International Standard

ISO 13702

Third edition
2024-03

Oil and gas industries — Control and mitigation of fires and explosions on offshore production installations — Requirements and guidelines

Industries du pétrole et du gaz — Contrôle et atténuation des feux et des explosions dans les installations en mer — Exigences et lignes directrices

Reference number
ISO 13702:2024(en)

Contents

Page

Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO document should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

ISO draws attention to the possibility that the implementation of this document may involve the use of (a) patent(s). ISO takes no position concerning the evidence, validity or applicability of any claimed patent rights in respect thereof. As of the date of publication of this document, ISO had not received notice of (a) patent(s) which may be required to implement this document. However, implementers are cautioned that this may not represent the latest information, which may be obtained from the patent database available at www.iso.org/patents. ISO shall not be held responsible for identifying any or all such patent rights.

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 67, *Oil and gas industries including lower carbon energy*, Subcommittee SC 6, *Process equipment, piping, systems, and related safety,* in collaboration with the European Committee for Standardization (CEN) Technical Committee CEN/TC 12, *Oil and gas industries including lower carbon energy,* in accordance with the Agreement on technical cooperation between ISO and CEN (Vienna Agreement).

This third edition cancels and replaces the second edition (ISO 13702:2015), which has been technically revised.

The main changes are as follows:

— visualized the risk treatment process in a flow diagram in 5.8;

— improved description of the explosion blast description in Clause A.3;

— improved guidance with respect to risk mitigation in Clause B.1;

— introduction of ESD hierarchy and guidance related to principles to protect pressurised equipment against fire in Clause B.2;

— improved guidance on ignition source control in Clause B.3;

— included guidance for control of spills related to floating LNG in Clause B.4;

— expanded guidance related to gas detection in Clause B.6;

— included guidance related to ignition source control for firewater pump drivers and external power supplies in B.8.2;

— addressing personnel safety related to CO_2 or other asphyxiating gases in B.8.11;

— introduced guidance related to passive fire-retarding surface for helidecks in B.8.13;

— introduced guidance related to tests in B.13;

— introduced the terms A-class and H-class for fire barriers in C.4.3.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

The successful development of the arrangements required to promote safety and environmental protection during the recovery of hydrocarbon resources requires a structured approach to the identification and management of health, safety, and environmental hazards applied during the design, construction, commissioning, operation, inspection, maintenance, and decommissioning of a facility.

This document has been prepared primarily to assist in the development of new installations through their lifecycle.

The content of this document is arranged as follows.

— Objectives: lists the goals to achieved by the control and mitigation measures being described.

— Functional requirements: represent criteria to meet the stated objectives. The functional requirements are performance-orientated measures and, as such, are applicable to the variety of offshore installations utilized for the development of hydrocarbon resources throughout the world.

— Annex A: describes typical fire and explosion hazardous events.

— Annex B: describes recognized practices that can be considered in conjunction with statutory requirements, industry standards, and individual operator philosophy to determine that the measures necessary are implemented for the control and mitigation of fires and explosions. The guidance is limited to principal elements and are intended to provide specific guidance which, due to the wide variety of offshore operating environments, cannot be applicable in some circumstances.

— Annex C: describes typical examples of design requirements for large integrated offshore installations.

This document is based on an approach where the selection of control and mitigation measures for fires and explosions primarily caused from loss of containment is determined by an evaluation of hazards on the offshore installation. The methodologies employed in this assessment and the resultant recommendations differ depending on the complexity of the production process and facilities, type of facility (i.e. open or enclosed), staffing levels, and environmental conditions associated with the area of operation.

NOTE Requirements, rules, and regulations can, in addition, be applicable for the individual offshore installation concerned.

Oil and gas industries — Control and mitigation of fires and explosions on offshore production installations — Requirements and guidelines

1 Scope

This document specifies the objectives and functional requirements for the control and mitigation of fires and explosions on offshore installations used for the development of hydrocarbon resources in oil and gas industries. The object is to achieve:

— safety of personnel;

— protection of the environment;

— protection of assets;

— minimization of financial and consequential losses of fires and explosions.

This document is applicable to the following:

— fixed offshore structures;

— floating systems for production, storage, and offloading.

Mobile offshore units and subsea installations are excluded, although many of the principles contained in this document can be used as guidance.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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.

ISO 31073, *Risk management — Vocabulary*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 31073 and the following apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

3.1
accommodation
place where personnel onboard sleep and spend their off-duty time

Note 1 to entry: It can include dining rooms, recreation rooms, lavatories, cabins, offices, sickbay, living quarters, galley, pantries, and similar permanently enclosed spaces.

3.2
active fire protection
AFP
equipment, systems, and methods which, following initiation, can be used to control, mitigate, and extinguish fires

3.3
ALARP
as low as reasonably practicable
implementation of risk-reducing measures until the cost (including time, capital costs or other resources and assets) of further *risk* (3.35) reduction is grossly disproportional to the potential risk reducing effect achieved by implementing any additional measure

Note 1 to entry: See UK HSE[41].

3.4
area classification
division of an installation into *hazardous areas* (3.24) and non-hazardous areas and the sub-division of *hazardous areas* (3.24) into zones under normal operation

Note 1 to entry: This classification is based on the materials that can be present and the probability of a flammable atmosphere developing. Area classification is primarily used in the selection of electrical equipment to minimize the likelihood of ignition if a release occurs.

3.5
cellulosic fire
CF
fire involving primarily cellulosic material such as wood, timber, or paper

3.6
control
limitation of the extent or duration of a *hazardous event* (3.25)

3.7
control station
place from which personnel can monitor the status of the installation, initiate appropriate shutdown actions, and undertake any emergency communication

Note 1 to entry: Control station is typically known as CCR or central point.

3.8
critical safety system
system that has a major role in the prevention and mitigation of releases, fires and *explosions* (3.21) and in any subsequent *escape, evacuation, and rescue* (3.19) activities

3.9
deluge system
system to apply fire-water through an array of open spray nozzles by operation of a valve on the inlet to the system

3.10
embarkation area
place from which personnel leave the installation during *evacuation* (3.18)

EXAMPLE Helideck and associated waiting area or a lifeboat or life raft boarding area.

3.11
emergency depressurization
EDP
controlled disposal of pressurized fluids to a flare or vent system when required to avoid or minimize a *hazardous event* (3.25)

3.12
emergency response
action taken by personnel on or off the installation to control or mitigate a *hazardous event* (3.25) or initiate and execute abandonment of the facility

3.13
emergency response team
group of personnel who have designated duties in an emergency

3.14
emergency shutdown
ESD
control (3.6) actions undertaken to shut down equipment or processes in response to a *hazardous event* (3.25)

3.15
escalation
spread of impact from fires, *explosions* (3.21), toxic gas releases to equipment or other areas thereby causing an increase in the consequences of the initial *hazardous event* (3.25)

3.16
escape
act of personnel moving away from a hazardous event to a place where its effects are reduced or removed

3.17
escape route
route that provides a safe path from an area of an installation leading to a *muster area* (3.31), *temporary refuge (TR)* (3.37), *embarkation area* (3.10), or means of *escape* (3.16) to the sea

3.18
evacuation
planned method of leaving the installation in an emergency

3.19
escape, evacuation, and rescue
EER
range of possible actions including *escape* (3.16), muster, refuge, *evacuation* (3.18), escape to the sea, and rescue or recovery

3.20
evacuation route
escape route (3.17) that leads from the *temporary refuge (TR)* (3.37) to the place(s) used for *evacuation* (3.18) from the installation

3.21
explosion
event characterized by a rapid release of energy which has the potential to generate high blast overpressures and drag forces, as well as blast waves propagating away from the ignition point

3.22
fire and explosion strategy
FES
results of the process that uses information from the fire and *explosion* (3.21) evaluation to determine the measures required to manage these *hazardous events* (3.25) and the role of these measures

3.23
hazard
potential source of harm

EXAMPLE A source for potential human injury, damage to the environment, damage to property, or a combination of these.

[SOURCE: ISO/IEC Guide 51:2014[13], 3.2, modified — Example has been added.]

3.24
hazardous area
three-dimensional space in which a flammable atmosphere can be expected to be present at such frequencies as to require special precautions for the *control* (3.6) of potential *ignition sources* (3.27) as a result of *area classification* (3.4) studies

3.25
hazardous event
event that can cause harm

EXAMPLE The incident that occurs when a *hazard* (3.23) is realized such as release of gas, fire, loss of buoyancy.

[SOURCE: ISO/IEC Guide 51:2014[13], 3.3, modified — Example has been added.]

3.26
human factors
environmental, organisational, and job factors that influence behaviour of work in a way that can affect health and safety outcomes including the performance of *critical safety systems* (3.8)

3.27
ignition source
source with sufficient energy to initiate combustion

3.28
integrated installation
offshore installation that contains on the same load-bearing structure *accommodation* (3.1) and utilities, in addition to process or wellhead facilities

3.29
jet fire
JF
turbulent diffusion flame resulting from the combustion of a fuel continuously released with momentum in a particular direction

3.30
mobile offshore unit
mobile platform, including drilling ships, equipped for drilling for subsea hydrocarbon deposits and mobile platform for purposes other than production and storage of hydrocarbon deposits

Note 1 to entry: It includes mobile offshore drilling units, including drill ships, *accommodation* (3.1) units, construction and pipelay units, and well servicing and well stimulation vessels.

3.31
muster area
designated area where personnel report when required to do so

3.32
operator
individual, partnership, firm, or corporation having control or management of operations on the leased area or a portion thereof

Note 1 to entry: The operator can be a lessee, designated agent of the lessee(s), or holder of operating rights under an approved operating agreement.

3.33
passive fire protection
PFP
coating or cladding arrangement or free-standing system which, in the event of fire, will provide thermal protection to restrict the rate at which heat is transmitted to the object or area being protected

3.34
pool fire
turbulent diffusion fire burning above a horizontal pool of vaporizing flammable or combustible liquid under conditions where the liquid has zero or very low initial momentum

3.35
risk
combination of the probability of occurrence of harm and the severity of that harm

[SOURCE: ISO/IEC Guide 51:2014[13], 3.9, modified — Note to entry has been removed.]

3.36
running liquid fire
fire involving a flammable liquid flowing over a surface

3.37
temporary refuge
TR
place provided where personnel can take refuge for a predetermined period while investigations, *emergency response* (3.12), and *evacuation* (3.18) preplanning are undertaken

4 Abbreviated terms

AB	accommodation block
API	American Petroleum Institute
BOP	blowout preventer
CCR	central control room
CS	control station
DIFFS	deck integrated fire fighting system
F&G	fire and gas
GOR	gas oil ratio
HC	hydrocarbon
HMI	human machine interface
HVAC	heating, ventilation, and air conditioning
IEC	International Electrotechnical Commission
IMO	International Maritime Organization
PA	public address
SSIV	sub-sea isolation valve
SSSV	sub-surface safety valve
TEMPSC	totally enclosed motor-propelled survival craft
UA	utility area
UPS	uninterruptable power supply

WH wellhead area

5 Fire and explosion evaluation and risk management

5.1 Management system

All companies associated with the offshore recovery of hydrocarbons shall have, or conduct their activities in accordance with, an effective management system that addresses safety and environmental issues. As an example, operators should have an effective management system; contractors should have either their own management system or conduct their activities consistently with the operators' management system and additionally address issues relating to health and safety. The management system shall include a process of evaluating and managing risk in a framework of policies, procedures and organizational arrangements that embeds the management of risk throughout the organization.

5.2 Risk assessment and the risk management framework

This document assumes that the risk assessment is performed within the principles and guidelines for risk management described in IEC 31010[12].

In particular, those carrying out risk assessments shall be clear about the following:

a) organization's risk management policy, its objectives, and the context in which the organization operates;

b) extent and type of risks that are tolerable and how to treat any risks that are deemed not to be tolerable;

c) how risk assessment integrates into organizational processes;

d) methods and techniques to be used for risk assessment and their contribution to the risk management process;

e) accountability, both for performing risk assessment and for making decisions taking account of the results;

f) resources required to carry out risk assessment;

g) how the risk assessment will be reported, reviewed and audited.

5.3 Risk assessment process

Risk assessment provides decision-makers and responsible parties with an improved understanding of risks that can affect achievement of objectives and the adequacy and effectiveness of controls planned or already in place. This provides a basis for decisions about the most appropriate approach to be used to manage the risks. The output of risk assessment is an input to the decision-making processes of the organization.

Risk assessment is the overall process of hazard identification, risk analysis, and risk evaluation. The way this process is applied depends on the context of the risk management process and on the methods and techniques used to carry out the risk assessment.

5.4 Hazard identification

The starting point for risk management is the systematic identification of the sources of hazards and their potential consequences which can be dependent on the location, activities, and materials which are used or encountered in them.

The hazard identification process shall be applied to all stages in the life cycle of an installation and to all types of hazards encountered as a consequence of the development of hydrocarbon resources.

5.5 Risk analysis

Risk analysis involves developing an understanding of the risks associated with the hazards identified. Risk analysis provides an input to risk evaluation and to decisions on whether risks need to be treated, and on the most appropriate risk treatment strategies and methods. Risk analysis can also provide an input into making decisions where choices are made, and the options involve different types and levels of risk.

Risk analysis involves consideration of the causes and sources of risk, their positive and negative consequences, and the likelihood that those consequences can occur. Factors that affect consequences and likelihood shall be identified. An event can have multiple consequences and can affect multiple objectives. Existing controls and their effectiveness and efficiency shall also be considered.

Unless a conservative approach is being taken (e.g. worst-case scenarios or pessimistic assumptions in the risk analysis), the risk analysis should address uncertainties in frequencies and consequences, e.g. in data and models, applied through an uncertainty or sensitivity analysis.

5.6 Risk evaluation

The purpose of risk evaluation is to assist decision-making and should be based on the outcomes of risk analysis.

Risk evaluation involves comparing the level of risk found during the analysis process with qualitative or quantitative criteria established when the context was considered. Based on this comparison, the need for treatment shall be considered.

Decisions shall take account of the wider context of the risk and include consideration of the tolerance of the risks borne by parties other than the organization that get benefits from the risk.

In some circumstances, the risk evaluation can lead to a decision to undertake further analysis or to consider other options. The risk evaluation can also lead to a decision not to treat the risk in any way other than maintaining existing controls. This decision will be influenced by the organization's risk tolerance and the criteria that have been established.

5.7 Risk treatment

5.7.1 General

The general hierarchy of risk reduction measures to implement is usually as follows:

- elimination (remove the hazard);
- substitution (of a lower risk alternative);
- engineering controls:
  - layout (segregation or separation);
  - passive barriers;
  - active barriers (preference for fail safe design);
- administrative controls (procedures);
- personal protective equipment (PPE).

Risk treatment involves selecting one or more options for modifying risks and implementing those options. Once implemented, treatments provide or modify the controls.

Risk treatment involves a cyclical process of

- assessing a risk treatment,

— deciding whether residual risk levels are reduced to ALARP and which then can be deemed tolerable,

— generating a new risk treatment, if risk levels are not tolerable, and

— assessing the effectiveness of that treatment.

Risk treatment options are not necessarily mutually exclusive or appropriate in all circumstances. The options can include the following:

a) avoiding the risk by deciding not to start or continue with the activity that gives rise to the risk;

b) taking or increasing the risk in order to pursue an opportunity;

c) removing the hazard source – inherently safe;

d) changing the likelihood; e.g. through improved knowledge;

e) changing the consequences; e.g. through more robust modelling or improved barriers;

f) retaining the risk by informed decision;

g) reducing the risk by deciding to decrease production, assuming losses.

The process of selecting risk treatment measures predominantly entails the use of sound engineering judgement, but it can be necessary to supplement this by recognition of the particular circumstances which can require deviation from past practices and previously applied codes and standards.

5.7.2 Prioritization of risk treatment measures

Preventative measures, such as using inherently safer designs and ensuring asset integrity, shall be emphasized wherever practicable. Based on the results of the evaluation, detailed health, safety, and environmental objectives, the functional requirements shall be set at appropriate levels.

5.8 Risk treatment in the context of offshore oil and gas operations

5.8.1 General

The development of a fire and explosion strategy (FES) is an iterative process that typically starts early in the design phase of a facility and is refined as the project progresses and more detailed information becomes available.

The objectives and functional requirements of the safety systems reported in Clause 6 to Clause 16 constitute a set of recommended minimum criteria applicable to the design of offshore installations. Then, following the identification of the minimum design requirements and the development of the preliminary project documentation, the risk management process shall be applied throughout the different project phases in order to ensure that risks are reduced to ALARP, as it is summarized in Figure 1.

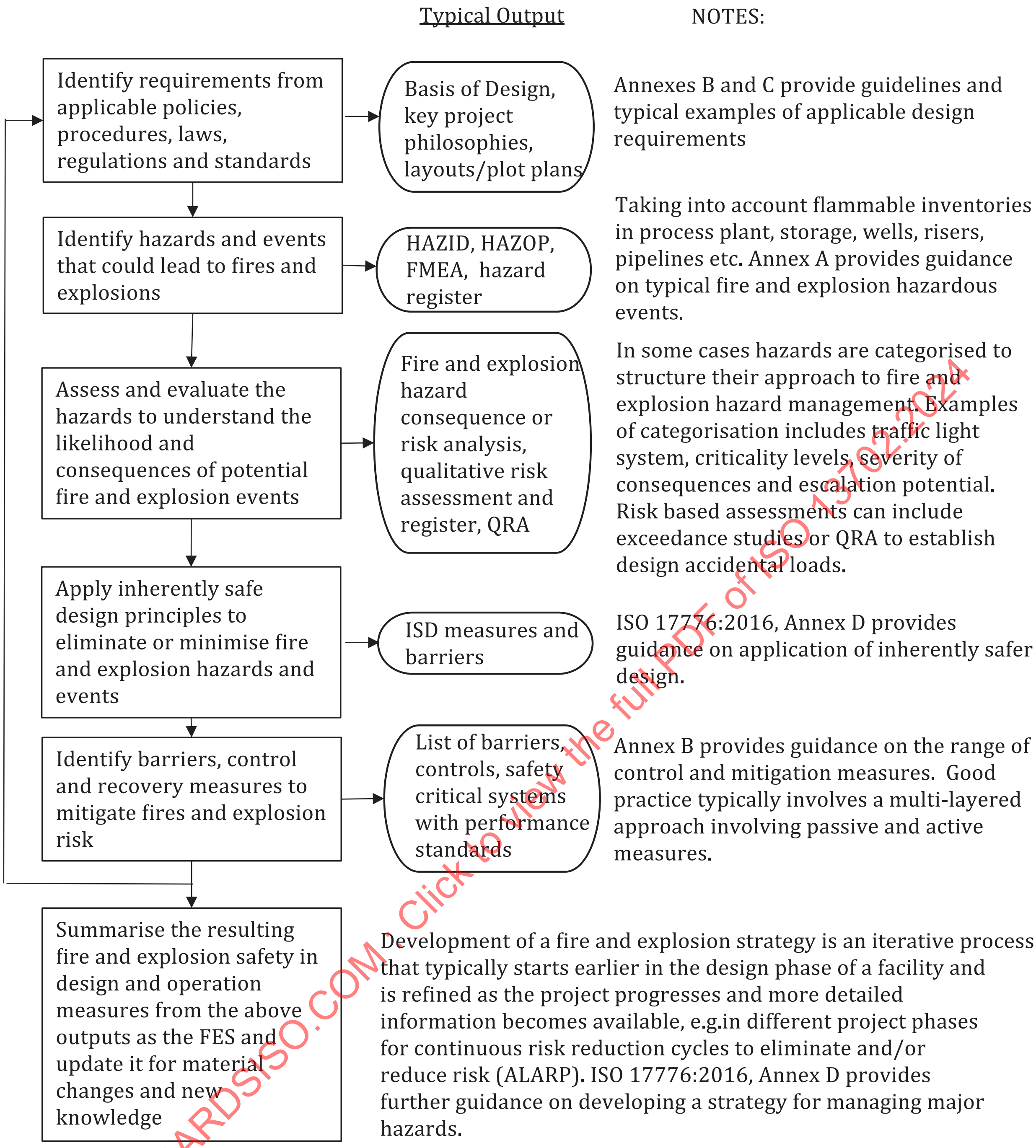


Figure 1 — Workflow

The workflow in Figure 1 is general and applies to all hazards and potentially hazardous events. In the context of fires and explosions, the evaluation of these events may be part of an overall installation evaluation or may be treated as a separate process which provides information to the overall evaluation. For further requirements and guidance related to hazard identification and risk assessment see ISO 17776[5].

In developing the risk treatment measures, there is a wide range of issues which shall be considered to ensure that the measures selected can perform their function when required to do so. These issues include the following:

a) nature of the fires and explosions which can occur (see Annex A);

b) risks related to fires and explosions;

c) offshore environment;

d) nature of the fluids to be handled;

e) anticipated ambient and metocean conditions, temperature, wind, wave, current, etc;

f) temperature and pressure of fluids to be handled;

g) quantities of flammable and toxic materials to be processed and stored;

h) flammability and toxicity of materials in non-hazardous areas including accommodation and control station;

i) amount, complexity, and layout of equipment on the installation;

j) location of the installation with respect to external assistance and support;

k) emergency response strategy;

l) production and staffing philosophy;

m) human factors;

n) interaction with adjacent facilities and vessels, e.g. jack-up, flotel, offtake tankers;

o) simultaneous operations e.g. drilling and production or production and construction.

5.8.2 Design loads

The evaluation of the fire and explosion hazards on the installation shall define the fire and explosion loads, which can be deterministic or risk based. The loads shall be summarized into a form to provide suitable input to the design process and thereby constitute the minimum loads that the installation shall be designed to withstand (regulatory requirements can require a higher resistance). It is often possible to provide a higher degree of resistance to fires and explosions and thus, the maximum reasonable resistance to fire and explosion shall be used in the design. The goal is to achieve a design where the risk is ALARP.

5.8.3 Fire and explosion strategy and performance standards

The results of the evaluation process and the decisions taken with respect to the need for, and role of, any risk reduction measures shall be recorded so that they are easily available for those who operate the installation and for those involved in any subsequent change to the installation.

NOTE Matters related to escape, evacuation, and rescue is covered in ISO 15544[4].

The FES does not have to be separately documented, and the relevant information may be included with other health, safety, and environmental information as part of the management of all hazardous events on an installation. For many existing installations, the FES may be contained in previous risk assessments or may be restricted to a simple statement of the standards or procedures, which are applied to deal with fire and explosion aspects of the installation.

The strategies shall be updated whenever there is a significant change in the risk picture which affects the management of the fire and explosion hazardous events.

The level of detail in a FES can vary depending on the scale and complexity of the installation and the stage in the installation life cycle when the risk management process is undertaken.

EXAMPLE 1 Complex installations, e.g. a large production platform incorporating complex facilities, drilling modules, and large accommodation modules, are likely to require detailed studies to address the fire and explosion hazardous events. Typical examples of some of the issues that can be necessary to address for such installations are given in Annex C.

EXAMPLE 2 For simpler installations, e.g. a wellhead platform or other small platforms with limited process facilities, it can be possible to rely on application of recognized codes and standards as a suitable base which reflects industry experience for this type of facility.

EXAMPLE 3 For installations which are a repeat of earlier designs, evaluations undertaken for the original design can be reviewed to judge if they are sufficient to determine the measures needed to manage the fire and explosion hazardous events, considering new knowledge, new technology, the environment, reservoir characteristics, etc.

EXAMPLE 4 For installations in the early design phases, the evaluations will be less detailed than those undertaken during later design phases, but are often more effective at achieving lower risk solutions by implementing risk reducing measures early than in later design phases where changes are more difficult to implement.

The strategies shall describe the role and main functional requirements for each of the systems required to manage possible hazardous events on the installation. Based on the strategies, performance standards shall be developed considering the following:

a) functional parameters of the particular system, e.g. essential duties that the system is expected to perform;

b) integrity, reliability, and availability of the system;

c) survivability of the system under the emergency conditions which can be present when it is required to fulfil its role;

d) dependency on other systems or operational factors that can have an influence on the performance of the safety function when needed.

5.8.4 Verification

The performance of the critical safety systems shall be periodically verified and registered for the lifecycle of the installation to ensure that the strategies remain valid and to identify the need for any remedial action.

6 Installation layout

6.1 Objectives

The following objectives pertain to installation layout as it affects the development of fires and explosions:

— minimize the possibility of hazardous accumulations of flammable liquids and gases and to provide for the rapid removal of any accumulations which do occur;

— minimize the probability of ignition;

— minimize the spread of flammable liquids and gases which can result in a hazardous event;

— separate areas required to be non-hazardous from those designated as being hazardous;

— minimize the consequences of fire and explosions;

— provide for adequate arrangements for escape and evacuation.

6.2 Functional requirements

The layout of an installation has a major effect on the consequences of fires and explosions and on the arrangements required for EER. Consequently, for a new installation or the modification of an existing installation, the impact of layout options on the FES shall be fully evaluated as a basis for the selection of the design which, as far as reasonable, minimizes the risks of fire and explosion.

In developing the layout of the installation, consideration shall be given to maximizing, as far as reasonable, the separation by distance of the temporary refuge (TR), accommodation and escape, evacuation, and rescue (EER) facilities from areas containing equipment handling hydrocarbons.

Either separation by distance or the use of barriers (floors and walls) can prevent the escalation of fire or explosion to another area. The provision of such barriers influences ventilation, access and escape routes, ESD/EDP system design, explosion resistance, and firewater demands. The interdependency of safety systems shall be considered during the design of the installation. Any penetration of a barrier provided to prevent escalation of a fire or explosion shall not jeopardize the integrity of the safety function of the barrier.

Critical safety systems (such as control stations, temporary refuge, muster areas, fire water pumps, and local control panels) shall be designed, located or protected so they can perform their function under emergency conditions. This includes locating the systems where they are least likely to be affected by fires and explosions. In some situations, such systems should be designed to withstand fire and explosions and be protected from the ingress of smoke, at least until people on board have been safely evacuated or the situation has been brought under control.

The blowout preventer (BOP) diverter assemblies shall be able to perform their functions under emergency conditions. This shall include the ability to initiate and operate this equipment during these conditions. The location and operation of well kill equipment shall allow it to be used under emergency conditions.

The installation layout can result in equipment being at risk from impact of dropped objects or collisions. The need to protect critical items of process equipment, especially where failure can result in a major loss of inventory, shall be considered to determine whether impact protection is required.

7 Emergency shutdown systems and blowdown

7.1 Objective

The objective of the emergency shutdown system is to initiate appropriate shutdown, isolation, and blowdown actions to prevent escalation of abnormal conditions into a major hazardous event and to limit the extent and duration of any such events which do occur.

7.2 Functional requirements

Depending on the severity of the event and level of the alarm, an emergency shutdown (ESD) system shall be provided, in accordance with the requirements of the FES, in order to

— isolate the installation from the major hydrocarbon inventories within pipelines and reservoirs which, if released on failure, would pose an intolerable risk to personnel, environment, and the equipment,

— where appropriate, sectionalize topside inventory to limit the quantity of material released on loss of containment,

— control subsurface safety valve(s), and

— where appropriate, depressurize hydrocarbon inventory and dispose of it to a safe location.

An ESD system shall provide adequate information at the CCR so that personnel involved in managing an emergency have the information they need. The information presented to the operator and the controls provided shall be such that the operator can effectively execute the required actions in an emergency.

An ESD system shall be designed such that it can fulfil its function under the conditions which can be experienced when the system is required to operate.

If the facility is in operation, the essential shutdown functions shall be available during maintenance activities which affect the operation of the ESD system.

Emergency depressurization (EDP) systems shall be considered for pressurized hydrocarbon systems to dispose of the gaseous inventory in emergency conditions to reduce the duration of an event, the quantity of material released, or the likelihood of a pressure containing system (pressure vessels and piping) failing in a fire. Rapid depressurisation should be prioritised over passive fire protection.

ESD manual stations shall be located in strategic positions, which provide a good prospect of being able to use them in emergency conditions, be well marked, and protected against unintentional activation. Guidance on what may be considered as strategic locations is provided in B.2.

The ESD system shall contain facilities for testing of both input/output devices and internal functions to ensure the functionality of the complete system.

8 Control of ignition

8.1 Objective

The objective of the control of ignition is to minimize the likelihood of ignition of flammable liquids and gases. Possible ignition sources are listed in A.4.

8.2 Functional requirements

Arrangements to minimize the likelihood of ignition shall be provided in accordance with the requirements of the FES. This shall include minimization of the number of potential ignition sources as far as reasonable.

The installation shall be classified into hazardous and non-hazardous areas in accordance with recognized standards or codes.

Ignition of flammable liquid and gas leaks shall be minimized, providing equipment in accordance with the area classification, disconnection of ignition source or other means for protection. The need for isolation or protection of equipment in non-hazardous areas during gas emergencies shall be considered in the FES. Isolation of EX-protected equipment should also be considered as a risk reducing measure.

Design measures or procedures to control the use of temporary equipment which can represent ignition sources shall be established.

Direct-fired equipment shall be located or protected to prevent ignition following loss of containment.

9 Control of spills

9.1 Objective

The objective of the control of spills is to provide measures for containment and proper disposal of flammable liquid spills.

9.2 Functional requirements

Arrangements for control of spills shall be provided in accordance with the requirements of the FES.

The design of the drainage system should minimise the effects of a spill and any escalation that can arise from the spill. Consider measures to minimize the risk of fires and to avoid damage to the environment. Examples of measures are drain capacity, bunding, deck coaming channels and drain fire seals.

Hazardous and non-hazardous open drains shall be physically separate without interconnection.

Hazardous closed drains shall be separate from all open drainage systems.

For floating LNG (FLNG) installations, a cold spill strategy should be developed that addresses the requirements of dedicated cryogenic drainage systems.

10 Emergency power systems

10.1 Objective

The objective of the emergency power system is to provide a reliable source of power upon loss or failure of the main power supply.

10.2 Functional requirements

On loss of main power supply, systems shall automatically switch to emergency power supply.

Systems requiring electrical power to fulfil their safety functions and to allow the installation to be safely shut down and evacuated shall have a secure power supply of sufficient capacity and duration for a period necessary for effective management of the installation while main power generation is unavailable.

An emergency power supply of sufficient capacity and duration, independent of the main power supply, shall be provided to allow the installation to be safely shut down and evacuated in the event of the loss of the main power supply. See IEC 61892-2[18].

Facilities shall be provided to allow maintenance of the emergency power system without significantly reducing the functionality of the system.

The location and design of the emergency power systems shall ensure that they will be able to perform their function under the conditions which can be experienced when called upon to operate.

With respect to centralised powered escape lights (UPS powered), consideration shall be made to ensure that no single fault will result in disconnection of all escape lights required for escape from the area in question. Consideration shall be given to the facilities required to maintain control of drilling and well activities. The consequences of loss of main power during drilling and well activities shall be evaluated to ensure that the emergency power systems, where necessary, allow required equipment to remain available during an emergency.

11 Fire and gas (F&G) detection systems

11.1 Objectives

The objectives of the F&G detection system are the following:

- the fire detection system provides continuous automatic monitoring functions to alert personnel of the presence of a hazardous fire;
- the gas detection system provides continuous automatic monitoring functions to alert personnel of the presence of a hazardous gas release, flammable, toxic or asphyxiant gas;
- allow control actions to be initiated manually or automatically in order to minimize the likelihood of escalation.

11.2 Functional requirements

A F&G detection system shall be provided in accordance with the requirements of the FES.

The FES shall describe the basis for determining the location, number, and types of detectors. This requires a process of identifying and assessing the possible F&G hazardous events in each area and evaluating the requirements to reliably detect these events.

The F&G detection devices shall be selected considering their response characteristics and the conditions which can be experienced when detection is required.

Gas detectors shall be selected to be suitable for detection of the types of hazardous releases that can occur in the area.

Fire detectors shall be selected to be suitable for detection of the identified design case fires that can occur in the area and oriented to avoid spurious detection (e.g. flare radiation).

The F&G devices should be suitable for Zone 1 due to their design intent to operate in a flammable gas cloud.

When necessary to prevent ignition of a gas in mechanically ventilated non-hazardous areas, the air intakes to these areas shall be fitted with gas detection and take the appropriate executive action, e.g. closing HVAC inlet damper.

The F&G detection system shall have facilities to allow testing of field devices, system internal functions, and executive outputs.

Manually operated devices to initiate F&G alarm and, where provided, control actions shall be available in a control station.

The F&G information required at the TR and control stations shall be identified during the design of the overall F&G system. The F&G system shall be designed, located, or protected so that it will be available in those emergencies where fire and gas detection is required.

12 Active fire protection

12.1 Objectives

The objectives of the active fire protection are the following:

— control fires, i.e. radiation and further spreading;

— extinguish relevant fires;

— reduce the effects of a fire to allow personnel to undertake emergency response activities including escape and evacuation;

— limit damage to structures and equipment and limit escalation, e.g. by cooling fire affected equipment and structure.

The objective supports selection of capacity, discharge density and other design details of the AFP and is critical information required for design and operation.

NOTE Extinguishing a jet fire from a gas leak can lead to a significant explosion hazard due to re-ignition.

12.2 Functional requirements

Active fire protection (AFP) systems shall be provided in accordance with the requirements of the FES.

AFP systems shall be designed, installed, and maintained in accordance with recognized standards relevant to the particular application.

If considered essential, AFP systems shall be located or protected so that they will be able to withstand the expected fire or explosion loading.

The capacity and discharge density (or application rate) of AFP systems and equipment shall be determined either by engineering evaluation or through use of a relevant recognized standard. The testing facilities for assurance of performance requirements shall be included in the selection of the system for particular areas.

Where provided, the fire-water pump system shall be selected to deliver the pressure and flow required for the operation of water-based AFP systems (deluge water spray, monitors, hoses, etc.) sufficient to meet the role of these systems. This will typically be the single largest credible fire water demand, plus any anticipated manual fire-fighting demand (monitors/hose streams). Where required in the FES, allowance shall be made to cope with the escalation of the fire to adjacent areas.

All AFP systems and equipment shall be marked with easily understood operating instructions.

For automatically initiated systems, a manual release station shall be provided and conveniently located outside the protected area.

AFP systems shall be returned to service following use. Where systems cannot be immediately returned to service, alternative actions to minimize the fire risks shall be considered and implemented where appropriate, before resumption of operations in the affected area.

NOTE The most effective way to limit escalation and damage is to detect and control fires at an early stage. In practice, fire control cannot be achieved until the source of fuel and ignition is isolated.

13 Passive fire protection

13.1 Objective

The objective of passive fire protection is to ensure sufficient fire resistance of equipment, structures, and enclosures in order to

— limit escalation,

— maintain functionality of critical safety systems, and

— allow emergency response including egress.

13.2 Functional requirements

Passive fire protection (PFP) shall be provided in accordance with the requirements of the FES which shall consider application of PFP to:

— prevent spread of fire by provision of fire barriers to separate different fire areas;

— protect critical equipment and their supports to prevent further release of inventory, such as from separators, risers, piping, or other large inventories;

— protect critical safety systems where they need to perform their functions under fire conditions as they can be exposed to the fire either directly or to their enclosures (e.g. fire water pumps, ESD valves and their actuators, piping supports for depressurisation, fire water systems and critical cables);

— protect critical structural members and in particular, those members essential to the support of the TR(s), the evacuation routes to and from the TR(s), and other critical equipment;

— avoid collapse of tall structures and equipment onto TR and evacuation facilities;

— protect personnel in the TR(s) until safe evacuation can take place;

— protect escape routes to the TR(s) to allow for safe escape from the area and allow for emergency response activities;

— protect any sections of the evacuation routes from the TR(s) to the locations used for evacuating the installation;

— protect the embarkation area and the means of evacuation.

For guidance related to fire barriers see Table C.5.

Where PFP is required to provide protection following an explosion, it shall be designed and installed such that deformation of the substrate caused by an explosion will not adversely affect its performance as specified in the performance standard. Reference is made to ISO 23693-1[42].

Selection of the PFP systems shall consider the duration of protection required, type of fire which can be experienced, and the limiting temperature for the structure and equipment to be protected.

14 Explosion mitigation and protection measures

14.1 Objective

The objective of the explosion mitigation and protection is to reduce the risk of an explosion affecting critical safety systems and other areas of the installation to a tolerable level.

14.2 Functional requirements

Measures to prevent, control, and mitigate explosions shall be provided in accordance with the requirements of the FES. These measures shall consider the following requirements:

a) reducing the probability of an explosion occurring;

b) techniques that reduce explosion loads;

c) mitigating the likelihood of escalation as a result of explosion loads.

As input to the FES, an evaluation of explosion loads shall be performed, and an assessment made of the ability of critical structures and equipment to withstand these explosion loads. The evaluation shall also identify the potential for escalation as a result of

— damage to the primary structure,

— impairment of critical safety systems, and

— fire that occurs after an explosion.

Explosion evaluations shall be performed at appropriate phases of the project to be able to influence design and implement improvements. It is important to incorporate anticipated congestion that is possibly absent in the earlier design phase in order not to underestimate the explosion design loads. The evaluation used to develop the FES shall determine the explosion design loads for all areas where there is the potential for a gas or vapour-cloud explosion. The evaluation shall identify those parts of the installation which are required to withstand these design loads (e.g. structures and boundaries required to maintain their integrity, major equipment, piping systems, or critical safety systems).

Measures to reduce explosion risk, shall be evaluated, see B.1, B.3 and B.10.

Functional requirements for passive explosion protection, when required by the FES, shall be expressed as pressure loads as a function of time. These loads shall be generated either from experimental or test data, or from suitable computational models. A suitable analysis methodology shall be used to assess the response of structure and equipment to the predicted blast loads.

The primary structure, walls, floors, and safety systems essential to the temporary refuge as a minimum shall be designed to meet the design accidental loads. For guidance refer to ISO 19901-3[6].

15 Response to fires and explosions

15.1 Objective

The objective of response to fires and explosions is to provide the facilities which will allow people to manage fires and explosions.

15.2 Functional requirements

The functionality and location of the equipment provided to allow people on the installation to manage fires and explosions can have a major impact on their ability to use them in emergency situations. Consequently, the FES shall aim to limit the exposure of people involved in managing fire and explosions and consider the following:

a) Automating shutdown and control actions to limit the need for staff on the location to make complex decisions in an emergency. When manual initiation is used, the systems shall be simple to operate and shall not require operators to make complex or non-routine decisions. Once initiated, all control actions shall occur automatically.

b) Presenting critical information at a control station so that personnel involved in managing an emergency have the information they need.

c) Providing the functions and controls that will allow those on the location to initiate any emergency actions they decide is needed.

d) Locating any emergency controls or equipment that are required for operation in a fire or explosion, such that there is a good prospect of being able to use them under emergency conditions.

e) Incorporating consideration of human factors for limiting the amount of physical and mental effort required to perform their emergency response role effectively.

Those required to perform safety critical actions shall have the proven ability to perform their roles under conditions representative of an emergency. Regular training, exercises, and drills shall be used to maintain the necessary skill levels.

Reliable means shall be provided to allow communications between locations that can be occupied, or need to be occupied, under emergency conditions.

Typical issues that should be considered in the design of the control room and operator interface are given in C.6.

16 Inspection, testing, and maintenance

16.1 Objective

The objective is to inspect, test and maintain systems and equipment covered by this document to ensure that they remain within their performance specification to prevent or mitigate a fire or explosion event.

16.2 Functional requirements

Safety systems covered by this document shall have facilities to allow demonstration of the functionality of the total system in as realistic an environment as is reasonable to achieve. The safety systems and functions shall, where reasonably practicable, allow for the required testing to be carried out without interrupting production or operations.

As part of an overall HS&E management system, each operator shall establish effective operations, inspection, testing, and maintenance procedures. This shall ensure that the functional requirements of the equipment and systems, as described in the performance standards, are maintained. This shall be achieved by implementation of suitable maintenance, inspection, and testing schemes, taking due account of the safety of personnel, protection of the environment.

In order to provide effective procedures, the following shall be carried out:

a) Systems shall be subjected to appropriate testing prior to first use, to confirm that they meet the functional requirements.

b) Written scheme shall be prepared, detailing the inspection, testing, and maintenance routines and frequencies to be followed, to determine that safety systems are functioning as designed.

c) All systems shall be thoroughly inspected and tested regularly, following established procedures. This determines if remedial measures are needed so that the item inspected and tested will function satisfactorily.

d) Adequate records of the results of the inspection, testing, and maintenance shall be kept and shall be periodically reviewed to confirm that the written scheme is appropriate and is being adequately implemented.

e) Maintenance procedures shall include for regular visual inspection.

f) Appropriate operational tests shall be conducted regularly.

g) The latest inspection or test report shall be available on the installation.

h) Use, impairment, and restoration of equipment or systems shall be recorded and reported as appropriate.

i) Any identified failures or impairments shall be recorded and promptly corrected. Where equipment cannot be promptly returned to service, contingency plans shall be implemented.

Annex A
(informative)

Typical fire and explosion hazardous events

A.1 General

A comprehensive description of offshore fire and explosion hazards is given in the UK Oil and Gas Fire and Explosion Guidance.[39] Some of the key features of fires and explosions are given in this annex.

A.2 Fire events

A pool fire is the turbulent diffusion fire burning above a horizontal pool of vaporizing hydrocarbon fuel under conditions where the fuel has zero or very low initial momentum. There is a degree of feedback between the fire and the fuel which controls the rate of evaporation and hence, the size of the fire and other characteristics such as flame height and smoke production rates. A pool fire is not necessarily static and can spread or contract depending on the supply of fuel. Depletion of fuel can occur due to drainage or overflow to other areas, perhaps giving rise to running liquid fires. The fire will take time to develop depending on the properties of the fuel (e.g. flash and fire point), as well as the temperature of the release, and cannot be eliminated quickly by isolating the fuel supply.

General area deluge in combination with foam additives can be very effective in controlling hydrocarbon pool fires and mitigating the consequences. The foam will form a protective top layer between the air and the fuel and thereby reducing or suppressing the fire.

Running liquid fires are broadly similar to pool fires in that they rely on thermal feedback from the flame for their fuel vapour supply, but the liquid fuel is in motion and can be on surfaces of any orientation.

Fires involving liquids such as methanol are very different to hydrocarbon liquid fires. The flame is non-luminous, the height is much smaller with lower radiative emissions and lower heat fluxes to engulfed objects than typical hydrocarbon liquid fires.

Liquid fires from spills or subsea releases, especially involving less volatile hydrocarbons, are difficult to ignite but once established will behave in a similar manner to a pool fire. Subsea releases of gas (or high gas-oil ratio condensates), if ignited, will give rise to a weakly turbulent diffusion flame strongly affected by wind.

An ignited pressurized release of a gaseous material will give rise to a jet fire. In the open, this will give rise to a turbulent diffusion flame resulting from the combustion of a fuel continuously released with some significant momentum in a particular direction. In jet fires, there is the absence of any direct feedback from the fire to the source. The behaviour of a jet fire in a confined or partially confined area will depend on the degree of confinement.

An ignited release of a pressurized liquid or gas mixture will give rise to a two-phase jet fire. As for a gas jet fire, the two-phase jet fire is a turbulent diffusion flame except when liquid drop-out occurs which, if it accumulates, can lead to a liquid pool fire. As for gas jet fires, the main benefit of area deluge will be the suppression of the incident thermal radiation to the surroundings.

When the fire is not able to entrain enough air for complete combustion, there is likely to be increased flame temperatures in regions close to the ceiling leading to increased heat flux on objects and surfaces in the compartment compared to unconfined fires. Under ventilation-controlled conditions, there can also be external flaming which can affect other areas.

Deluge has little effect on the size, shape, and thermal characteristics in the high momentum region of a high-pressure gas jet fire. The main benefit of area deluge with jet fires arises from the suppression of the incident thermal radiation to the surroundings, which will aid protection of adjacent plant and aid escape by personnel.

Unlike pool fires, jet fires have minimal development time and reach their full intensity almost instantaneously. In principle, they can be turned off very quickly and thus, isolation and minimization of inventory are important techniques to reduce the potential impact of jet fires.

Fire impingement on a vessel containing a pressurized liquefied gas causes the pressure to rise within the vessel and the vessel wall to weaken. Even within a short timeframe, this can lead to catastrophic failure and the total loss of inventory. The released liquefied gas flashes producing a vapour cloud which is usually ignited; these events are known as boiling liquid expanding vapour cloud explosions (BLEVEs). This event generates an extensive fire ball, pressure wave, and fragments of the vessel can cause damage to other equipment and escalation.

A cellulosic fire is a fire involving materials such as rags, paper, and wood. In addition, many surface linings used on walls, floors, and ceilings give the same type of fire. The fire grows by heat transfer and flame spread. When the fire has developed, all three modes of heat transfer (convection, conduction, and radiation) contribute to fire growth until there is no more flammable material. Compared to hydrocarbon fires, the development of cellulosic fires is slower and they do not usually reach such high temperatures.

Lithium-ion batteries contain electrolytes that are highly flammable. 'Thermal runaway' can cause these batteries to rapidly overheat and create self-sustaining fires that cannot be easily extinguished by water spray or use of a fire extinguisher.

A.3 Explosion events

An explosion is an event characterized by a rapid release of energy which, for offshore installations, is usually either mechanical (vessel rupture, either high pressure gases, or BLEVE) or chemical (vapour or mist cloud combustion). The rapid combustion of hydrocarbon vapours and mists in air represents the major explosion concern on an offshore installation and has a potential to generate high overpressures and strong explosion wind (drag) inside the explosion, as well as blast waves propagating away from the explosion source.

The duration of an explosion event is usually of the order of one second or less, while blast waves can have durations from a few milliseconds to a few tenths of a second. The strength of an explosion depends on the rate at which energy is released and, on the confinement, which can hinder expansion of combustion products. Vapour or mist cloud explosions can occur in enclosed volumes such as process equipment. pipes and storage tanks. This requires vapour or mist to be present in a flammable mixture with air (or oxidizer) inside the equipment. Controls for prevention are part of process design, e.g. inerting, purging and flame arrestors, and maintenance procedures, and are not subject of this document.

Offshore, vapour or mist explosions more commonly occur as a result of a loss of containment, leading to the formation of flammable clouds outside of vessels and piping and hence is within scope of this document. Offshore installations come in a variety of designs, from very open (unconfined) modules or areas to fully enclosed (confined) installations. The pressure rise associated with vapour or mist explosions in essentially enclosed volumes of moderate size is mainly due to the temperature rise caused by the combustion process (and subsequent lack of expansion due to the confinement) and is less dependent on the congestion in the volume. For larger confined volumes containing flammable clouds, the congestion level will normally influence local explosion loads.

Vapour or mist explosions in less confined offshore environments can also lead to significant overpressures depending on the rate of combustion and the mode of flame propagation in the cloud.

In an area with significant amounts of congestion (typical for offshore installations), the burning cloud causes hot combustion products to expand. This results in a flow of the flammable mixture ahead of the flame, past obstacles, creating turbulence which upon flame arrival increases local transport through the flame, as well as flame surface area and subsequently, the combustion rate increases. This further increases the velocity and turbulence in the wake of obstacles ahead of the flame front, leading to a strong positive feedback mechanism causing further flame acceleration and eventually resulting in high overpressures when expansion of the burning gas can no longer happen quickly enough. For the most severe explosion scenarios with large vapour or mist clouds and high flame speeds due to congestion, a deflagration to detonation transition (DDT) can take place, which would result in very high explosion loads.

When a blast wave from a vapour cloud explosion (deflagration) hits a flat structure, the blast is reflected leading to a higher blast overpressure loading than the free field blast overpressure. There can also be local variations in the blast load over the surface as the blast wave propagates over the structure. These effects mean that the design of flat area structures to withstand blast should consider the following:

a) The peak and duration reflected blast load locally over each small area of the structure. This is required to assess whether the panels making up the structure can fail.

b) The global blast load and duration onto the entire structure (averaged over a large area). This is required to assess whether the structural supports of the wall can fail.

c) The eigenfrequency of the structure. The designer should know whether the structure is load-controlled (where the intensity is the driving parameter) or impulse-controlled (where the duration and intensity are both important).

The smaller the objects are, the sooner pressure will equalize around the object and the duration and usually, the magnitude of the differential pressure load are reduced. For smaller objects such as piping, this effect will be very rapid and except when exposed to very strong or sharp blast waves, the loading can be reasonably well estimated by the dynamic pressure associated with the gas flow in the explosion (the drag load).

In general, the most onerous of either the net differential blast loading (taking account of reflections) or the drag loads (e.g. for blast waves over piping) or a combination should be considered in establishing the relevant design accidental loads. . For mid and small-sized objects, the drag loads and the differential loads should be combined to obtain the net forcing.

For more information for designing offshore installations for explosions refer to FABIG technical notes[43].

A.4 Potential ignition sources

A.4.1 General

Ignition occurs when there is sufficient energy to initiate a chain chemical reaction leading to combustion. Factors influencing resultant combustion from a given ignition source include temperature, exposure time, and energy. Ignition sources that can be present in offshore installations are discussed in A.4.2 to A.4.9. Further examples can be found in ISO 80079-36[14] and EN 1127-1[21].

A.4.2 Chemical reactions

Chemical reactions can produce heat. This heat can ignite flammable materials and products of the chemical reaction or nearby materials. An example of a chemical reaction that can occur on an offshore installation is auto-ignition of oil-soaked lagging on hot pipework.

Offshore facilities where hydrogen sulphide is present can develop pyrophoric iron sulphide as a product of corrosion of steel in the absence of oxygen. This is a highly reduced form of iron sulphide, which will convert to a more stable form on exposure to air with the release of heat which can cause the material to glow and ignite any hydrocarbon (HC) which can be present.

A.4.3 Electric sparks and arcs

An electric spark is a discharge of electric current across a gap between two differently charged objects. Although static electricity and lightning are forms of electric sparks, they are listed as separate ignition sources to emphasize their importance. Electric sparks from many of the electrical supplies on an offshore installation can contain sufficient energy to ignite a flammable mixture. An electric arc occurs when an electric circuit carrying current is interrupted, either intentionally as by a switch or accidentally as when a contact or terminal becomes loosened or a current-carrying conductor is broken. Sources of electric sparks and arcs can be the following:

- electric motors and generators;
- switches, relays, and other arcing components of electric circuits under normal operating conditions;
- electric wiring and equipment malfunctions;
- electric arc welding;
- storage batteries;
- fired equipment ignition devices;
- internal combustion engine electrical systems;
- lighting fixtures;
- radio-frequency energy;
- impressed current cathodic protection systems.

A.4.4 Mechanical sparks

Mechanical spark is energy generated by mechanical friction created by metal tools and falling objects. This energy can be high enough to ignite a flammable mixture.

A.4.5 Lightning

Lightning is the discharge of an electric charge on a cloud to an opposite charge on another cloud or on the earth. Lightning can develop very high temperatures in any material of high resistance in its path. Lightning tends to discharge to high points such as antennae and flare or vent stacks. The design of offshore installations usually ensures that lightning is not a major source of hazard except to some well operations involving explosives and at any unignited vent.

A.4.6 Static electrical sparks

If two objects in close proximity move relatively to each other, the objects sometimes collect an electric charge through friction or induction. Similarly, electric charges can be generated by rapid flow of gases or liquids.

If the objects are not earthed, grounded, or bonded, they can accumulate sufficient electric charges that a spark discharge can occur. These static electrical sparks are normally of very short duration and do not produce sufficient heat to ignite ordinary combustible materials, such as paper. Some, however, can ignite flammable vapours and gases. This situation is more common in a dry atmosphere. Static electrical sparks can be a problem in situations such as the following:

- fuelling operations;
- filling containers, tanks, and pressure vessels;
- high fluid exit velocities (high-pressure water sprays, gas jets);
- drive belt operation;
- shot blasting;
- steam cleaning;
- snowstorm;
- static accumulation on personnel;

— static accumulation related to use of glass reinforced plastic or fibre reinforced plastic, e.g. grating;

— development of charges in plastic packaging.

A.4.7 Flame

Flames are generally present when fuels and combustibles are burned. Examples include the following:

— hydrocarbon flaring;

— fired equipment (boilers, heaters);

— gas welding and cutting;

— engine operation;

— exhaust backfire and exhaust gases;

— combustion chamber (burn back to air inlet if gas is present);

— personnel smoking particularly matches and lighters;

— heating and cooking appliances.

A.4.8 Hot surfaces

Hot surfaces can be a source of ignition. These sources can include the following:

— welding slag and hot metal particles (sparks);

— fired vessel stacks;

— hot processing piping and equipment;

— engine exhaust systems;

— high-temperature electrical devices, such as incandescent lighting fixtures or heating elements;

— frictional heat such as slipping belt against a pulley, un-lubricated bearings;

— heating and cooking appliances;

— clothes dryers and exhaust systems.

A.4.9 Heat of compression

If a flammable mixture is compressed rapidly, it will ignite when the heat generated by the compressing action is sufficient to raise the temperature of the mixture to its ignition point. Combustion as a result of heat of compression can occur when hydrocarbon vapours or gases are mixed with air under situations such as the following:

— improper purging of pressure vessels and other equipment when introducing hydrocarbons;

— packing or seal failure that allows supply air to mix with supply or process hydrocarbons;

— lubricating system failure in air compressors;

— admission of air into the suction of hydrocarbon gas compressors.

Annex B
(informative)

Guidelines to the control and mitigation of fires and explosions

B.1 Installation layout

The installation should be oriented so that, if there is a dominant wind direction, it will minimize the likelihood of gas release or smoke drifting towards the accommodation, TR, helideck and evacuation points. If ingress of smoke or gas into the accommodation is possible, the design of any ventilation system should be such as to minimize the likelihood of contamination of the inside of the accommodation and spaces occupied during emergencies. On installations where the accommodation is on the same structure as the processing facilities, consideration should be given to the appropriate siting of the accommodation to minimize the likelihood of impairment by fires and explosions. In some cases, locating the accommodation on a lower level of the installation can be appropriate. The amount of venting available and the degree of congestion in the area of the explosion significantly influence the severity of an explosion.

Examples which illustrate the effect of module geometry on explosions are provided in B.10 and B.11.

In this respect, the following points should be considered:

a) long and narrow modules, enclosed on the long side, containing pressurized hydrocarbon systems should be avoided, as large distance between possible ignition points and the vent can contribute to high over pressures. If long, narrow modules cannot be avoided, vents or open areas should be located in the longer walls;

b) explosion pressure is dependent on blockage, so blockage should be reduced;

c) repeated obstacles (vessels transverse to ventilation path, see Figure B.1 in B.11) should be avoided. If this cannot be achieved, vent openings along the wall with repeated obstacles should be provided.

Where explosion vents are provided, the vents should be located to minimize the distance between any potential source of ignition and the vent. The vents themselves should have the maximum possible free area. If the vents do not have a continuous open path (i.e. if instead vent panels are installed), then the vent panels should open sufficiently fast to reduce explosion load without introducing flying object hazards. The arrangement of equipment in an area, and particularly near the vent, can have a major influence on the peak overpressures expected in an area. Where explosion vent panels are used to mitigate blast overpressure, consider the effects of the opening of the panels and vented explosion loading into other areas. Critical safety systems and vulnerable process equipment should not be located in the path of explosion vents, due to possible damage by blast effects (overpressure, drag forces, and flying debris). Furthermore, such equipment should not be placed close to walls which can be displaced in an explosion.

Cable trays, junction boxes, piping, and miscellaneous equipment should not be allowed to block the explosion vents and reduce the free vent area, nor should they be located where they will increase turbulence and thus, explosion overpressures.

Services for critical safety systems should be routed to ensure they will be able to survive and perform their function in an emergency. If it is not possible to eliminate exposure to fires and explosions or to adequately protect them, routing by diverse paths can ensure adequate integrity for critical safety systems. Care should be taken to ensure that loss of part of a system will not jeopardize the whole system.

Risers and conductors should be designed and positioned or protected to minimize the likelihood of damage, including that due to ship impact and dropped objects.

Topsides riser ESD valves should be located as low down the riser as practicable, so as to minimize the likelihood of damage below the ESD valve and release of non-isolatable pipeline inventories. The riser ESD valves should be protected to withstand the effects of design accidental loads. Riser ESD valves should be located to allow access for operation, maintenance, and inspection.

The following should be considered for process equipment layout:

a) process equipment and piping containing high-pressure gas preferably located in the upper decks above the module support frame or main hull;

b) process liquid vessels preferably be located lower than gas equipment;

c) low-pressure equipment containing large amount of liquids preferably be located and arranged so that exposure to jet fires is minimised.

The installation design should consider how an ignited blowout can be handled should such an event occur on the installation. Consideration should be given to the strategy for well killing and interaction with and role of any multipurpose support vessel which can be available during emergencies.

The integrity of physical barriers between hazardous and non-hazardous areas (refer to B.3) is important to prevent gas and smoke migration to non-hazardous areas. Penetrations between such areas should be kept to a minimum and any penetrations for piping, cables, ducts, etc. should be adequately sealed. For heating, ventilation, and air conditioning (HVAC) penetrations, dampers, where provided, or ductwork should be of the same fire integrity as the boundary through which any ductwork passes.

Effective ventilation of hazardous areas will aid dispersion of small releases, reduce the likelihood of flammable atmospheres accumulating, and minimize the duration of any accumulations which do occur.

Ventilation systems supplying air to hazardous areas should take air from non-hazardous areas.

Ventilation discharges from hazardous areas should be located so that any emissions will not present a hazard to personnel nor be directed toward possible ignition sources, during normal operations and under emergency conditions. Where utilities, such as cooling water, are shared by process systems and equipment in non-hazardous areas, the utility system should be designed to prevent migration of flammable liquids and gases into non-hazardous areas.

Offshore installations will contain a variety of systems and processes that can emit gases and hot air plumes, typically generated by turbine generators, diesel engines, flares, and emergency depressurisation systems. Hot air flow from these systems can create turbulence and other thermal effects that can severely affect helicopter operations and should be catered for, see CAP 437[31] for guidance.

B.2 Emergency shutdown and blowdown systems

ESD systems can be based on one or more of a range of technologies including programmable electronic, electronic, electrical, pneumatic, and hydraulic systems. Whatever configuration is selected, the functionality, performance, and integrity should ensure that the system can fulfil its role as stated in the FES.

ESD systems should be designed in accordance with recognized codes or standards applicable to the area of operation. Methods of determining functional requirements for electrical, electronic, and programmable electronic systems and guidance on how these functional requirements can be achieved are given in IEC 61511-1[17] for identified safety instrumented functions. Loss of power or key input signals should be considered in determining the reliability of the ESD system.

The ESD functions should be arranged in a tree-structured hierarchy. The ESD hierarchy should be simple and unambiguous minimizing number of sub-levels. A higher ESD level should initiate lower levels. A signal on a certain level should never initiate shutdowns or actions on higher levels. The cause and effects should be documented in the ESD C&E matrix or similar.

ESD system status should continuously be available in CCR, and the system should raise alarms in CCR for operator awareness or actions, considering:

— ESD level initiation,

— ESD function failure to execute actions upon demand,

— ESD function (sensor, logic solver or final element) defect or failure.

The impact of loss of power and input signals on the functionality of the ESD system should be considered. In many applications, this can require that the ESD system is inherently “fail safe”, such that the system achieves a safe condition. For more information on hydraulic and pneumatic systems which can supply power for ESD system operation, see B.12.

Simplicity of operation and maintenance should be considered in system design.

The requirements for ESD actions regarding drilling and well-servicing activities need special consideration. Manual initiation of ESD actions, which affect drilling or well-service operations, is usual.

Platform-based wells capable of flowing to surface should be separated from the platform by automatic downhole safety devices. ESD valves on incoming pipeline risers and well heads should be provided. The requirements for boundary isolations should also address the needs of any gas-lift lines. Topside riser ESD valves can be supplemented by subsea isolation valves to limit the duration of leaks associated with failure of a riser. The potential benefit of such subsea isolation valves should be considered in developing the FES.

ESD valves within the topsides process systems can be required to limit the amount of hydrocarbons released on loss of containment, to separate systems with differing operating conditions, and to facilitate EDP system design. ESD valves having a role in a fire scenario and that can be affected by the fire should have adequate fire protection in order for the valves (and actuator) to fulfil their role. This can also be applicable for EDP valves with manual activation or time delay.

Some examples of strategic locations for ESD manual stations can be CCR, helicopter deck, temporary refuge, TEMPSC embarkation area, bridge-linked evacuation routes and walk-to-work bridge landing point.

The objective is generally to avoid shut in volumes of pressurized hydrocarbons without EDP, and to minimize their volumes by proper location of valves. If trapped volumes cannot be avoided the consequence to personnel (exposure time to escape) and escalation should be considered.

The EDP rate and times should be set based on a study reflecting the risk on the specific installation and principles in API STD 521.[11] EDP times should be in accordance with specified requirements for protection of pressurised systems exposed to fire. Analysis regarding equipment or structural time to failure versus EDP should be performed. Fast and effective EDP can reduce the duration of jet fires to the extent that the need for or the amount of active and passive fire protection (AFP or PFP) can be reduced or omitted for some events. Reduction in system pressure by EDP will also reduce the leakage rates. Critical EDP pipework and supports should be able to withstand the fire loads it can be exposed to until it has performed its function.

The provision of an EDP system can possibly not in itself be sufficient to prevent pipe failure or vessel failure if engulfed in a fire. Protection provided by EDP systems will normally only be effective if the EDP is initiated at the earliest opportunity, which is likely to require automatic initiation by the F&G detection system. Where an assessment indicates that such pressure vessel failures or pipe failures represent a significant risk, additional forms of protection such as AFP or PFP should also be considered.

EDP may be initiated either manually or automatically, but automatic systems are generally preferred where a delay in initiating EDP presents a significant risk to personnel or the installation. A sequenced EDP can be required on some installations to limit the peak flow rates in the vent or flare system. Where sequenced EDP is used, the failure modes of the timer systems should be considered to ensure that the overall system integrity is adequate. For automatic EDP systems, it can be acceptable to provide a cancel facility to stop or delay the EDP if the operator decides that EDP is unnecessary or unsafe.

The consequences of venting or flaring gas when EDP is initiated should be evaluated to confirm that this does not introduce any unacceptable hazard due to, for example, liquid carryover, high levels of heat radiation, or flammable or toxic gas affecting personnel on the installation.

The design of flares should be based on dispersion calculations to prove that the foreseen gas rates can be released without creating explosive air and gas mixtures on the installation or endanger helicopter operations, see CAP 437[31] for guidance in the event of unignited flare. A robust and reliable system with back-up capacity should be considered for flare ignition.

The possibility of an unintended ignition should be taken into account in the design of vents for flammable gases, e.g. radiation loads, possible need for snuffing systems. Release from a vent should not endanger helicopter operations, see CAP 437[31] for guidance or cause ignitable gas concentrations anywhere on interfacing areas unless designed accordingly. Local venting of hazardous gases should not be permitted unless it can be done without hazard to the personnel (including occupational health) or the installation.

ESD and EDP valves should be accessible and equipped with position indicators locally and where appropriate. Valve-position indication should also be available at the control station.

ESD valves in topside processes should either have spring return or local accumulators to ensure fail-safe function under flowing conditions, i.e. normally fail-safe close.

The flare capacity should normally allow for simultaneous opening of all EDP valves in preference to sequenced EDP. The EDP valves should have fail-safe open function.

Typically travel times for topside ESD valves should not exceed 2 second/inch (valve size) to reach safe state, unless a specific process safety time has been defined. New valves should have a design margin to allow for degradation during service life. The maintenance and testing requirements should be addressed during the design and the necessary facilities to allow these activities without significantly reducing the level of safety should be provided. If maintenance and testing are not possible without significantly reducing the functionality of the system, special precautions and procedures should be developed to maintain an equivalent level of safety. In some cases, this can require that maintenance and testing operations are only performed when the installation is shut down.

B.3 Control of ignition

Potential ignition sources are described in Annex A.

Ventilation rates in open installation will vary considerably with weather conditions and layout. Consideration of a mixture of free and forced ventilation can be necessary.

In undertaking a hazardous area classification of the installation, the main factors affecting the zoning and the extent of the zones are the source, grade of, likely frequency, duration of a release, and the characteristics of the fluid released and the ventilation in the area of the release. Hazardous-area classification is intended to be applied when there can be a risk of ignition due to the presence of flammable gas and vapour mixed with air under normal operations. i.e. based upon an assessment of reasonably foreseeable and minor releases that may result from non-catastrophic failures or leaks, typically flange gaskets, pump seals and valve packing. It is not intended to cover failures normally referred to as catastrophic (major releases), e.g. where mechanical or structural failure occurs such as ruptured pipe work, tanks or vessels. The extent of each hazardous area or zone should be determined using a recognized standard, such as IEC 60079-10,[16] IEC 61892-7,[20] EI 15,[34] API RP 500[26] or API RP 505[27].

During major gas release scenarios, the extent of the gas cloud can extend beyond classified areas into non-classified areas. For these cases, consideration shall be given to the following:

— tripping of non-Ex rated equipment that can be a potential source of ignition (Zone 2 rated non-emergency equipment may be tripped as a risk reducing measure);

— equipment and safety systems that are meant to be operational in abnormal situations, where an explosive atmosphere can exist outside classified areas, should fulfil requirements to Zone 2, minimum, or be placed in protective rooms;

— preventing gas ingress into enclosures containing ignition sources.

During major gas release scenarios in classified areas where equipment is intended to be operative further reduction risk should, where practical, be achieved by increasing the rating of equipment, i.e. from Zone 2 to Zone 1.

The rate of ventilation will influence the zoning. The effect of loss of forced ventilation or the frequency of periods of low natural ventilation should also be considered and, if appropriate, the precautions identified to deal with the consequent change in zone rating. Pressure differentials created by ventilation systems are also important in limiting gas spread.

Ventilation rates for enclosed hazardous areas should take into account the amount of gaseous hydrocarbons which can be expected in normal operations, although some area classification codes contain minimum air change or velocity requirements which should be used. Air intakes for non-hazardous areas should be positioned as far as practical from hazardous areas.

All electrical equipment should be suitable for use in the area in which it is installed considering the location and the possible effects of environmental conditions or mechanical damage. In order to prevent and protect against ignition of flammable liquids and explosive gases, a systematic identification of potential electric and non-electric ignition sources should be performed. For guidance see IEC 61892-2,[18] IEC 61892-6,[19] IEC 61892-7[20] (for electrical equipment) and ISO 80079-36[14] (non-electrical equipment).

Consideration should be given to minimizing the amount of electrical equipment installed in hazardous areas.

For electrical equipment (suitable or non- suitable to operate in hazardous areas), which is required to remain energised in an emergency, facilities should be provided to selectively disconnect them manually or automatically in alignment with the ESD philosophy. Consideration should be given to tripping, either automatically or manually, all non-safety critical equipment once gas is detected in a non-hazardous area.

Electrical isolation should be defined as disconnection of the power feeder cable at the distribution boards. For simplification and reliability of the isolation function, the numbers of breakers to be tripped should be minimized, e.g. trip the inlet feeder.

All equipment that is not safety critical should be shutdown upon confirmed gas detection according to the shutdown hierarchy. Safety critical equipment not shut down by an APS (abandon platform shutdown) should be Zone 1 certified if located outdoors. This includes escape and evacuation lighting and navigation aids (sea and air).

Non-electrical equipment and hot surfaces can also be potential ignition sources. Precautions, such as automatic shutdown, should be provided to prevent ignition if a gas release should occur while the equipment is in use. This is also applicable for any combustion engines not required during an emergency situation even if rated for hazardous area operation.

Intakes and exhaust outlets from turbines, combustion engines and fired units that are not specially designed for operation in a hazardous area, should be terminated in a non-hazardous area and directed away from the hazardous area. Where possible, this type of equipment should be located in non-hazardous areas or electrically driven alternative be used.

Diesel engines can provide a source of ignition for flammable vapours. Diesel engines located in hazardous areas should be designed and installed in accordance with a recognized standard, such as ISO IEC 80079-41[15].

Diesel engines in non-hazardous areas should be provided with protection such that the diesel engine can safely shutdown if gas reaches the area in an emergency. Diesel engines that do not immediately shutdown upon gas detection anywhere on the installation should be provided with a flame arrestor in the combustion air inlet. In addition, diesel engines in non-hazardous areas powering critical safety systems should be provided with protection such that the diesel engine can continue to operate if gas can realistically reach the area in an emergency. This can include isolation of non-suitable electrical components, over-speed protection, spark arrestor, and maintaining hot surfaces below auto-ignition temperature.

Turbine-driven process equipment can represent a significant ignition source which needs special consideration in line with ISO 21789[9] requirements. The combustion air and ventilation air intakes should be located as far away from hazardous areas as practicable. Electrically driven process equipment should be considered instead of gas turbine drives to limit this ignition potential. Gas turbine acoustic hoods contain potential ignition sources and flammable materials (such as the fuel supply and lubricating oils) in close proximity. Provisions should be made to supply air from a location as far away from a hazardous area as reasonably possible and at sufficient flowrates to dilute any small leaks of flammable fluids and to purge the enclosure prior to start-up. Flammable mists generated by high pressure releases of diesel or lubricating fluids are unlikely to be picked up by gas detection and thus, provision of oil mist detection should be considered to initiate the actions needed to prevent ignition of oil mists on the hot surfaces in the enclosure or apply mist guards or tapes to prevent mist release. Detailed information on ventilation, detection, and ignition control is given in ISO 21789[9].

Objects should be protected against accumulation of static electricity due to physical contact and then separation or due to rapid flow of gases or liquids. Particular precautions can be required if nonconductive materials (including surface coating) are applied, (i.e. connection to earth can be insufficient), e.g. fibre-reinforced grating.

Guidance on these questions is given in API RP 2003[28] and ISO 80079-36[14].

A protection system to prevent sparks from anchor or mooring operations during an emergency situation to ignite a hydrocarbon release should be considered, e.g. partial enclosure, fire water coverage spraying (deluge) or other relevant measures.

Portable or temporary equipment for use in hazardous areas should be suitable for use in such areas. Where this is not possible, additional precautions should be introduced to minimize the likelihood that this equipment will ignite a release of hydrocarbons.

B.4 Control of spills

The capacity of the drainage system should be sufficient to handle credible spills coincident with deluge or fire-fighting activities. The design of drainage systems should make allowance for possible blockage which can restrict the capacity of the system and it should be designed to prevent burning fuel spreading fire to other areas.

Separate larger drainage systems can be necessary to control major releases and any associated firewater. In order to limit the size of drainage recovery systems, it can be acceptable to provide firewater drains which discharge firewater directly to the sea.

Consideration should be given to the role of the drainage system to prevent a major hydrocarbon spill accumulating under vessels or contaminating lower levels of the installation.

Consideration should be given to the need to prevent fires spreading to sea level where they can affect the integrity of the installation-supporting structure and impede evacuation.

Helidecks should be designed to quickly remove spills of aviation fuel from the vicinity of the aircraft without impeding the escape routes, see B.8.13.

On some installations, hazardous and non-hazardous open drains can terminate in a common tank, caisson, or sump. This is acceptable provided that backflow into the non-hazardous open drains is prevented (in both normal and emergency conditions), for example, by routing the drainpipe below sea or liquid level. Where such an arrangement is used, care is needed to ensure backflow does not occur due to corrosion of non-hazardous drains pipework.

Consideration should be given to the marking of drain lines to avoid non-hazardous drains being used for hazardous fluids and highlight those hazardous drains which can be affected by operational or maintenance activities.

Bunding, kerbs or drip-pans should be provided around vessels, pumps, and other potential sources of leakage to limit the spread of small spills. Containment of spills will limit the size of a fire should the spill ignite and is likely to increase the effectiveness of firefighting foams applied either manually or automatically.

Where movable containers of flammable liquids are to be stored, consideration should be given to possible leaks or spills. Measures for handling such spills should be in place.

Floating LNG (FLNG) installations require dedicated cold spill control and protection systems, to maintain the integrity of the topsides modules and the hull deck for the duration of credible cryogenic liquid spillage. This is to reduce the risk of embrittlement, the risk of escalation on the facility and protecting the asset against catastrophic loss (further guidance can be found in ISO 20257-1[8]). Aspects to be considered in the design should include selection of proper coating materials, drainage systems foreseeing potential for overboard disposal of larger inventories of cryogenic spill material, water curtains to protect critical areas which can be submitted to embrittlement (e.g. for avoiding damage to the hull of the FLNG in areas where cryogenic fluid is disposed of over the side). See also ISO 20088[7].

B.5 Emergency power systems

Emergency electrical power may be provided by one of the following systems:

— emergency generator;

— installation mains power generation provided that it can reliably provide power under emergency conditions;

— cables with suitable integrity from land or other installations;

— battery systems;

— or some combinations of these.

On small simple installations, it can be possible to rely entirely on battery systems.

More details of typical emergency electrical power requirements are given in C.1.

Consideration should be given in the design of the emergency power system to ensure that there will be adequate arrangements to provide a reliable source of power during maintenance of the emergency power system. The design of the emergency electrical power system should consider providing automatic-start arrangements to avoid the need for manual intervention during emergency condition.

Emergency lighting should be provided on routes which may be used for escape and evacuation and for those places where personnel will muster. Where emergency lighting is predominantly supplied from an emergency generator, a portion of the light fittings should also have battery backup.

In order to manage evacuation of the installation, radio communications are required. Emergency communications equipment with independent battery supplies should be provided.

The duration of the uninterruptable power supply (UPS) to systems, such as the emergency lighting, F&G detection system, emergency communications, ESD systems, should be designed to cater for the emergency conditions which can be experienced. Where UPS systems are selected, they should provide power for a period longer than the TR endurance time, as identified in the FES to cater for those events where immediate evacuation is unnecessary or not practical.

The navigational aids and centralized escape light systems should be provided with independent battery supplies from other UPS powered consumers.

Cabling for systems supplied with emergency power should be of a standard that will allow the system to operate long enough to perform its role under the emergency conditions, and the cables should be routed to minimize being damaged.

Deluge-control valves and other critical valves may be held in the closed position by the instrument air system. In a major gas emergency, mains power generation can stop, resulting in the loss of the instrument air compressor(s). If the integrity of the air supplies cannot be guaranteed, the need to power an air compressor from the emergency generator should be considered. Similar considerations are relevant for hydraulic system.

B.6 Fire and gas (F&G) detection systems

The issues which should be considered in determining the control actions initiated by the F&G detection system should be documented in the F&G C&E matrix or similar and should include the following:

— isolate the installation from the reservoir and pipelines;

— initiate EDP;

— isolate electrical equipment to prevent further development of electrical fires;

— initiate shutdown of ventilation system, including isolation of air intake, to minimize ingress of smoke, toxic or flammable gas;

— initiate isolation of electrical equipment and other potential ignition sources upon detection of flammable gas to minimize the risk of ignition;

— initiate AFP systems where these have been provided to control or mitigate hydrocarbon fires;

— initiate public address or alarm system or both for muster of personnel.

For installations with toxic gas hazards, toxic gas detection can also be required if the F&G detection system cannot be relied on to detect a toxic gas situation in time to allow appropriate actions and escape. Where fixed toxic gas detection system is required for personnel protection, it should be integrated into the into the overall F&G detection system. The specific requirements for toxic gas detection and the response to toxic gas situations are not covered in this document.

The design basis for gas detection (e.g. type and location of detectors) shall be established according to relevant gas characteristics (e.g. light or heavy, vapour, or flammable). Detectors shall be provided according to an assessment of gas leakage and accumulation scenarios within each area. Gas dispersion simulations can be used as an aid to verify and optimize type, location, and number of gas detectors.

The following aspects should be considered for the determination of the location of gas detectors:

— conditions such as ventilation and the probability of detection of small leakages within the area;

— natural flow "corridors" (e.g. access ways or walkways along flow direction) and potential obstructions should be assessed;

— where relevant, detectors should be positioned at different heights in an area or enclosed premise ensuring coverage of different natural flow paths;

— consideration shall be given to both lighter and heavier than air gases;

— voting system requirements.

NOTE Temperature effects due to temperature variations day or night, summer or winter.

Flammable gas detection performance requirements shall specify the minimum cloud size to be detected for each gas or vapour type, per zone as follows:

— either: minimum cloud size is based on explosion analysis and the predicted explosion overpressures compared with those considered tolerable for the zone;

— or: minimum prescriptive cloud sizes for general volatile hydrocarbon vapours. Typically, a gas detector grid spacing of 5-7 meters is used depending on the level of confinement and congestion.

Different types of gas detector have different detection principles and sensitivities to the range of hydrocarbon which can be experienced. The calibration should be based on the relevant range of hydrocarbons.

Acoustic gas leak detectors should be considered for use in addition to the more traditional infrared and catalytic detectors.

In some locations, there can be a hazard from oil mists as a result of the release of pressurized low flashpoint fluids such as diesel or lubricating oils. Conventional gas detection is unlikely to detect oil mists and thus, appropriate detectors should be selected where determined to be necessary in the FES such as in turbine hoods where hot surfaces capable of igniting an oil mist are present.

Multiple alarm levels for gas detection can be used to allow investigation or limited control action at low gas levels without stopping production. These low alarm levels should be set to as low a level as possible which would give reliable early detection, see BS 60080[23] for guidance.

Information on the level and location of gas present in an area should be available in CCR and control stations where applicable.

The number and location of fire detectors should be suitable to ensure timely detection of fires, considering the potential for escalation of fires in the area.

To minimize the potential for spurious trips due to F&G detection or from testing, detector voting can be applied for executive actions as follows:

— 2ooN detector to reach specified alarm limit when N ≥ 3.

— Voting should include all detectors of the same type within a detection area. Voting of detectors between different type may be applied within a detection area.

— Voting between detectors of the same type in different detection areas (intelligent voting) may be applied.

— Detection on single detector 1ooN and N > 2 may exceptionally be used provided failure probability is documented to be sufficiently low and consequences of single detector failure is tolerable.

The F&G detection system should be capable of operating under the conditions to be experienced at the time that the F&G detection is needed.

Cabling of fire detectors should be routed such that the likelihood of damage due to external accidental loads and simultaneous loss of detection in several detection areas is minimized. Fire resistant cables should be applied.

The F&G detection system should contain test facilities.

Faults of detection systems should, once detected, raise an alarm at CCR and control station as applicable.

Following the installation of the F&G detection system, there should be a physical review to confirm that the layout of detectors is able to provide an adequate response.

Manual call points should be provided at convenient locations around the installation to allow personnel to initiate an alarm of a hazardous situation and allow rapid initiation of any necessary control actions.

Where there is a likelihood of smoke and flammable or toxic gas affecting the TR, the F&G detection system should be designed to provide signals to allow effective shutdown of the ventilation systems, including isolation of air intake, before impairment of the TR occurs.

F&G detection systems should be designed in accordance with recognized codes and standards applicable to the area of operation to achieve the level of performance stated in the FES. Methods of determining requirements for electrical, electronic, and programmable electronic systems and guidance on how these requirements can be achieved are given in IEC 61511-1.[17] The effects of loss of power or key input signals should be considered in determining the reliability of the F&G detection system. Fire detection systems using CCTV with embedded software to detect heat shimmer can be considered.

Where provided, the F&G detection system should be designed to perform the following functions:

a) monitoring:

— detect hazardous accumulations of flammable, asphyxiant (typically low oxygen) or toxic gases or oil mist;

— where considered necessary, to detect leaks (e.g. near pump seals);

— detect fires at an early stage;

— detect ingress of smoke and flammable gas into places where they can present a hazard;

— permit manual initiation of alarm.

b) alarm:

— indicate the location of any fire or hazardous accumulation of flammable or toxic gases, or oil mist;

— immediately alert people of possible fire or gas incident.

c) control action:

— immediately initiate appropriate control actions.

Guidance on audible and visual alarms being adopted in some parts of the world for alarm harmonization is given in B.7.

Typical applications of fire and gas detectors are given in C.2 and further guidance can be found in BS 60080[23].

B.7 Typical audible and visual alarms

Table B.1 presents guidance on audible and visual alarms that is being adopted in some offshore operating locations, in an attempt to harmonize alarms across all installations operating in that area.

The primary alarm should be audible, supplemented by flashing beacons in high noise areas and areas where high noise level is expected in emergency situations.

Table B.1 — Alarms

Alarm type	Primary	Supplementary
Muster	Intermittent signal of constant frequency	Flashing yellow
Prepare to abandon	Continuous signal of variable frequency	Flashing yellow
Toxic	Continuous signal of constant frequency	Flashing red in affected area

NOTE The International Maritime Organization's Code of Alarms and Indicators (IMO resolution A.1021(26)[33]) is applicable to many mobile offshore units.

B.8 Active fire protection

B.8.1 General

Initiation of AFP systems can be automatic, manual, or both. The means of activation depend on the expected location, size, extinguishing agent, and type of fire and the fire-response strategy for the installation.

Many considerations influence the selection of AFP systems, e.g. the size and complexity of the installation, the nature of the operations, availability of external fire-response equipment, and the fire-response strategy adopted by the operator.

The guidance in B.8.2 to B.8.13 are not intended to imply that all of the AFP systems described will be needed on a particular installation.

C.3 provides guidance on the selection of AFP systems for typical areas on a large integrated offshore installation and gives examples of application rates of water-based AFP systems.

Normally, it is possible that unattended installations don't have fixed active protection systems and the safety of people visiting the installation are managed by application of other safeguards and controls.

B.8.2 Fire-water pump systems

The fire-water pumps, their prime movers, and starting arrangements should be designed to operate for a minimum period sufficient for them to fulfil their functions.

The speed of response of the fire-water pump unit should be selected so that fire-water is made available to the systems which use fire-water in time for them to fulfil their function.

The FES should identify the number of fire-water pumps required and the arrangement necessary to provide a reliable supply of fire-water. This should consider situations such as when a fire-water pump unit is unavailable due to maintenance or breakdown. Installations routinely accommodated by people can require at least two independent pump units.

Fire-water pump units should be designed to minimize the risk of common mode failures occurring during emergencies. Pump inlets should be separated such that in the event of an incident rendering a pump inoperative, the other pump unit (s) is/are not affected.

Suitable arrangements should be provided to allow verification of fire-water pump system performance over the full range of the fire-water pump curve.

Fire-water pump stop should be local only. Special consideration should be given to remote stop for semi-submersible and tension leg installations due to possible stability issues. Except during testing, any alarms from pump monitoring systems should not automatically stop the fire pump.

The fuel supply shut off valve to the diesel engine should be operable from outside the room. The valve should be secured in open position.

Fire-water pumps should normally have two different start arrangements and these means should be tested, as well as pump and deluge performance.

Fire detection at the fire-water pump should not stop the pump or inhibit the start of the fire-water pump driver. Confirmed hydrocarbon detection in the combustion air inlet of the driver should inhibit the pump start of the pump in question. An alternative is to provide a flame arrestor in a separate combustion inlet to avoid burn back. In the latter case, gas detectors in combustion air and pump inhibit may not be required. This does not affect the need for gas detection in the pump enclosure air inlet.

The system should be designed to start automatically in a fire emergency. In addition, facilities should be provided for local and remote manual start of the pumps, e.g. CCR, helideck.

If the connection to the control room is lost, the fire-water pumps should start automatically.

The fire-water pump system should be located, or protected, so that it is able to supply water in a fire emergency. Protection against damage of associated power cables, hydraulic piping, and control circuits should be considered. The diesel engine exhaust combustion gases should be routed to a safe location (e.g. far away from air intakes, embarkation station, escape routes). The exhaust pipe should be fitted with a spark arrestor.

Pumps powered through cable(s) from an external source should be subject to special consideration for aspects such as reliability, configuration, ignition source control and survivability.

Fire-water pump units required to operate when gas is present should be designed to be suitable for such operation.

Water treatment can be necessary to prevent marine growth from impairing fire-water system performance. The requirements for inlet filtration should be considered where debris can damage the pump.

Sufficient instrumentation (both local and, where appropriate, control station, etc) should be provided to enable personnel to ascertain the operational status of any pump unit.

The provision of relief devices or other arrangements can be required at the pumps to prevent damage to pipework due to high operating pressures or surge. Such devices should reset automatically once the excess pressure has been relieved.

For further guidance, see NFPA 20[35].

B.8.3 Fire-water mains

Fire-water mains are the means by which water for fire-fighting is transmitted from the fire-water pumps to the points of use. The fire-water mains should be designed to avoid internal corrosion problems, e.g. by material selection or avoiding dead legs, and provide an adequate amount of water to the discharge points at the required pressure.

Fire-water mains can be dry or filled. The speed of response required should be considered to determine if the fire-water mains should be filled and pressurized.

Fire-water mains should be equipped with an adequate number of shut-off valves to allow sections of the mains and branches from the mains to be isolated. Easy access for operation of these valves should be provided. In developing the FES, incidents which can result in damage to the fire mains should be considered. Where necessary, fire-water mains should be routed or protected to avoid such damage. The design should consider whether arrangements are necessary to provide adequate fire protection when a section of the fire mains is isolated due to damage or maintenance.

Fire-water mains should be designed using a recognized technique for the hydraulic analysis of this system.

The operation of systems connected to the fire mains can lead to significant surge pressures which can damage pipework and equipment. The need for surge protection should be considered in the system design.

Options to avoid surge problems should be investigated before surge-protection measures are considered.

Suitable provision should be made to protect fire-water mains against freezing during low ambient-temperature conditions. However, care is needed to ensure that such provisions do not introduce a problem of corrosion under any insulation provided.

The fire-water mains should be provided with suitable arrangements to permit testing of the pump units and the fire-water mains under full operating conditions to verify performance and determine any deterioration in capacity.

Selection of piping and valving materials and their proper installation is critical to the integrity and reliability of a fire-water system.

Materials readily rendered ineffective by heat should not be used for dry fire-water mains and fittings, unless provided with adequate fireproof insulation or otherwise protected.

B.8.4 Fixed deluge systems

Fixed deluge systems may be provided to

— control pool fires and thus, reduce the likelihood of escalation,

— provide cooling of equipment and structures not impinged by jet fires,

— provide a means to apply foam to extinguish hydrocarbon pool fires,

— limit effects of fires to facilitate emergency response and EER activities, and

— reduce explosion overpressure.

The four broad types of deluge protection are:

a) area protection designed to provide non-specific coverage of pipework and equipment within hydrocarbon-handling areas;

b) equipment protection designed to provide dedicated coverage of critical equipment such as vessels and well heads;

c) structural protection designed to provide dedicated coverage of structural members;

d) water curtains to reduce thermal radiation and to control the movement of smoke in order to provide protection to personnel during escape and evacuation.

Fixed deluge systems should be designed using a recognized technique for the hydraulic analysis of these systems.

The speed of response required for a deluge system to fulfil its function should be determined and the system should be engineered accordingly.

The water pressure available at the inlet to the system or an individual section should be sufficient for the efficient operation of all nozzles in that system or section under design flow conditions.

The types of deluge nozzle selected, and the location of these nozzles should be suitable to fulfil the role of the system during the fire events and the environmental conditions which can occur.

The sizes of nozzle and associated pipework should be selected to avoid blockage caused by corrosion products or build-up of salt deposits after operation and testing. Self-draining design is an important feature in this respect.

The properties, location and orientation of spray nozzles should be defined so that the required quantity of water will impinge on the surface of the fire or objects and area to be protected. Due account should be taken of the effects of obstructions and air movements on the stream of droplets.

Remote operation should be provided from a control station at which the operating status of the system (e.g. deluge valve open and closed) is indicated.

Isolation of any automatically operated deluge system should be possible by means of a manually operated valve located outside the protected area.

Piping should be designed to be robust and should be adequately secured and supported. The effects of surge should be considered. Consideration should be given to protecting deluge pipework and its supports against the effects of fires and explosions.

Means should be provided to enable the testing of deluge valve performance without discharging fire-water through the pipework and nozzles. Deluge valves should be provided with manual bypass matching intended flow through the valve. The deluge valve arrangement including bypass line should be supplied from two different sections of the ring main ensuring firewater supply also during maintenance situations.

Fixed deluge protection should be considered for temporary equipment such as well test packages. The design of the installation fire-water pumping system should consider the needs of any anticipated temporary deluge systems.

The discharge effects from the deluge system should be considered in selection of equipment to prevent water ingress causing impairment (e.g. the effects of water on electrical equipment and PFP). The need for equipment deluge coverage or PFP should be assessed based on relevant scenarios (load, duration and escalation potential).

For floating installations, the additional mass of water held-up in kerbed or bunded areas can potentially affect stability of ballasting and should be considered.

B.8.5 Water-mist systems

Water-mist systems are an alternative to gaseous systems in some applications. Applications in relatively small compartments are well documented but local applications in large compartments or in the open are limited to well-defined fire situations. Local application requires even distribution of water and an appropriate droplet size distribution.

The mechanism by which the water-mist extinguishes a fire is by the action of heat extraction and oxygen displacement within the flame. It is necessary for the water-mist to interact with flaming fires of a certain size to obtain a protection similar to gaseous extinguishing systems.

Considerations which should be addressed in evaluation of the use of water-mist systems include the following:

— suitability of the system for the particular application;

— provision of a suitable water supply and air or expellant gas (e.g. N_2) supply, if needed for the particular system;

— size of the protected area and degree of congestion;

— fuel type and nature of the fires which can be experienced;

— effect on electrical and other sensitive equipment within the area of water-mist application;

— easily accessible manual release facilities should be provided at the entrance of the protected areas.

B.8.6 Foam systems

Foam-forming additives can significantly increase the effectiveness of water in controlling liquid hydrocarbon pool fires. Fire-fighting foam is a stable aggregation of small bubbles, of density lower than water or oil, having a tenacious ability for covering and clinging to horizontal or inclined surfaces. It has the capability of flowing freely over a burning liquid surface, cooling the liquid, and forming an air-excluding, continuous blanket to seal flammable vapours from access to air.

Foams are ineffective for fires such as pressurized oil or gas jet fires where smothering effects cannot be achieved.

Foams can be employed using hose stations, fixed systems, portable extinguishers, or fixed monitors. The foaming agent can be applied by directly introducing foam concentrate into the fire-water system in fixed proportions or can be applied as a premixed solution of concentrate and water.

Where foam concentrates are introduced directly into the fire-water system, the method of proportioning should provide sufficient accuracy so that the required performance is obtained over the full range of flows and pressures which can occur in the fire-water system.

The foam concentrate selected should be suitable for use on the flammable liquids present in the protected area, in the expected environmental conditions. Nozzle type and foam type need to be matched to ensure efficient pool fire suppression. Also, where foam concentrate is injected into the fire-water main, it should be of a type which is compatible with sea water. Generally, fluorine free foam is preferred for environmental reasons.

Where provided, the foam pump, its sources of power supply, foam concentrate, and means of controlling the system should be readily accessible, simple to operate, capable of being put into operation rapidly, and located or protected so that it will be able to operate when required.

If fire water is released upon confirmed gas detection, then foam should not be released. This should not prevent release of foam upon confirmed fire detection.

Central foam systems should not be utilized as the primary source of supply of foam solution to hand-held equipment as accurate proportioning cannot be guaranteed at low flowrates.

The foam concentrate should conform to a suitable standard and should be suitable for use and storage at anticipated ambient temperatures. Stocks should be checked routinely to ensure that they remain within the manufacturers' recommended shelf-life and should be tested to ensure adequate performance. The foam generated should also be compatible with dry powder.

Some foam concentrates contain materials that are harmful to the environment if discharged, for example, during system testing. In this case, either alternative suitable foam concentrate should be selected or means provided to allow system testing without environmental impact should be provided.

B.8.7 Automatic sprinkler systems

Automatic sprinkler systems are typically used in areas where fires are expected to involve cellulosic fuels and where slow fire growth is expected. Once initiated, sprinkler systems can be effective to control fire spread, to reduce fire and smoke damage, and to provide alarm at a control station.

Automatic sprinkler systems should be connected to a water supply pressurized so that the system is capable of immediate operation and no action by personnel is necessary.

The standing charge in the system (wet pipe automatic sprinkler systems) should be treated freshwater due to potential corrosion problems and salt accumulations at the sprinkler head.

A means should be provided to indicate the pressure of the standing charge in the system and to alert personnel if the pressure drops to a predetermined low level.

Where an automatic sprinkler system is connected to an unpressurized main, it should have a reliable supply of water available with sufficient capacity to provide protection until the main is pressurized. Automatic supply from a pressurized fire main or deluge main which activates upon drop of pressure in the sprinkler system can be an acceptable water supply arrangement.

If sprinklers are provided in cooking areas, they should be prevented from impinging directly on to equipment used for heating cooking oil or fat. Electrical power supply to the galley should be switched off automatically in the event that the sprinkler system is operated.

Facilities should be provided to enable each part of the system to be drained and tested and to remove all air from water-filled systems.

For large sprinkler systems, consideration should be given to dividing the system so that each section can be monitored to indicate which section has operated.

B.8.8 Monitors

Fire-water monitors can be used to provide water-spray coverage or apply water-foam solution. They can also be provided to supplement fixed deluge systems.

The design of monitors should consider location, size of supply piping, and arrangement of control valves.

Monitors can be operated either remotely or locally.

Monitors arranged for local operation should be provided with an access route, which is remote from the part requiring protection and so sited as to protect the operator from the effects of radiant heat, unless the monitor is also automatically or remotely operated.

Each monitor should have sufficient movement in the horizontal and vertical planes to permit the monitor to be brought to bear on any point of the part protected by that monitor. There should be means for locking the monitor in position.

Each monitor should be capable of discharging under jet and spray conditions. The locations and discharge characteristics of the monitor should be selected to suit the role and exposure protection required from the monitors and the local environmental conditions.

Monitors which can be remotely actuated should be arranged so that they cannot cause injury or impede escape routes when operated. Local manual override controls should be provided.

B.8.9 Hydrants and hose reels

Nozzles and hoses (and portable foam equipment, if used) should be located in the most suitable positions considering the probable direction of approach of fire teams.

Where appropriate, enclosures should be provided to protect this equipment against mechanical damage and against the environment.

Fire-water mains should be equipped with hydrants to which hoses can be connected or provided with fixed hose reels. The number and position of hydrants and hose reels should be sufficient to permit effective fire-fighting by the emergency response team.

Where hydrants and hose reels are supplied by a fire-water main, the system should be designed so that the pressure available allows safe operation of such equipment at the maximum pressures which can be present in the fire-water main.

Pressure-control devices should be provided where standing pressures can pose a hazard to hose-handling personnel.

Consideration should be given to the provision of suitable foam-making equipment and concentrate for use with hydrants and hose reels.

Hoses, nozzles, valve keys, etc. should be stored adjacent to hydrants. Couplings should be standard throughout the installation. Nozzles should be of robust construction, easy to operate, and made of materials suitable for the intended duty.

Hydrants and hose reels should not be supplied from the same section of a fire main as a deluge or sprinkler system protecting the same area.

Electrical disconnection of equipment with voltage rating of 440 V and higher in electrical equipment room should be possible from outside the room, (e.g. from CCR) removing energy sources, in order to facilitate personnel entry for manual firefighting. The electrical disconnection may be realised together with disconnection of lower voltage supplies used for removing energy sources in connection with early detection.

B.8.10 Dry chemical fixed systems

Dry chemical fire-fighting systems can provide an effective means for extinguishment. A major advantage is their self-contained feature which provides for protection without reliance upon an external energy source. The nature of potential fires should be carefully considered in selecting and sizing the type of dry chemical and equipment.

Dry chemical from fixed systems can be applied from hand hose line or fixed nozzle systems. To cover several areas with a single supply of agent, hand hose lines with local actuators can be connected by rigid piping to a single dry-chemical supply. A major disadvantage of using a single large supply unit for fire protection is the loss of fire-fighting capability if the unit malfunctions (e.g. due to compaction of the powder or nozzle blockage) or is damaged. This disadvantage can be overcome by using several smaller units.

Dry chemical systems provide no security against re-ignition and it is also possible to have an explosion due to the subsequent build-up of a flammable atmosphere following the extinguishing of jet fires or those involving volatile liquids.

The discharge of dry chemical and expellant gas is a two-phase flow and the flow characteristics depend upon the particular dry chemical, expellant gas, and equipment being used. Therefore, it is important to use the manufacturers' data which have been established by investigation and tests when designing the piping.

When dry chemical and foam extinguishing agents are expected to be used at the same location, compatibility should be confirmed. Combined-agent self-contained systems are available for simultaneous use or sequential use of foam and dry chemical. Such systems offer the advantages of a rapid knockdown by dry chemical and the securing ability of foam.

B.8.11 Gaseous systems

Gaseous systems can be used to extinguish fires or, at higher concentrations, to inert a space and prevent ignition.

Gaseous extinguishing agent systems have traditionally been used for electrical equipment areas or areas which can be damaged by water or dry chemicals. Before selecting a fixed gaseous system, consideration should be given to the fire risk, the segregation from adjacent area, or other approaches which can be appropriate for the identified possible fire events. Examples of such approaches are early smoke detection, isolation of power, and rapid manual intervention.

Carbon dioxide and halogenated hydrocarbons have commonly been used in fire-extinguishing systems. Halogenated hydrocarbons are being phased out due to environmental concerns and should not be used in new applications. New gaseous extinguishing agents have been developed and can be considered where gaseous extinguishing is found to be required, provided that the gaseous agent selected is suitable in terms of fire-fighting effectiveness, toxicity to personnel, and effects on the environment. Carbon dioxide or other asphyxiating gases should be avoided for protection in areas that can expose personnel.

The use of some gaseous agents in enclosed areas can produce an oxygen-deficient atmosphere which can adversely affect human health. Such an atmosphere can produce dizziness, unconsciousness, and death if personnel remain in the area. Although some gaseous extinguishing agents have a low toxicity during fire and are possibly not asphyxiant, their decomposition products can be hazardous. Where such hazards are confirmed, appropriate safety measures should be implemented.

If admission of a gaseous agent can be harmful, then the feed pipe on such total flooding systems should be provided with an isolating valve arrangement which will be closed before personnel enter the area.

Automatic discharge of gaseous extinguishing agents should be inhibited when personnel are in an area, if there is a likelihood of harm to the personnel as a result of the discharge.

The discharge of any gaseous extinguishing agent can expose personnel to a combination of noise, turbulence, high velocity, and low temperature.

Means of initiating the systems should be readily accessible and simple to operate. Where systems are arranged for remote or automatic release, they should also be capable of manual operation with manual release points located at strategic points, generally at the control valves and at entries to the protected space.

Where appropriate, the system should be monitored to enable the detection of faults which can affect the operational efficiency of the system.

Clear audible and, if necessary, visual warnings should be given automatically within the space both prior to and during release of the system.

Visual indication of system status should be provided at each entry point to the protected space.

Enclosure boundaries should be designed so that an extinguishing concentration can be maintained for a minimum period as identified in the FES. Means should be provided for automatically stopping all ventilation fans and closing openings serving the protected space before the agent is released.

Where a gaseous extinguishing agent system is provided for ventilated machinery rooms, the discharge period should be extended to allow for losses during the shutdown of the machinery and automatic gastight dampers should be provided on all ventilation ducts.

Discharge nozzles should be so positioned that a uniform distribution of the extinguishing agent is obtained.

If a static electricity hazard can exist when discharging a gaseous extinguishing agent, then consideration should be given to grounding nozzles and objects exposed to the gaseous extinguishing agent.

B.8.12 Mobile and portable fire-fighting equipment

Mobile and portable fire-fighting equipment are intended as a first line of defence against fires of limited size and should be provided even when other AFP systems are provided.

Suitable extinguishers should be provided such that personnel in an area have ready access to permit rapid intervention while fires are still in their incipient stage. Various standards, such as API RP 14G,[24] contain guidance on the number and location of portable fire-fighting equipment.

The extinguishing media for portable fire extinguishers should be appropriate to the anticipated type of fire. Particular attention should be paid to the distribution, siting, and visibility of portable extinguishers in order that they are accessible and can be clearly distinguished. Extinguishers should be clearly marked to identify the extinguishing medium contained and the type of fire for which it is suitable for. Extinguishers should be provided with suitable means for mounting.

Portable fire extinguishers containing an extinguishing medium which, either by itself or under expected conditions of use, gives off toxic gases in such quantities as to endanger persons should not be used.

Portable fire extinguishers should be simple to operate and be designed in accordance with a recognized standard, such NFPA 10[35], which is suitable for anticipated environmental conditions.

Means should be provided to control the discharge of mobile extinguishers.

Suitable arrangements should be made for mobile extinguishers to accommodate the hose so that the hose can be handled quickly and without kinking.

Mobile extinguishers should be fitted with discharge hoses of length sufficient to reach any part of the protected area. The hose should not be of such length as to preclude efficient discharge of the extinguisher's contents.

B.8.13 Helideck fire protection

The type and quantity of fire-fighting equipment should be based on the types of fire which can occur and should be summarized in the FES. Protection requirements can vary depending on helicopter types, the size of facility, the staffing arrangements, and the area of operation. Existing practices include portable fire extinguishers, local dedicated foam systems, foam monitors and deck integrated fire fighting system (DIFFS) connected to the fire main. The helideck fire protection should be designed to deal with fires on the helideck without placing helideck crew in undue danger. CAP 437[31] encourages consideration to use DIFFS. Typically, on installations where people are routinely accommodated, AFP systems suitable for fires involving aircraft engines, crash incidents, or fuelling activities should be provided. Fire-extinguishing equipment should be readily accessible at the helideck. Where firewater is required, location of fire-water pump start facilities should be considered at each helideck emergency response location and the supply arrangements should ensure that there is no interruption in fire-water supply during fire-fighting.

The helideck may be fitted with Passive Fire-Retarding Surface constructed in the form of a perforated surface or grating, which contains numerous holes that allow burning fuel to rapidly drain through the surface of the helideck, the use of water in lieu of foam is accepted, see CAP 437[31].

If foam protection is selected, a central foam system which injects foam concentrate into the fire-water mains at the fire pump discharge should not normally be used as the primary means of helideck protection, unless it can be shown that the delay in the fire-water foam solution reaching the helideck foam monitors is acceptable. Such a central foam system may, however, be used as a back-up system for protection of the helideck should the dedicated helideck foam system be unavailable. Central foam systems may be used if foam is immediately available for induction at the helideck foam system.

Where foam is applied by means of fixed monitors, sufficient monitors should be provided, spaced at approximately equal distances around the helideck.

B.9 Passive fire protection

B.9.1 General

Screening evaluations of credible fire scenarios can be sufficient to determine the passive fire protection (PFP) requirements without more detailed calculations. These evaluations can show that certain fire scenarios are beyond the capability of critical safety systems. It can then be necessary to undertake risk evaluation, either due to authority or class requirements or for risk reduction in general, to evaluate whether it is reasonably practicable to provide additional PFP for these cases or to use some other approach to prevent, control, or mitigate the identified fire hazardous events.

In some applications, it may be appropriate to provide a level of PFP beyond that needed for safe evacuation of personnel, e.g. for asset protection or prevention of a major environmental impact.

Annex C provides guidance on typical PFP applications for offshore installations. The need for PFP should be considered in developing the FES for all types of installations.

Fire-resistance tests can be undertaken by the manufacturer as part of general approvals and by the operator for a specific application.

B.9.2 Fire-resistance test criteria

The fire-resistance test should be based on exposure to an established fire time-temperature curve or a simulated fire test, appropriate for the expected type of fire. The expected fire can be a jet fire (gas, liquid, or mixture), a pool fire, or a cellulosic fire.

The standard fire tests for cellulosic and hydrocarbon fires are limited by the size of the furnace and the capacity of an open test site in which they are tested. Hence, it is important to consider in the planning of a test the important details of the objects being protected.

The standard fire tests represent a variety of fire situations and normally give the tested object a more severe impact than many accidental fires. However, the limited scale of the test means that caution should be used when extrapolating to very large applications, when failure modes not revealed by the test can occur. Some important fire types, such as jet fires with high momentum and efficient combustion, can exceed the conditions experienced in a standard test.

An actual fire can have characteristics different from those which can be reproduced in a fire test. If critical, an alternative approach to demonstrate that a particular system is adequate should be developed. This can require “ad hoc” tests or demonstrations to be undertaken.

It should be stressed that many important parameters concerning the fitness of PFP materials or systems are not taken into account in the standard tests and in the reporting of the test. Such parameters include resistance to different environmental conditions, ageing, and mechanical impact.

Functional requirements for PFP materials include the period of resistance (expressed in time) to a certain fire exposure before the first critical point in behaviour is observed.

The functional requirements of PFP can be split into the following three categories:

— stability: to maintain the load-bearing capacity (structural capability);

— integrity: to maintain the integrity by preventing the transmission of flame, smoke, hot, and toxic gases;

— insulation: to keep the unexposed side cool when the other surface is exposed to a fire.

Standard fire tests should be used to qualify PFP materials and systems. ASTM E119[30] and ISO 834-1[1] are recognized standards for testing of PFP performance in cellulosic fires. UL 1709[40] should be used for PFP materials performance under pool fires and ISO 22899-1[10] should be used to test PFP materials under hydrocarbon jet fires. It should be noted that higher heat fluxes have been experienced in large scale test, reference FABIG technical note 13.[37] Consideration should also be given to resistance to explosion effects, when establishing the functional requirements for PFP materials. The smoke and gases produced from PFP should have low toxicity. The selected PFP should not unduly spread the fire or contribute to the fire load.

B.9.3 Selection of materials

The selection of the different materials should consider the type and size of fire, the duration of protection, the environment, application and maintenance, and smoke generation in fire situations.

PFP materials should be approved for their intended use. Where general approvals from a recognized third party or governmental body are not available, their fire performance should be documented by test reports from a recognized fire test laboratory.

Interpolation of test results for the optimization of the quantity of material to be applied should be documented.

Documentation for a passive fire-protection material can vary according to the type of application and can include the following:

a) quality control aspects:

— verification of application temperatures and humidity requirements;

— installation time;

— inspection and control requirements;

— surface preparation.

b) mechanical tests:

— abrasion and impact damage;

— mechanical damage;

— destructive compression;

— sea-water absorption;

— flexure;

— adhesion and vibration;

— deluge and hose-stream resistance.

c) corrosion protection:

— corrosion protection properties and inspection requirements for substrate;

— effects of temperatures and thermal shocks;

— cathodic disbondment;

— ozone and ultraviolet ageing;

— ease of reinstatement following inspection of substrate.

d) fire resistance tests:

— cellulosic fire performance;

— hydrocarbon fire performance;

— jet fire performance;

— fire spread characteristics;

— combustion products.

e) long-term performance including weathering effects;

f) explosion resistance;

g) full-scale experiments where limitations of tests are obvious;

h) occupational health aspects.

The test requirements should not be defined by the above. The need for each type of test should be based on engineering judgement and expected usage. For example, sea-water absorption only needs to be considered for PFP materials submerged or directly exposed to sea water. Another consideration can be the performance of combined passive cryogenic and fire protection resistance.

B.10 Explosion mitigation and protection systems

The effects of explosions that should be considered when developing the FES are the following:

— possible projectiles as a result of equipment and pipework failing;

— blast overpressure and flame front, which is a function of among other parameters type and amount of flammable material, overall dimensions and geometry, obstacle-generated turbulence, and confinement of the area;

— drag forces which are developed ahead of or behind the flame front and which can impose significant loads on equipment, pipework, or structure and which can escalate the damage created by the explosion.

The severity and consequences of an explosion can be minimized by the use of blast divisions, explosion relief vent panels, equipment installation layout, use of active explosion suppression systems, or sufficient equipment strength to prevent escalation. However, the preferred method of protection should be by the avoidance of features which will cause high overpressures and by providing adequate openings in module walls to allow unburned gas and combustion products to flow out of the compartment before dangerously high pressures develop.

Blast overpressures can be effectively reduced by adopting the approach of inherent safety by design. This requires that the layout and location of equipment is such as to minimize equipment and pipework congestion, limit the use of confining walls, limit module volumes, and provide adequate ventilation (natural or mechanical) and explosion venting. For these reasons, open-type installations are generally preferred. It should be noted that this often conflicts with requirements for weather or environmental protection (e.g. plated vs grated deck). Special attention is needed to develop solutions accounting for both explosion safety and weather protection.

The use of deluge will, in many instances with large hydrocarbon gas clouds, reduce flame speeds and thereby explosion loads, e.g. in congested naturally ventilated modules. Implementation should be assessed to ensure that adverse effects also are considered, such as:

— enhanced blast overpressure for smaller hydrocarbon gas leaks;

— water ingress and static discharge effects on equipment leading to increased ignition probability;

— corrosion under insulation due to more deluge releases due to initiation on confirmed gas detection (more inspection and maintenance);

— impact on ability to escape from the area under deluge.

Explosion-suppression systems which are initiated by detection of the early stages of an explosion are not normally used on offshore installations due to the cost of these systems. If considered, however, the system performance should address the response time for the detection system, time for suppressant release, and location and qualities of the agent used. Suppression systems are unlikely to prevent re-ignition if a flammable mixture and an ignition source are still present.

The performance of blast-relief and ventilation panels should be verified by suitable type testing. As a minimum, the following test data should be available:

— normal ambient conditions inside the module;

— relief pressure;

— time to relief.

Blast protection can provide an effective means of controlling lesser explosion overpressures, even though it is not always practicable to design against the overpressures generated in the worst-case scenarios. A decision to use design overpressure less than the predicted maximum should be based on an evaluation, e.g. based on a probabilistically estimated load, of the implications of the decision on the safety of personnel on the installation.

If it is established that the hazardous events involving explosions are not tolerable, then the following explosion-mitigation measures should be explored:

a) locating equipment in hydrocarbon service in areas which are well ventilated, where the consequences of an explosion are limited or where the structure can be designed to withstand the forces generated by an explosion;

b) avoiding accumulation of flammables by provision of walls to separate areas or modules, avoiding perimeter cladding or using grated decks;

c) minimising number of the ignition sources;

d) mitigating by venting or explosion suppression;

e) designing collapse in a cascade fashion such that failure occurs first in less critical directions;

f) being conservative in estimating explosion loads and response due to the uncertainty of any predictions of explosion overpressures;

g) making critical equipment, structures, walls and floors as strong as reasonably practicable and not limiting the design to a calculated explosion overpressure;

h) optimising the layout of equipment and piping within a module or area and location of walls and blast relief panels in accordance with the following:

- orientate horizontal vessels so that the longest dimension is in the direction of main vent flow;
- do not obstruct the openings in the module boundaries;
- maximize openings, particularly in floors and ceilings, if possible;
- consider grated floors and ceilings;
- recognize that the accuracy of any predictions of explosion overpressures is not fully known, and in particular, depends on the predictive tool being used;
- avoid long narrow modules;
- minimize flame path.

Examples for optimizing layout are provided in B.11.

The damage created by drag forces can lead to further escalation which is not tolerable. Resistance to such drag forces can be achieved by increasing the strength of supports for piping, vessels, and equipment.

Objects that can become a projectile from an explosion and can significantly impair critical safety equipment should be fastened. Examples of projectiles include well hatches, panels, and temporary equipment.

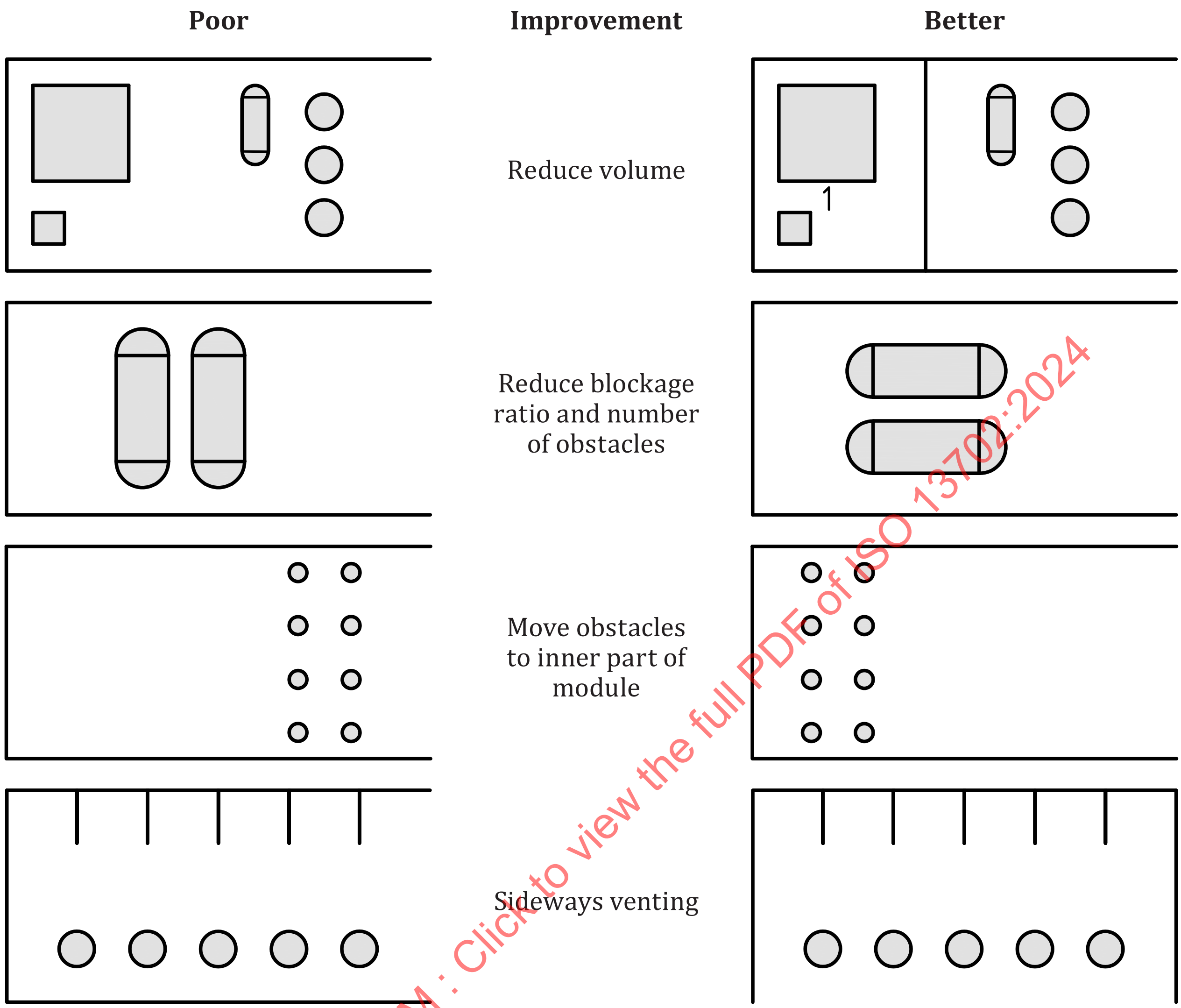
Models used to calculate explosion loading should be validated as far as possible and allowance should be made for the uncertainty in the model.

Explosion-protection requirements for structures, equipment, piping, and supporting structure should be documented, with structural calculations which take into account the dynamic behaviour related to the short duration of explosion loading. In special cases, simulated tests may be accepted according to recognized standards or procedures. In other cases, an engineering judgement may be accepted.

Guidance regarding the design of structural members for explosion loading can be found in ISO 19901-3[6] or API RP 2FB[24].

B.11 Module geometry to mitigate explosion effects

Figure B.1 shows the effect of layout on explosion severity.



Key

1 safe area

Figure B.1 — Effect of layout on explosion severity

B.12 Pneumatic and hydraulic supply systems

B.12.1 Purpose

Many of the safety systems on an installation require a pneumatic or hydraulic supply system in order to execute the appropriate actions. These systems can provide motive power (e.g. for valve movement or engine start) or can be required for effective control of the system (e.g. instrument air). In order to function reliably, the fluids in these systems should have the required cleanliness and be available at sufficient pressure to perform their functions when called upon to do so.

B.12.2 Fluid supply properties

Fluids which can be used include instrument air, plant air, nitrogen, natural gas, oil-based hydraulic liquids, and non-oil based hydraulic fluids. The initial specification of the system should identify the requirements of any pneumatic and hydraulic systems. This should include consideration of the maximum acceptable content of the following:

— water (both free water and water vapour);

— hydrocarbon;

— solids;

— possible corrosive contaminants.

When air is used as a pneumatic supply source, the system should be designed to prevent the mixing of air and hydrocarbon from the process or utility systems under both normal and abnormal conditions. If an alternative pneumatic supply source is provided, the alternative medium should be of a composition that does not create a combustible mixture when combined with the primary source.

The effect of venting natural gas should be considered in the classification of the area in which the equipment is located.

B.12.3 Supply and response

The design of the supply system should be sufficient to ensure that there will be adequate pressure to allow the system to fulfil its function. This should include consideration of the maximum usage which can be experienced at one time and the possible need for repeated operations. Where power for the supply systems is provided by the installation utility systems, the possibility of these systems not being available during an emergency should be considered and, if necessary, dedicated reservoirs or accumulators provided.

The failure mode of the safety system supplied by a pneumatic or hydraulic system should be considered to ensure that the required integrity is maintained. It is generally preferred to have an arrangement where the pneumatic or hydraulic supply keeps the system in a normal operating condition and that failure of the pneumatic/hydraulic supply will cause the system to move to a safe condition.

To achieve the required speed of response, consideration should be given to line sizes, safety device bleed-port sizes, and the need for auxiliary quick-bleed devices. Lines that supply and bleed should be sized for optimum bleed conditions. Because of volume and flowrate characteristics, a line that is either too large or too small will require excessive time to bleed.

The design of the pneumatic or hydraulic system should consider the vulnerability of components to damage, both during normal operations and under emergency conditions. It is preferable to have the pneumatic or hydraulic components located as close as practical to the safety system they serve.

B.13 Inspection, testing, and maintenance

B.13.1 General

Inspection, testing, and maintenance frequencies should be determined as part of the project development, reflecting the role and importance of the system in managing fires and explosions. The program should be based upon performance requirements, manufacturers' recommendations, operating experience, relevant plant maintenance strategy and updated as appropriate with results from the inspection, testing and maintenance.

The following subclauses discuss the issues to be considered and offer guidance for the inspection, testing, and maintenance of the safety systems and equipment covered by this document.

Prior to start-up, commissioning tests should be performed under as realistic operating conditions as possible. The fire water system should be subject to full scale dimensioning fire water demand scenario test. Some tests, e.g. depressurisation systems or hydraulic power for ESD systems may have to be put through final capacity testing shortly after operations have started.

Clause C.5 provides detailed guidance for typical inspection and maintenance frequencies.

B.13.2 Fire and gas (F&G) detection systems

- F&G detectors should be subject to a regular maintenance and testing programme. The design of the F&G detection system field devices should consider the requirements for maintenance in order to minimize the need to provide special access arrangements for calibration, cleaning, or testing.
- F&G control panel: functional checks should be conducted to ensure that detectors annunciate correct zones and initiate the appropriate alarms and actions according to the “Cause and Effect matrix”.
- General alarm: alarms initiated from the F&G detection system should be regularly tested.

B.13.3 Emergency shutdown and blowdown systems (ESD)

Periodic tests should be performed to confirm functionality and performance.

B.13.4 Fire-water pump systems

Inspection and tests:

- Drivers and pumps should be regularly started and operated for a period sufficient to establish normal operating conditions. They should start reliably and run smoothly at rated speed and load.
- Pump performance (pump speed, flow volume, and discharge pressure) should be tested to ensure the pumping system satisfies the fire-water system functional requirements.

Maintenance:

- Engines should be kept clean, lubricated, and in good operating condition. Correct oil and coolant levels should be maintained.
- Diesel fuel tanks should be checked after each engine run to ensure an adequate fuel supply exists and that the fuel is not contaminated.
- At a frequency dictated by flow test and experience, submerged pumps should be lifted to inspect for corrosion and wear which can cause failure when required to function during an incident.

B.13.5 Deluge and sprinkler systems

Deluge systems can be susceptible to plugging due to corrosion, biological fouling, or other foreign objects. Preference should be given to corrosion resistant materials as part of inherent safe design. Inspection and testing should be established to verify that the system has the capability to function as designed. It is recommended that the established procedures allow for verification of the integrity of the system. Open drains functionality and capacity check should be part of deluge testing. Provisions for flushing fire water piping with fresh water following testing with sea water should be considered. Other testing options may be considered, for example dry flow testing in combination with internal inspection can be used in combination with less frequent wet testing. This option can bring long term advantages through improved asset integrity performance by minimising deluge system blockage mechanisms (e.g. marine growth, corrosion products) and by less frequent wetting of topsides equipment and insulation.

Where installed, sprinkler system water-flow alarms should be tested for correct operation.

Testing of alarms and actions (e.g. fire-water pump start) should be possible from deluge and sprinkler systems.

B.13.6 Fire hoses, nozzles, and monitors

Where necessary to confirm integrity, all fire hoses should be tested by subjecting them to the maximum safe fire-water system operating pressures.

Nozzles should be function-tested for proper operation.

After each use, fire hoses should be inspected for damage and returned to their storage device.

B.13.7 Fixed dry chemical systems

All dry-chemical extinguishing systems and other associated equipment should be inspected and checked for proper operation.

All expellant gas containers should be checked by pressure or mass against required minimums.

All stored dry-chemical pressure containers should be checked by pressure and mass against specified data.

Except for stored pressure systems, the dry chemical in the system storage container should be sampled from the top centre and near the wall. Any samples which contain lumps that will not be friable when dropped from a height of 100 mm should result in the replacement of the chemical.

After use, hoses and piping should be cleared of residual dry chemical.

B.13.8 Gaseous systems (including water-mist systems)

Discharge of the systems during function-testing should not be required.

All stored pressure containers should be checked by pressure and mass against specified data.

B.13.9 Mobile and portable fire-fighting equipment

Extinguishers should be visually inspected on a frequent basis to ensure that they are in the designed location to ensure that they have not been activated or tampered with and to detect any obvious physical damage, corrosion, compaction of powder, or other impairments.

Hand-portable extinguishers should be hydrostatically tested in accordance with a recognized standard.

Any cylinder which shows evidence of corrosion or mechanical damage should either be hydrostatically tested or replaced.

Nitrogen cylinders used for inert gas storage and used as an expellant for wheeled extinguishers should be hydrostatically tested in accordance with a recognized standard.

At regular intervals, extinguishers should be thoroughly examined. Deficient extinguishers should be repaired, recharged, or replaced, as appropriate. Manufacturer's recommendations with respect to cleanliness and dryness should be followed for refilling extinguishers.

Extinguishers out of service for maintenance or recharging should be replaced by an extinguisher(s) having the same classification and at least equal rating.

Each extinguisher should have a permanently attached identification tag indicating the maintenance or recharge date and the initials or name of the person who performed the work.

The mixing of different powders can cause a corrosive mixture and abnormal pressures to develop, resulting in, in the extreme, explosion of the extinguisher. Extinguishers should only be refilled with the same type powder originally contained in the unit.

B.13.10 Batteries and charger systems

Batteries with a safety function should be kept charged at all times. They should be regularly tested to determine the condition of the battery cell.

The automatic-charging feature of a battery charger is not a substitute for proper maintenance of the battery and the charger. Periodic inspection should ensure that the charger is operating correctly.

B.13.11 Emergency systems

The emergency (support) systems provided for the management and control of an incident include the communications systems, escape and evacuation arrangements, power generation system(s), and explosion protection (vents or suppression system). Periodic maintenance, inspection and functional tests of these systems should be performed to substantiate the integrity of each system.

Specific test procedures should be in accordance with equipment manufacturer's recommendation.

B.13.12 Passive fire protection

The following outlines the approach to be adopted for the inspection of applied passive fire protection on structures:

Generally, passive fire protection systems have few maintenance demands. However, periodic visual inspections are recommended, with repairs to damaged areas as appropriate. The inspections should identify damage such as cracks or voids, either in the top coating or the fireproofing itself. Repairs should be carried out in accordance with manufacturer's recommendations.

These periodic inspections are important in order to maintain the integrity of the fireproofing coating and to provide early detection of substrate corrosion. If partial debonding of the fireproofing coating has occurred and there are surface cracks in the area of the debonding, moisture can migrate into the substrate, establish a corrosion cell, and become a source of corrosion. This corrosion potential highlights the need to have a fireproofing coating application procedure which ensures that a proper bond is established between the fireproofing compound and the substrate.