is likely to be generated wherever materials are moved or fresh surfaces are formed. The presence of more than one phase, e.g. powder plus liquid or two liquid phases, usually increases the amount of charge generated.

Different circumstances can generate sparks with different energies. The largest spark energies are possible when a large metal item insulated from earth becomes charged. In most cases gases and vapours are more sensitive to ignition than dusts, and some types of electrostatic charging are a low risk where only dusts are handled.

The risks from static electricity should be controlled by suitable design or selection of equipment, and there are specific requirements in the standards for ATEX electrical and mechanical equipment.

Some risks should be controlled at the time the process facility is constructed, such as earthing to ensure fixed items of metal plant cannot become charged. Periodic checks of this type of precaution should form part of planned preventative maintenance.

Safe systems of work should be adopted for each type of activity is undertaken, such as earthing a container prior to filling or wearing antistatic footwear.

NOTE 2 Detailed recommendations for all these types of measures are set out in BS PD CLC/TR 50404.

Section 10: Works fire brigades and fixed fire protection

47 Works fire brigades

Apart from refineries, relatively few sites have a full-time team of staff members trained to undertake large-scale firefighting or other emergency response activities. More often, a small number of staff members, whose principal role is in production or maintenance, are trained to use specialist equipment available on site. This option should only be adopted where the numbers on site make it likely that the minimum team size will always be available. The need for an on-site emergency response capability should be determined after an assessment of the risks to personnel on site, neighbouring populations and the environment, from fire or a release of chemicals. The likely response time and capabilities of the local authority fire and rescue services should be taken into account.

Whenever staff are expected to make use of specialist equipment they should be fully trained, including periodic refresher training.

NOTE Specialist equipment can include trolley-mounted fire extinguishers, fixed fire protection equipment that needs to be manually brought into service, fixed or mobile fire pumps, ground monitors to create a protective water curtain, rescue equipment for people trapped in confined spaces or at high level on a plant, and self-contained breathing apparatus.

Fire team members may also undertake non-emergency activities, such as providing a presence during hot work or making routine checks on fixed equipment (sprinklers, foam systems).

Advice appropriate to very large sites is contained in Energy Institute Model Code of Safe Practice Part 19 [54].

48 Fixed fire protection

NOTE 1 Fixed fire protection on chemical sites is most often provided for the purpose of property protection rather than life safety. Most types require the extinguishing medium to be applied or contained close to the hazard, and this might restrict the options for plant or storage in the open air. BS 5306-0 outlines the different types of fixed fire protection available, gives advice on the information to be made available for the selection and design of the most appropriate type of system, and indicates who is to be consulted before the type of system is selected. It also gives examples of typical applications for the different types of system.

Fixed fire protection is recommended where:

a) fire can be expected to grow very rapidly, and is likely to be out of control before intervention by staff or professional fire fighters is possible;

Examples: Coating or spraying processes using flammable solvents, manufacture of foamed plastics, storage of materials capable of self-heating and causing fire.

b) fire can start in an area that is normally unoccupied;

Examples: Buildings housing compressors, engines, cable tunnels, large tank farms.

c) the nature of chemicals released by a fire would make firefighting hazardous even to those in protective equipment;

Examples: Plant handling highly toxic gases, and also a significant inventory of flammable chemicals.

d) *fire might cause explosions of storage containers or process equipment, making firefighting hazardous;*

Examples: Large LPG tanks, indoor storage of large quantities of flammable liquid containers.

e) *water is an unsuitable firefighting medium and large-scale alternative means of firefighting cannot be rapidly provided from outside the site;*

Examples: Rooms containing electrical switchgear or electronic control equipment for the chemical process, particularly if loss of these services would cause unpredictable additional risks to the chemical processing.

f) *the inventory is very large and would be difficult to extinguish.*

Examples: Large-scale floating roof tanks, or other storage tanks for flammable liquids

Where fire could involve flammable gases, isolating the source of supply or depressurizing it to a safe place is the most appropriate strategy, rather than extinguishing the fire.

Where fixed fire protection is to be provided, it should be designed in accordance with the standard(s) applicable to that type of system, e.g. BS EN 671, BS EN 12094 (all parts), BS EN 12259 (all parts), BS EN 12416, BS EN 12845 (all parts), BS EN 13565-1, BS EN 13565-2, BS EN 15004, DD CEN/TS 14816, as appropriate (see BS 5908-2).

Specialist advisors (e.g. consultants), insurers, suppliers of fire protection systems and equipment and, as necessary, the fire and rescue service should be consulted as to the system most appropriate for the site.

Documentation setting out the design details for all such systems should be retained on site.

Preventative maintenance should be planned and performed, as necessary.

NOTE 2 This is often best left to the specialist installer of the original equipment.

Fixed fire protection provided should be available at all times. Isolation of sprinklers or other fixed fire protection should only be permitted after contact with the insurers, and any special restrictions on activities or supervision put in place.

Where fixed fire protection is provided, staff members should be trained in its operation, what action to take if it operates automatically, any precautions needed prior to entry into a protected area, and the necessary response if an alarm system indicates that an automatic system has activated in an unoccupied area.

Annex A (informative) Classification of chemicals

A.1 General

The terms used to classify chemicals in international transport legislation and in the European rules relating to the supply of chemicals have significant differences, as well as different labelling requirements. The classification systems are now undergoing change to the UN Globally Harmonized (UNGH) System.

The European Regulation concerning supply of chemicals (REACH) [55] distinguish between extremely flammable and flammable gases. Flammable gases are a small group with either a lower flammable limit >13%, or a narrow flammable range, less than 12 percentage points. Most of the common flammable gases come within the definition of extremely flammable.

The older CHIP Regulations [6] subdivide classed materials with a flash point below 0 °C as extremely flammable, materials with a flash point below 21 °C as highly flammable, and materials with a flash point in the range 21 °C to 55 °C as flammable.

The new REACH Regulation [55], using the UNGH System, also subdivides flammable liquids into three categories. The subdivisions are now essentially the same as the packing groups used in the transport legislation.

Flammable liquids are defined as materials having a flash point lower than 60 °C, and are subdivided into the three categories in Table A.1.

Table A.1 **Categories for flammable liquids**

Category 1	**Category 2**	**Category 3**
Flash point <23	Flash point <23	Flash point ≥23 and ≤60
Initial boiling point ≤35	Initial boiling point >35	
Extremely flammable	Highly flammable	Flammable

For hazard assessments, the statutory classification schemes do not provide all the necessary information.

A.2 Modes of combustion

Fires involving gases, vapours, liquids and solids have different characteristics, and a broad understanding of these is relevant to specifying fire precautions.

A.3 Flammable gases

Flammable gases released from pressurized storage or pipework might ignite at the point of release and produce a stable flame. If the release rate is high, the flame could lift off and extinguish. If flammable gas is released but does not ignite immediately, mixing with air could produce a gas cloud of varying concentration. Ignition of this cloud could produce a fireball, with a large pulse of radiant heat, or under other circumstances an explosion, a pressure wave as well as a pulse of heat.

If a flammable gas is mixed with air in the right concentration, inside a closed container (storage vessel, reactor, pipework or process plant), ignition results in an explosion. The concentration range within which the mixture can be ignited is a characteristic of the material, and the upper and lower concentration limits can be measured. These are tabulated for a large range of materials, and can be calculated, with some limitations on precision for gas mixtures. The explosion overpressures developed depend strongly on geometry, turbulence and other factors.

Flammable gases can have a density much smaller or greater than air, and depending on the release conditions might stratify at high or low level if released into a building. This is most likely where the gas stream has a low momentum (i.e. low pressure at the source of release), making mixing less likely. Ignition of a layer of dense gas close to floor level could produce visible flames, followed by an explosion.

Flammable gases are characterized by the explosion limits, minimum ignition energy and temperature, and the density, as this influences dispersion.

A.4 Flammable liquids

Vapour is produced by evaporation above the surface of a flammable liquid. The concentration of vapour is influenced by the volatility of the liquid, the liquid temperature, any air movement across the surface and any process tending to increase the surface area, by creating splashing or formation of a spray.

When an ignition source is brought close to the liquid surface and sufficient vapour is present, a flame forms and this continues to burn if liquid is vaporized at a rate sufficient to replace the product that is burned.

When the liquid produces only a low concentration of vapour at room temperature, the liquid might not ignite, unless some solid material capable of acting as a wick is present.

When liquid is spilt and a large pool is formed, ignition at one location leads to burning across the whole surface in a very short time, producing a "pool fire".

Inside closed containers with air above the liquid level or in poorly ventilated areas, volatile liquids can produce a vapour/air mixture with a concentration within the explosive range. Ignition of such a mixture is likely to produce an explosion followed by a continuing pool fire.

Liquids are commonly characterized by their flash point, explosion limits, minimum ignition energy and minimum ignition temperature.

NOTE Tests for these are described in BS 5908-2.

A.5 Flammable solids

The range of behaviour in fires of flammable solids is more diverse and complex than those for liquids or gases. Fire behaviour is not simply controlled by chemical composition, but also geometrical factors, heat of combustion, rate of heat release, particle size and other factors. Relatively small amounts of additives, added as flame retardants can strongly influence the ease of ignition or rate of fire development.

Thermoplastic materials soften when exposed to intense heat, and their geometrical shape changes. Laminar materials, such as reels of paper, can unwind as new layers are exposed. Granular materials might flow from a container which has been burnt through by a fire, and either fall to the floor or be carried up in convection currents. Other materials melt, flow and then solidify in drains, causing blockages.

Fire can also start in the middle of a silo holding products in granular or powder form. Fire growth might then be limited by the supply of oxygen, and develop over hours or days. Combustion often proceeds without any visible flames. Special fire detection measures might be needed.

A.6 Explosible dusts

Many organic chemicals, polymers, some metals and other elements are capable of burning. The nature of that burning depends strongly on the degree of dispersion. Where the dust is in the form of a pile, combustion can take the form of flames, spreading across the surface. Some solids melt and fire creates a pool so that it is no longer a powder that is burning.

Alternatively, combustion can start within the pile, and if oxygen supply is limited, no flames are formed, but the fire develops gradually over a period of hours, days or even longer. If the pile is subsequently disturbed, so that more air becomes available for combustion, the fire can grow suddenly.

Many processes involving dusts create dust clouds. Where these reach a certain concentration, flames can spread rapidly through the clouds. If this is in the open, a flash fire results. If a cloud is enclosed, typically inside process equipment, the heat from combustion generates pressure and an explosion results. The pressures generated are usually capable of destroying equipment that is not specifically designed to withstand the pressure.

Some particular characteristics of dust explosions need to be understood when considering fire precautions.

The site of the ignition and the site of the explosion are often not the same. Burning material can be carried through process and explode only when it enters a dense dust cloud.

Dust explosions generate pressure waves, which disturb dust layers, forming further clouds. In this way explosions can spread widely through equipment and buildings.

A large proportion of dust explosions start within the process, as this is the location where dense dust clouds form.

Annex B (informative) Ignition sources

B.1 Hot surfaces

Many incidents occur where materials ignite on surfaces that are intended to be hot, e.g. the exhaust of an engine, the external surface of heated equipment, pipelines carrying hot fluids. Such locations are relatively easy to identify. Ignition is often time-dependent, with a brief contact generating local melting or blackening and longer contact producing flames.

Suitable insulation can prevent ignitions in many cases, but if flammable liquids can penetrate lagging fires might result.

A small number of chemicals, most commonly organic peroxides, are sensitive to decomposition at comparatively low temperatures.

B.2 Flames and hot gases (including hot particles)

Any fired plant is an ignition source if vapours or gases are drawn into the air intake.

A very serious hazard is the application of heat to a drum, tank or similar closed vessel containing a flammable atmosphere, or to a substance which can generate a flammable atmosphere by the application of heat. A combination of gas testing and visual inspection is essential.

Welding and burning produces hot particles which can ignite a fire some distance from the welding work, and might not be immediately noticed by the welder. Where welding is carried out at high level a very large area might need to be cleared.

B.3 Mechanically-generated sparks

Sparks can arise from a single impact, perhaps from a falling object striking a hard surface with a glancing blow, or repeated rubbing between a moving part and a stationary object, without lubrication, for example a fan blade striking a casing or a bearing that has lost lubrication.

Continuous rubbing produces local hot surfaces and, depending on the material pairing, fragments of metal might break off as a shower of sparks. Mechanical sparks are comparatively ineffective (many thousands can traverse an explosive gas mixture before ignition occurs) and ignition often occurs at the hot surfaces created at the point of rubbing, rather than by the sparks.

Advice on the conditions capable of producing incendive single sparks or showers of sparks is given in BS EN 13463-1.

B.4 Electrical apparatus

Where explosive atmospheres can be anticipated and hazardous areas assigned, ignitions need to be prevented by correct selection and installation of ignition protected equipment.

Where flammable solids are processed, fires might be caused by electrical apparatus, although no zoning is appropriate, e.g. a dryer with radiant heating elements. Employees' clothing is regularly ignited by radiant heaters.

B.5 Stray electric currents, including cathodic protection systems

Electrical currents might flow through metalwork forming pipes or structural supports, or similar, even where these are not intended as conductors. The current could be induced by high currents in conductors nearby or formed as an earth leakage in the case of faulty electrical equipment, or result from an earth return during electric welding or other causes. Cathodic protection and some railway signalling systems deliberately generate currents in metalwork not intended simply as a conductor. Sparks are possible in these circumstances, where items of equipment are separated or placed in contact. If the hazard is recognized, it is usually practical to avoid generating any spark at a location where an explosive atmosphere is present.

B.6 Static electricity

Static electricity is usually created by movement of materials or exposure of fresh surfaces. It can accumulate on metal items isolated from earth, or insulating surfaces, on people or within a pile of powder or quantity of liquid. The ignition hazards depend on the sensitivity of the fuel, and the potential energy released by a sudden discharge. Gases and liquids are, in most cases, much more sensitive to ignition than dusts and require a greater range of control measures.

Where flammable gases, liquids or dusts are processed all metal items or other conductors in direct contact with the potential explosive atmosphere need to be earthed.

Further assessment of hazards arising from static requires much more detailed analysis of any process and the materials present. Further advice is given in *Avoiding Static Ignition Hazards in Chemical Operations* [56] and BS PD CLC/TR 50404.

B.7 Lightning

Lightning strikes are most likely where there are tall structures. General advice on the design of lightning protection measures is provided in BS EN 62305-1, but this cannot be eliminated as an ignition hazard.

B.8 Radio frequency waves (sparks induced by absorbed radiation)

The limited range of circumstances in which this is a potential ignition source is described in BS 5908-2.

B.9 Electromagnetic radiation (hot surfaces created by absorbed radiation)

This is most likely to occur where lenses can concentrate solar radiation, or where very intense radiation sources such as lasers are used.

High-powered lamps and radiant space heaters can cause fires from associated infrared radiation where an easily ignited material is close to the source.

B.10 Ionizing radiation

Where radioactive materials are present, a very high standard of fire protection measures is important, as any fire is likely to disperse radiation producing material to the environment.

B.11 Ultrasonic energy

Ultrasonic energy occurs in comparatively few sites.

B.12 Adiabatic compression

Compressors produce predictable and controllable amounts of heat. Ignition is only possible when both air and a potential fuel are present. Air compressors can form degradation products from the lubricating oil, which collects within the system and subsequently ignites. Such events produce a very high rate of combustion because of the high air pressure, and can cause explosive damage.

B.13 Exothermic reactions, including self-heating products

Exothermic reactions are carried out under controlled conditions in many chemical plants. Loss of control of such reactions can produce major plant damage and loss of containment, but less frequently generates temperatures high enough to cause ignition.

Fire more commonly arises from exothermic chemical changes as a result of reaction with air.

The following are common examples.

a) Self-heating of powdered or granular products in bulk storage. Smouldering combustion or slow burning might start inside a silo or large pile of material. Flaming combustion might break out when the pile is disturbed.

b) Ignition of unsaturated oils dispersed onto rags or lagging when the large surface area and thin film promote this source of heating.

c) Self-heating of temperature-sensitive products, including many free radical initiators. Some of these come with recommended maximum storage temperatures/storage duration.

d) Reaction between water and substances which release hydrogen.

e) Combustion within a polyurethane foam-making process, where the insulating nature of the foam promotes high temperatures in the block centre.

Any use of pure oxygen, particularly as a liquid or high-pressure gas, requires extremely strict controls over the materials which could come in contact with the gas. Extremely high temperatures are generated when fire occurs.

Annex C (informative) Hazards from smoke

Smoke inside buildings prevents people finding a route to a safe place in the open air, so means of escape need to be designed to allow people to escape before escape routes are filled with smoke. In addition, smoke contains toxic components, particularly carbon monoxide, which kills people without their being exposed to heat.

A wide range of toxic, irritating or corrosive components might be present, depending on the chemicals present, but also on the temperature within the fire.

The strong convective smoke plume could carry toxic products from the fire and, if these are persistent in the environment, they might cause lasting harm or require expensive remedial measures.

It is generally difficult to provide reliable information during the course of a chemical fire about the risks from the components in the smoke, and this causes public concern.

If dense black smoke is generated inside a building, the available time for escape might be less than that assumed by the design standards. Polyurethane foam manufacturing sites are a particular example.

Particularly dense smoke can also create difficulties for those outside the building. Nearby road and rail links can be affected. Firefighting operations might be possible only from an upwind direction.

Major fires from process or storage facilities not inside a building can produce smoke in large quantities such that the off-site risk from the smoke is more serious than the risk to small populations on site.

For major hazard chemical warehouses, smoke dispersion models have been developed that allow predictions to be made about the off-site consequences of a major fire. The predictions are strongly influenced by the weather, assumptions about firefighting tactics, and the disposition of stock. If the risks are considered unacceptable, the main options are to reduce the risk of a fire involving the substance(s) of concern and to reduce the maximum potential size of a fire. The techniques available to achieve these aims are not specific to major hazards.

At other sites, the risks from smoke are considered as part of the risk assessment, when fire precautions for the site are being considered. However, the options available specifically to reduce the risk from smoke are limited.

Smoke and heat exhaust ventilation systems (SHEVS) are available that control smoke and provide clear air for means of escape. These are designed specifically to the requirements of the means of escape from the building, the building layout itself and the fuel sources. They were originally designed for factories. Smoke curtains are also useful in controlling smoke movement around large open spaces (see BS 7346-4 and BS 7346-5).

Annex D (informative) Approaches to hazardous area classification

DSEAR [1, 2] identifies area classification as one precaution forming part of the package of controls for protecting people. Area classification is also an appropriate tool for determining equipment standards for the purposes of protection of assets, or preventing damage to the environment from a fire which escalates.

For many simple situations, rigorous analysis is not justified, and a cautious approach that generates large areas of zone 1 or 2 may be adopted. This is satisfactory as long as the only consideration is selection of fixed electrical equipment, and there is comparatively little need for this in the zone, such as a storage area. This approach breaks down if people are expected to work for extended periods in a zone 1 area, where a flammable atmosphere is expected to form regularly. The safety and health risks that this implies are likely to be severe.

A simple approach also breaks down where there are transient but repeated activities, such as movement of delivery vehicles designed for the public roads. These might need to make a close approach to a zoned storage area.

BS EN 60079-10-1 takes an intermediate approach. It identifies the need for all sources of release to be identified and the grade of release to be assigned. A primary grade of release is one which occurs periodically or occasionally in normal operation. A secondary grade release occurs infrequently and for short periods, with some estimates made of the quantities involved. The release rate and other factors which influence the dispersion are identified. The influence of ventilation in determining the number extent of a zone is set out, as are standardized marking schemes for area classification drawings and reporting forms from an area classification study.

However, advice on hazardous area classification is also published by many other sources. These have been developed by different industries for their specific circumstances. Some are essentially very simple, with a few standard diagrams. Others take a more sophisticated approach and consider the risks to individuals.

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