Fire system integrity assurance

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Fire system integrity assurance

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These guidelines have been prepared for the OGP by the Fire & Explosion Hazard Management Subcommittee

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1 Introduction

1.1 Background

Experience has shown that fire detection and protection systems are not always designed or specified in sufficient detail to ensure that they meet the performance criteria necessary to reliably achieve their intended role. In some areas this role is not even clearly defined. The problem is compounded because often the system designer/specifier has not the operational experience or feedback necessary to ensure system practicability. Also, as fire systems do not provide a direct contribution to production and revenue, they are sometimes not given the inspection or maintenance priorities that they deserve. In any event it is impracticable to give them a full performance test on site that truly reproduces the design fire event.

This situation can result in fire systems not providing the performance required, when called upon to do so.

A structured approach from design phase through to implementation is required for fire systems to ensure that they have a clearly defined role with respect to fire hazards, and that they provide appropriate levels of risk reduction.

1.2 Scope and objectives

This guidance document addresses the issues involved in the assurance of fire system integrity, from development of appropriate performance criteria, through to routine system testing and inspection to assess ongoing performance against the original criteria. For the purposes of this document the term Fire System means a fire detection system, passive fire protection or an active fire protection system such as waterspray, foam or gaseous extinguishing system.

The objective of the document is to describe a structured approach to Fire System Integrity Assurance and give guidance on its application. In keeping with a hazard based approach to the provision of fire systems, the guidance is not intended to be prescriptive, but to act as a template to develop facility specific assurance programmes appropriate to the levels of risk reduction provided by the systems.

It is emphasised that this document is intended to give guidance on the assurance process itself once it has been decided from a risk assessment that a fire system is justified. It is not intended to give any detailed guidance on the overall risk management process, other risk reduction systems (such as Emergency Shutdown) or the suitability of different types of fire system for different applications.

The Fire System Integrity Assurance (FSIA) process is described in more detail in Section 2.

1.3 Health, safety and environmental management

Health, Safety and Environmental (HSE) management systems have, over the last ten years, become generally accepted in the oil production and processing industry as part of overall business management.

The benefits have been recognised of having a clear HSE Policy and proactively managing resources, organisation, procedures and risk/hazards, coupled with improved monitoring and audit of design, construction, commissioning, operations and maintenance.

Experience has shown that companies with a functioning HSE Management System generally perform better in the field of managing hazardous processes and prevention of fatalities and lost time injuries than those with a less structured approach.

Additional information on HSE Management Systems can be obtained from the OGP document, *Guidelines for the development and application of health, safety and environmental management systems.*

1.4 Hazard management and the role of fire systems

Central to an effective HSE Management System is the way in which hazards are dealt with. Identification, assessment and management of hazards in all phases of the life of a facility are the keys to keeping HSE related risks as low as reasonably practicable (ALARP).

Although terminology varies across the industry, fire risk reduction usually involves the following steps:-

- Inherent safety (design out or reduce the hazards at source)
- Prevention (maximise plant and operational integrity measures to prevent failure and minimise the likelihood of release - i.e. reduce incident frequency)

- Control (install measures to reduce the severity of potential hazardous events, e.g. shutdown initiated by fire detection)
- Mitigation (stop escalation of potential hazardous events, e.g. fires, and so protect personnel or the environment from their effects)
- Assessment, feedback and review

Hazard Management should be focussed primarily on inherent safety and prevention in order to minimise the chances of hazardous events. However, incident mitigation measures can still play an important part in an overall hazard management approach. Also, many operating units processing or storing hydrocarbons were designed at a time when prescriptive requirements for hazardous event mitigation measures were the main method of risk reduction; as a result, fire detection and protection systems continue to have a key role in hazard management to minimise risks as far as is practicable.

Whilst the focus of risk reduction is towards life safety and environmental issues, the fire systems can also play an important role in reduction of risk to ongoing business and assets. As such, the risk based cost effectiveness of the fire protection system should be assessed using a form of Cost Benefit Risk Assessment (CBRA) or Cost Benefit Analysis (CBA). This needs also to consider the system's effectiveness. Formulae such as those given in Appendix 2 should be used in this assessment.

1.5 Performance standards

To be demonstrably effective in reducing risks, fire detection and protection systems need their role and performance to be matched to the potential consequences of the hazard release they are intended to manage. A facility Fire Hazard Analysis (FHA) or Fire Risk Assessment (FRA) is essential, and fire systems deemed to be required should be designed with a performance standard that permits them to be effective in detecting or mitigating potential fire events.

Experience has shown that while these fire system performance standards may be visible enough in design, their purpose can be lost during subsequent construction, commissioning and longer-term operation of a plant, particularly if the fire hazards are not well understood or communicated.

Installation contractors often leave a site without demonstrating whether the system they have installed will perform as envisaged in design and hence provide the necessary level of risk reduction. Once operations have started, detection systems are sometimes locked out when they appear to compromise continuous operations, thus affecting risk reduction arrangements.

Fire detection and protection systems are usually classed as 'HSE Critical Systems'. Maintenance regimes, however, are often not clearly focused on making sure that the performance standards for these fire systems are not compromised over time; this results in them becoming less effective when called upon to manage hazardous events.

Many regulatory authorities worldwide have changed from prescriptive legislation requiring the provision of specific detection and protection systems, to a requirement for the assessment and understanding of fire hazards, and the implementation of an effective management system for them and the risks they present. The UK PFEER regulations are a good example; these regulations are supported by detailed guidance on *Fire and Explosion Hazard Management* published by UKOOA. Although written for the UK offshore sector, the principles described apply to fire and explosion hazards universally. Guidance is also available in the ISO document ISO 13702, Control and Mitigation of Fire and Explosions on Offshore Installations.

2 Fire system integrity assurance (FSIA) process

Fire System Integrity Assurance (FSIA) is the process of identifying fire system performance standards decided upon in design, and checking they are appropriate to foreseeable hazardous events (fires). FSIA then deals with ensuring that these standards are not compromised in the later phases of the life of a facility, particularly installation, operations and maintenance, and confirming that they meet the requirements on an ongoing basis.

This guidance note links documents such as the UKOOA hazard management guidance to the fire systems hardware level and looks at how fire system integrity assurance can be achieved, and the benefits that accrue from implementing it.

The FSIA process and its part in overall Fire Hazard Management is shown in Figure 1. The actual point at which FSIA starts is really after the decision from the Risk Assessment that a fire system is required and its role is specified. However, in practice the precise point is not so well defined because the decision to provide a Fire System is an iterative process involving the review of potential fire incidents, defining the role required of any fire systems and the selection of appropriate systems. Having selected the system type it may subsequently be found that it cannot practicably meet the required performance criteria that are developed. It would then be necessary to revisit the iteration loop and review alternative methods of achieving the required levels of Hazard Management.

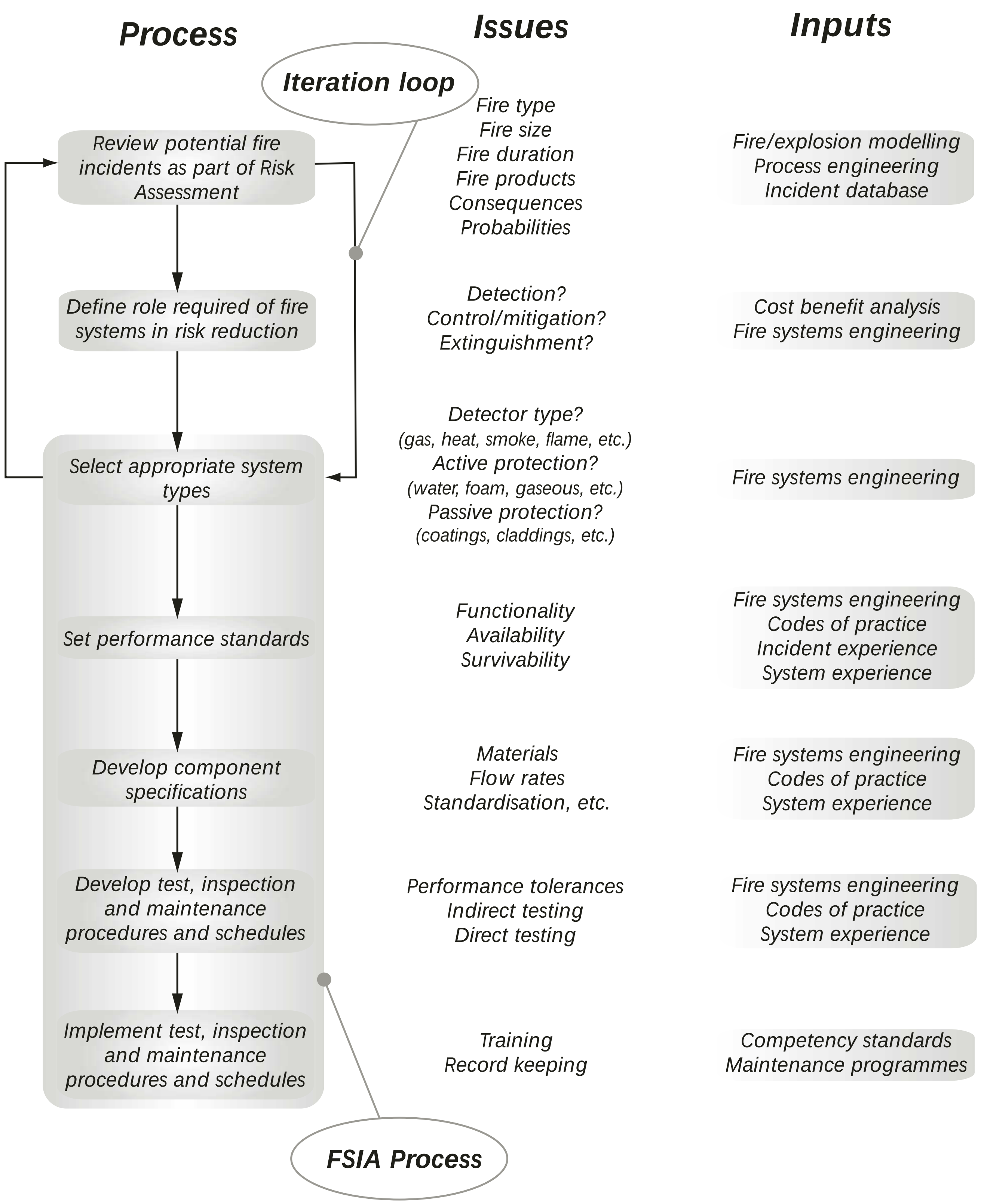
2.1 FSIA process steps

The FSIA steps are: -

- Set performance standards to clearly define exactly what measurable criteria the system must meet.
- Develop component specifications which are required to meet the performance criteria.
- Develop relevant test, inspection and maintenance procedures through which ongoing performance can be assured.
- Implement and keep records of the test, inspection and maintenance programme.

The following sections of this document give guidance on all the steps within the FSIA process, as well as general aspects of the overall Fire Hazard Management process of which FSIA is an integral part.

Figure 1 – Fire System Integrity Assurance



3 Assessing potential fire events

3.1 Introduction

Assessment of the consequences and frequency of potential fire events is essential to the identification of appropriate fire prevention, control and mitigation measures necessary to reduce risk to acceptable levels. If the potential fire scenarios have not been thoroughly assessed as part of a Risk Assessment it is not possible to match the overall role or the detailed performance of fire systems to the risk reduction required. For example, it would be pointless specifying a smoke detection system for an area where the potential fire event was a methanol or hydrogen fire which burn with a clean flame.

The identification of potential fire events should commence at the early stages of design and address all foreseeable fires and explosions. In its own right the assessment and quantification of fire events is not part of FSIA but it is an essential step prior to it, as it leads to the selection of an appropriate fire system to manage the hazard.

Additional information on fire/explosion assessment can be found in the UKOOA Guidelines and the Handbook for Fire Calculations and Fire Risk Assessment in the Process Industry.

The first stage in the assessment is to divide the installation into discrete areas and to consider the hazards which may exist in each. Having done so, fire and explosion events can be identified and scenarios developed according to the hazardous material involved and the conditions relevant to the system and inventory.

In selecting the fire scenarios for analysis, probability or frequency of incidents should be considered as well as consequences.

3.2 Fire hazard identification

Typical fire and explosion events include: -

- Cellulosic fires (involving wood, paper, etc.)
- "Electrical" fires (involving cables or control panels etc.)
- Pool fire (combustion of flammable liquid pool)
- Spray fire (pressurised or flashing liquid spray fire)
- Jet fire (gas fire)
- Flash fire or deflagration (combustion of flammable gas, insufficient flame speed to result in damaging overpressures)
- Explosion (combustion of flammable gas/vapour resulting in damaging overpressures)
- BLEVE (Boiling Liquid Expanding Vapour Explosion - a rapid ignited release of flammable, pressurised gas/vapour resulting in heated vessel failure, blast overpressure, missiles and fireball)

It is also important to consider external fire sources which may not be immediately obvious. Potential initiators of fires and explosions not related to plant/processes may include collisions, such as helicopter crashes or tanker incidents.

Each identified hazardous event will be associated with a range of possible scenarios. The most important scenarios are those in which the initial release and ignition are likely to cause the most significant damage to personnel, the environment or production.

In selecting scenarios, a balance must be struck between considering larger, less frequent events causing serious damage to the installation, and smaller, perhaps more frequent events, which could cause local damage and lead to escalation. Due consideration should be given to the likely design features of the plant, failure modes and resulting sizes, shapes, arrangements and location of releases/failures in order to ensure that any fire system installed is appropriate.

3.3 Fuel inventory and pressure

When identifying hazards the factors which determine the type of fire/ explosion event should be addressed.

Parameters relating to the stored inventory include: -

- System pressure
- System temperature
- Fuel composition, density and flashpoint
- Combustible load
- Potential release points
- Degree of isolation/quantity of isolated inventory.
- Presence of oxidising agents
- Auto-ignition temperature
- Location of ignition sources

3.4 Size, severity and duration

Estimates of the size, severity and duration of a fire/explosion event are necessary to provide information about the effects of exposure to personnel/plant and safety systems (collectively, "Consequence Analysis"), so that a decision can then be made regarding the fire systems required. (Validated Fire Modelling software packages are available to assist in this exercise). Research on fires and explosions is an ongoing exercise so additional information becomes available on a regular basis.

For fires, the necessary information may include: -

Type

Hydrocarbon pool, jet, etc.

Size

Fire spread, diameter, flame length, shape, etc.

Products of combustion

Smoke, heat, flame. In the case of smoke, the particular characteristics are required - particle size and temperature - because different types of smoke can be detected more efficiently by different types of smoke detector. For example an 'incipient' fire in cabling or printed circuit boards will give off a 'smoke' which is relatively cold and have very small particle size. Such smoke would not be detected by conventional point detectors located at ceiling height.

Severity

Internal/external heat flux, smoke concentration, toxicity and travel. Of particular importance is the incident severity and its effect on life safety.

Location

Location of release or fire and degree of impingement.

Duration

Change in above characteristics with time plus the overall duration of the event can affect selection and performance criteria of fire systems. (e.g. If the fuel inventory and fire size is such that it burns out within a very short time without escalation, then an active fire protection system would not be justified.)

In the case of explosions, consideration should be given to the extent of the flammable gas cloud, degree of confinement/congestion and the damaging effects of overpressures brought on as a result of high flame speed combustion.

3.5 Escalation

In addition to the initial effects of a fire or explosion, consideration should be given to whether and how an event can escalate to endanger personnel, the environment or an adjacent plant.

The effects of escalation on the installed safety systems should also be determined to give an indication of how this may affect subsequent escalation.

Escalation analysis can be carried out using Event Trees or some other form of Consequence Analysis to show the sequences of events which need to occur to result in a particular level of risk. Using such analyses enables system designers/operators to add further risk reduction measures (including fire systems), or enhance those already in place.

3.6 The "Design Event"

The scenarios which are selected from the risk assessment as meriting risk reduction measures due to their consequences and/or their frequency are sometimes known as 'Design Events'.

Facility specific selection of Design Events depends on several factors. The type of considerations that are required as part of the overall risk assessment include: -

- Do you 'design' for the event at all? (e.g. pipeline fractures).
- What ESD time is used for Design Events?
- What hole sizes are to be used for design releases?
- Do you design for the 'ultimate catastrophe' or is the main intention to control the smaller events?

4 Setting fire system performance standards

This section outlines the principles of setting fire system performance standards. Section 5 gives examples of the typical performance criteria that should be considered for different types of fire system.

4.1 Performance standard definition

A **performance standard** is a statement, which can be expressed in qualitative or quantitative terms, of the performance required of a system, item of equipment, person or procedure, and which is used as the basis for managing the hazard - e.g. planning, measuring, control or audit - through the lifecycle of the installation.

4.2 Overall role ("goal")

The first step in specifying an appropriate and relevant fire system is to define its role in risk reduction. Broadly, the overall role of a Fire System can be split into three categories: -

1 detection

2 control/mitigation

3 extinguishment

Examples: -

(i) Passive Fire Protection, such as cladding, would be seen as a control/mitigation measure; it does not actually extinguish the fire but it does limit its consequences.

(ii) Waterspray systems may be designed to provide control or extinguishment. (If the role was control, the intention would be to limit fire spread by cooling structures or equipment for sufficient length of time for the fire to burn out or be extinguished by other means and so prevent escalation.)

The role of a fire system is usually complementary to that of others to form effective hazard management. For example, passive protection will have a finite duration in a given fire incident and so meeting its overall role will probably be dependent on effective process isolation which, in turn, is dependent upon effective incident detection.

In practice the overall role does need some qualification in the form of definition of the relevant incident and the goal in terms of qualitative or quantitative objectives.

Example: -

The role of passive fire protection could be: -

To prevent the catastrophic failure of vessel VXXX when directly exposed to crude pool fires for 60 minutes or jet/spray fires for 30 minutes.

4.3 Performance specifications

This section is intended as an overview only of the principles of Performance Specifications. If additional, more detailed guidance is required, the UKOOA Guidelines for Fire and Explosion Hazard Management which gives advice on format as well as content should be used.

Once the overall purpose has been determined, it is necessary to define more specific performance requirements. These can be broken down into 4 categories, collectively known as FARS: -

Functionality
Availability
Reliability
Survivability

It is important to emphasise that performance must be defined for an overall system as well as individual components, and as such, may include system control features and competency requirements for system operators. For example, in an automatic foam spray system there will be performance requirements for the firewater system valve actuators, foam proportioning system, control system, and of course, the detection system that initiates the foam spray discharge as well as the discharge devices themselves. Also there may be a need to develop minimum competency standards for personnel responding to back-up the system.

The performance standards are the minimum standard which must be achieved throughout the working life of the system. They are not 'as new' but more the performance levels below which remedial action is required. 'As new' standards should therefore have a tolerance to allow for deterioration with time. This emphasises the need for a measurable criteria against which the ongoing performance of a system can be checked.

It is advisable initially to concentrate on definition of the overall system performance rather than that of individual components. These can be specified at a later stage and tend to require more specific engineering detail, which may be best presented in the form of detailed data sheets.

4.3.1 Functionality

Functionality performance requirements are those parameters required for the system to meet its defined overall role in a manner appropriate to the scenario for which it is intended. They define what needs to be achieved, not how to achieve it.

4.3.2 Availability and Reliability

Availability is a measure of the system's state of readiness to operate at any given time.

Reliability is the system's ability to operate and perform its intended function when called upon to do so.

The combination of ***availability*** and ***reliability*** is thus the proportion of the hazard occurrences when the system is available to operate and fulfil its defined role.

It is important that some quantification is made of the availability and reliability required to ensure the desired levels of hazard management. 100% availability is not normally necessary or, indeed, possible. The level of reliability required will depend on the criticality of the system.

The UKOOA document *Fire and Explosion Hazard Management* gives guidance on the categorisation or ranking of hazard management systems using a safety integrity level approach. In turn, this references the International Electrical Committee (IEC) code (IEC 1508), which quantifies bands of reliability and availability appropriate to safety integrity levels. It is noted that although the specific levels of availability described may not be appropriate, the concept can be adapted to suit hazardous events and systems within the oil industry.

Systems may not be available due to maintenance, testing, repair, breakdown or impairment while other unrelated activities are being carried out. There should be clearly defined limits for the periods when a system may be out of commission.

In some cases it may be appropriate to shutdown hazardous operations or take other temporary risk reduction measures when systems are not available.

Overall availability can be improved by duplication of critical components or complete systems. *Unreliability* can arise from the use of poor quality or unsuitable components, poor system design or installation; or failure to understand, commission, test or maintain the system. This emphasises the need for a Fire Systems Integrity Assurance approach. Following the process described in this document should improve reliability.

There is always a need for an appropriate testing and inspection regime to check ongoing system performance and thus help maximise reliability.

4.3.3 Survivability

Survivability is the system's capability to withstand the effects of an incident prior to, and during, its operation. For example, the discharge nozzles and pipework of a waterspray system may be exposed to an overpressure due to an explosion preceding a fire for which the system is intended. In such cases the exposed components must withstand the overpressures and the effects of the event itself until the system is fully operational and for the designed duration of system operation. Factors that affect survivability include strength of materials and the speed of actuation of any control systems.

Typical features that are considered in survivability performance specification are: -

- Resistance to overpressure from explosion scenarios
- Resistance to cold shock from initial contact with spilled vaporising liquids, such as LPG
- Resistance to heat radiation or direct flame impingement prior to actuation of system

4.4 Component specifications

In order to back up overall system performance criteria it may be necessary or convenient to develop system component specifications including such information as materials of construction, flow rates, certification requirements etc. It is important to ensure that such system component specifications are complementary to the overall performance criteria and designed to ensure, based on practical experience or theoretical calculations, that the component will play its part in ensuring that the overall performance is met. Component specifications can be particularly valuable when they confirm suitability for 'Design' fire characteristics.

4.5 Codes of practice/manufacturer's data/operational input

It is important that system operational knowledge and experience forms a major input into system performance specifications and, indeed, individual component specification. It is not sufficient to rely on system manufacturers or design engineering houses having sufficient experience to ensure that systems will be suitable for the hazards or meet performance requirements in a practicable way. This is because there is, unfortunately, very little feedback to them from operators of the systems on the practical issues that arise on site.

Codes of Practice such as those published by NFPA are not usually, in their own right, sufficient as performance standards although they can form a useful part of them. This is because such documents tend to be generic in format and therefore cannot provide sufficient detail to suit all specific site conditions and requirements and so may not be appropriate to the particular hazard. It is therefore essential that any Code of Practice used in performance criteria development is reviewed to confirm that it is appropriate to the type of fire, combustion, operating and environmental conditions in question.

For example, the NFPA Code of Practice for foam systems describes several different methods of proportioning foam concentrate into the water supply; final choice of the type chosen must take into account specific local requirements.

4.6 Performance specification summary

Overall it should be recognised that it is not possible to be prescriptive regarding the features that should be included in a performance specification. Instead, a process such as Fire Risk Assessment is required to consider and develop system specific requirements from an understanding of the system's role in a specific incident scenario. This demands a full understanding of potential fire events, their characteristics and their consequences. The disciplines and tools that can be used as inputs to this process are shown in Figure 1.

5 Typical critical performance criteria for fire systems

The justification for any particular system should have been developed from the Fire Risk Analysis and subsequent Fire Hazard Management Strategy. Once the system has been justified, it is important that performance standards are directly relevant to the facility-specific requirements derived from the risk assessment process. It is therefore not possible to provide a universally applicable list of the features that should be considered for different types of fire system in the development of performance criteria. However, experience "on site" has shown that some particular critical performance criteria are not developed at design stage or, if they are, are not carried through to installation, commissioning and routine testing/maintenance. In some cases it may be that any generic system data available for development of performance criteria is not appropriate and it becomes necessary to carry out fire tests to obtain specific relevant information.

This section gives guidance on these critical criteria that should be addressed to ensure appropriate performance. It is not intended as a comprehensive list of criteria but to highlight those that are most important. Most of the issues would fall into the "functionality" category although some have an impact on availability and survivability.

5.1 Detection systems

The most important performance consideration for a fire detection system is matching the type of detector and its response time to the type of combustion product that is developed in a potential incident. This, again, highlights the necessity of analysing fire scenarios and understanding their consequences and effects.

Functional standards to be met for detection systems therefore include: -

- Type of sensor according to combustion 'product' type - smoke, CO, UV or IR radiation, temperature, temperature rate of rise
- Sensitivity to fire size to be detected
- Speed of response to the given fire size/type
- Coverage of detector/location of fire
- Control actions

Fire detection can be broadly categorised as flame, smoke or heat detectors. Some guidance is given below on the achievement of these standards and considerations for design relative to all types as well as to the individual categories.

All detection types

- **Response time to the products of combustion of the 'design' events.**

  Recognised international standards are finally realising the importance of this and demanding different detector head testing techniques more relevant to real fires. For example EN54 - Fire Detection and Fire Alarm Systems now describes 6 different tests relevant to different fires: - Cellulosic, smouldering pyrolysis, glowing pyrolysis, open plastics, heptane and methylated spirits. Such tests can be demanded for individual detector heads to ensure that they are suitable for the hazards.

- **Performance under different potential operating conditions.**

  This is particularly true for smoke detectors because air conditioning, rotating machinery and environmental conditions can have a considerable effect on smoke travel. It is also important, however, for other types of detection. For example, presence of hot rotating equipment can affect the performance of flame detectors and, of course, it is important that heat detectors are calibrated to actuate at a temperature higher than any normal operating environment temperature.

- **Commissioning and routine regular testing should include total system testing using a method directly relevant to the fire type.**

  As an example, the tests described in EN54 can be adapted for use for total system testing. Tests should be carried out under different operating conditions. Additional guidance is given under the sections on individual detector types.

- **Detection should have well defined relevant sensitivity or adjustable sensitivity capability so that site adjustment can be made if necessary to suit actual conditions.**

- **Normally some type of voting from detectors would be required prior to automatic executive action to assure system reliability.**

  If this is the case, it may be necessary to increase the number of detectors considerably in order to maintain the response time required.

- **Control Panels and power supplies must be designed to conform with overall system reliability**

requirements such as those described in ISO 61508 - Functional Safety of Electrical/Electronic Programmable Electronic Safety Related Systems.

Fire alarm control panels are often purchased as a specialist item. The requirements for power supply integrity, component reliability and failure mode and effect analysis need to be specified to an appropriate level consistent with criticality of the system.

5.1.1 Smoke detection

- **Smoke travel tests should be required using "smoke" relevant to the applications.**

  Testing should be relevant to the particular hazard and combustion conditions and the overall purpose of the system. The characteristics of 'smoke' and smoke travel vary greatly according to the material being burned and the operating conditions. The tests described in EN54 can be adapted as mentioned previously for many smoke detection systems. However, for incipient fire smoke detection systems, the test method that has become a recognised standard is the 'hot wire' test described in BS6266 - Code of Practice for Fire Protection of Electronic Data Processing Installations. This test is appropriate to situations where the smoke has very small particle size and is relatively 'cold' due to it being produced at a very early stage of fire development. OGP document 'Incipient Fire Detection' gives additional guidance on the use of detectors of this type.

  Individual detector head testing is not usually sufficient to assure system integrity.

5.1.2 Flame detection

- **Line of sight to all potential "design fire" areas must be provided for at least the number of detectors required to bring about automatic executive actions.**

  Flame detectors generally have a cone of vision. Very often, when systems are designed on paper, the "fire area" is obscured in practice due to equipment or structural elements in the area. Commissioning and routine testing should include use of an appropriate device (such as a UV flashlight) to check both sensitivity and line of sight.

- **Suitability for relevant fuels and operating environment.**

  The suitability for the environment must be confirmed. Not all fuels give off UV and/or IR radiation. It is therefore important to ensure that the flame detector chosen is suitable for the type of fuel. Also, other contaminants such as silicones, ice or oil mists can affect detector response as well as, in the case of IR detectors, hot/rotating equipment.

5.1.3 Heat detectors

- **Location and number of detectors to allow sufficiently fast response.**

  Heat detectors are often used as a reliable back up to other detection, recognising that they are often slower to respond than other types.

  It is important to ensure that the actuation temperature and the location of the detectors are appropriate to a performance requirement. This is particularly true where point detectors are used in open areas. Air movement can mean that temperature levels take a long time to increase sufficiently to activate the detector.

5.2 Water systems

The potential role of water systems includes: -

- Prevention of escalation
- Prevention of catastrophic rupture
- Prevention of structural failure
- Control of smoke and/or flame movement
- Combustion interaction/reduction of flame temperature, heat flux and size
- Extinguishment

Functional parameters relevant to the performance of water systems include: -

- Speed of response and time to full flow condition
- Application rate
- Coverage (in some cases this might be general area coverage, in others, specific vessel or support structure coverage)
- Nozzle location and characteristics (droplet profile and velocity)
- Application duration

Guidance on these issues can be found in standards such as NFPA 15 - Waterspray Fixed Systems and ancillary publications such as NFPA 20 - Fire Water Pumps. However, it is important to ensure that the guidance is directly relevant to the actual applications. If not, theoretical calculations or even experimental validation may be required. (It is important to note that NFPA 15 should only be considered applicable to pool fire situations and not to gas/spray fires.)

- **Application Rate should be specified in litres/min/m^2 of 'wetted surface' (gpm/ft^2) to achieve the desired level of cooling or extinguishment.**
- **The system should be such that coverage of all areas is achieved at the required Application Rate under all potential operating conditions taking into account windspeeds and directions.**

  Water droplet size and density will also affect area coverage in that they must be such that the flame is penetrated and the water reaches the area where it is required. This can often be addressed by requiring an independent certification of the discharge nozzle, making sure that the certification is directly relevant to the application.
- **The time to full flow must be such that escalation of the incident to unacceptable levels does not occur and the distribution system must not fail before water starts to flow.**

  This feature is also dependent on actuation method.
- **The system run time must be directly relevant to the incident duration including any extended cooling time required.**
- **Manual actuation devices should be in accessible and safe locations.**
- **Water application and any fuel spill should be contained or drained off in a controlled manner.**

  In many cases waterspray systems have been designed and specified without recognising that very large quantities of water will be applied and it is essential that run off is controlled. In the worst case, if this is not done, then fires can actually be escalated by fuel being carried to other areas.
- **Reliability of water supply to a water based system must be considered in the overall system design.**

  This requires due consideration of redundancy of water supply, pumps, and firewater system distribution sections according to the frequency of the design events. For example, lower levels of redundancy might be acceptable for less frequent events.

Water Mist systems are not at the same stage of development as waterspray systems and it is interesting to note that the relevant NFPA Code (NFPA 750) is more in the style of a performance setting standard than a prescriptive one.

5.3 Foam Systems

Foam is one of the most important extinguishing media for hydrocarbon contained liquid pool fire incidents, yet it is an area where poor understanding, specification or testing often leads to ineffective system performance. It should be noted that foam is generally not effective against pressurised liquid fires.

Guidance can be sought on many aspects of system design from NFPA 11 - Foam Systems, but it is important to ensure that the guidance is directly relevant to the application. For the special area of aviation related incidents (helidecks and airstrips), ICAO documents CAP 168 and CAP 437 are of more direct relevance.

Considerable amounts of research work have been carried out on foam systems for the special application of LNG/LPG spill vapour suppression and fire control. Standards are currently being developed for these applications.

Functional parameters relevant to the performance of foam systems include: -

- Response time
- Application method
- Foam quality produced: -
  - Expansion
  - Drainage time
  - Proportioning rate concentration
- Application rate
- Foam coverage/spread
- Duration of discharge
- Vapour suppression capability
- The foam concentrate must be of a type suitable for the application

There are many "approval tests" for foam concentrates. It is very important to select one directly relevant to the application. Many national standards organisations have, in the past, developed their own standards on foam.

An ISO Standard (ISO 7203 - 1 - Fire Extinguishing Media - foam Concentrates) is also now available. However, this is intended for generic applications rather than any specific hazard.

The most relevant foam system standards for the oil industry applications are: -

LASTFIRE Group

Test method developed to assess a foam's capabilities in tank fire scenarios.

UL 162

Underwriters Laboratories test method for foams in different types of systems. This would be relevant to general use of foam in handlines but is also relevant to foam spray systems.

ICAO

International Civil Aviation Organisation documents CAP 168 and CAP 437 give guidance and test methods for foam concentrate for helideck and airstrip application.

CEN

CEN document EN 12065 (draft) gives guidance on testing a foam's capability in the suppression of LNG fires.

It should be recognised that in some cases system specific tests may be required, especially those involving fuels other than hydrocarbon.

To ensure these criteria are met, the following must be considered: -

- **Acceptable accuracy of the foam concentrate proportioning rate must be specified over the entire range of possible system flows.**

  In many cases several foam systems are fed from one centralised proportioning unit. Therefore, there may be different operating flow rates for the proportioner. Also, an individual system will have different flow rates according to operating pressures, use of supplementary equipment from the same system and blockage of some outlets. It is important that the proportioner can provide accurate proportioning over the complete flow range. If no more specific information is available, then NFPA 11 should be used for guidance. This essentially allows +30%, -0% from the nominal proportioning rate for most applications.

- **The application rate of foam solution reaching the fuel surface must be sufficient to gain control and extinguishment under all operating conditions.**

  NFPA 11 can be used for guidance on this subject as it quotes minimum application rates for different situations based on previous experience. However, the rates are those required to reach the fuel surface so allowances must be made for losses due to wind, thermal updraughts, etc.

- **Foam quality (stability, flowability, etc.) must be appropriate to the hazard.**

  Foam quality is usually measured by means of an expansion rate and a drainage time for 25% of the foam solution to drain from the foam. In some cases a large tolerance can be accepted without major loss of performance, but in some cases, such as sub-surface injection, these parameters are very critical. Although standards such as NFPA give guidance on this subject it is not definitive and in some cases it is necessary to resort to manufacturer's data, checking that the data is based on sound operating experience.

- **The system run time must be sufficient to ensure extinguishment and develop a foam blanket to minimise possibility of re-ignition.**

  Guidance for many situations can be found in NFPA 11 which includes minimum system run times for a variety of applications.

5.4 Gaseous systems

With the recognition of the contribution of Halons to the breakdown of the Earth's protective ozone layer and the subsequent reduction in their use, alternative agents have been developed and "fast tracked" into service without as much testing as may have been liked. Under these circumstances it is even more important to develop system specific performance criteria.

Functional parameters relevant to the performance of gaseous extinguishing agent systems include: -

- Safety features regarding personnel exposure to the agents, their by-products or low oxygen concentrations
- Concentration of agent or levels of oxygen depletion achieved to ensure extinguishment for the fuel(s) in question
- Speed of system response and time to achieve the design concentrations throughout the protected volume
- Retention time for the design concentration to be maintained
- Agent quality
- Supporting control actions
- Enclosure integrity/venting

Guidance can be obtained from documents such as NFPA 2001 - Clean Agent Systems, BFPSA Code of Practice for Gaseous Fire Fighting Systems and OGP document 'Inert Gas Fire Extinguishing Agents'.

- **Appropriate measures must be specified to ensure personnel are not subjected to potentially dangerous levels of gas or their breakdown products.**

  Several of the gases used for extinguishing systems have potential to cause harm to individuals either by toxicity of the gases themselves or their breakdown products or by oxygen depletion. It is therefore essential to provide safety features, the performance criteria of which are such as to prevent exposure of harmful levels to personnel. Such facilities can include lock out devices, time delays and post discharge ventilation systems.

- **Agent concentration must be sufficient to gain extinguishment.**

  Concentration required will depend on the fuel and fire type. Test work may be required to develop specific criteria for some situations. Normally a safety factor over the minimum concentration would also be required.

- **The time to achieve the design concentration throughout the relevant area must be sufficiently fast to prevent excessive escalation.**

  The acceptable maximum time to achieve design concentration should be assessed from the review of potential fire events. If no other relevant information is available, the BFPSA guidance is for liquefiable gases to be discharged within 10 seconds and non-liquefiable within 60 seconds. The need to achieve distribution throughout the area will normally require a validated flow analysis and nozzle-sizing program to be used along with post installation discharge testing for confirmation.

- **Agent quality**

  It is obviously essential that the gas used in the system be of the correct quality. Colour coding of cylinders should be in accordance with local regulations to minimise the possibility of using the incorrect gas. Quality requirements for different gases are given in NFPA 2001 and the BFPSA document referenced above.

- **Retention time should be such that the extinguishing concentration is maintained for sufficient time to ensure that the fuels have cooled so that re-ignition will not occur and/or the required system post-discharge back-up response can be achieved.**

  Retention time will depend upon the amount of losses due to leakage, ventilation, etc. as well as amount of gas discharged. Therefore, the performance criteria must include information on enclosure integrity. It may be necessary to demand an enclosure integrity test and NFPA 2001 gives guidance on this. It should be remembered that the gas concentration must be retained to at least the height of the highest combustible/flammable materials in the area.

- **Enclosure integrity and/or venting arrangements should be such that the overpressures developed do not jeopardise the enclosure's integrity.**

  Different construction types can withstand different levels of overpressure. Any level of overpressure can be accommodated by means of venting and/or structure strength. This requirement will normally demand use of validated software to calculate overpressures and assess venting requirements. Enclosure integrity tests will normally be required to assess actual vent conditions. Another aspect of enclosure integrity is the prevention of gas migration to other areas where it may become a hazard. Integrity test methods are described in NFPA 2001.

5.5 Passive protection

Functional parameters to be considered for passive protection include: -

- Fire type and characteristics: -
  - Heat flux
  - Temperature
- Erosion resistance for jet/spray fires
- Substrate/protected item threshold temperature
- Durations of protection required
- Performance changes over the lifetime of the facility
- The passive protection must be suitable for the type of fires identified during the risk assessment

Standard fire tests assess a material or structure's capability of maintaining its integrity and preventing heat transfer to items on their "cool" side. Normally this is done by specifying a maximum cool side temperature during a test sequence. Standard fire tests can be used to define this criterion provided the test represents the actual on-site situation.

Different fire tests are available, such as BS 476 or UL 1709 to identify the capability of a material to withstand heat flux and insulate facilities on its "cool" side. It is important to ensure that the test method specified is directly relevant to the application. In the case of cellulosic material fires and hydrocarbon pool fires this is relatively straightforward as the tests do reproduce the temperature rise curves and heat fluxes of such fires.

However, in the case of jet fires, the effects on passive protection can vary considerably according to fuel type, flow rate and pressure. Therefore, standard jet fire tests can only be used as guidance and correlation with actual conditions or a specific test has to be used to assess performance. The document OT1 95-634 'Jet Fire Resistance Test of Passive Fire Protection Materials', published by the UK Health and Safety Executive describes a test that has become accepted as an assessment method for passive protection in this type of fire.

Other considerations for passive fire protection are: -

- **The time for which the passive protection maintains its integrity and its ability to prevent heat transfer to the desired level should be specified following the assessment of potential fire incidents and their duration.**

  For example, if the maximum fire duration is 90 minutes, the passive protection would typically be required to meet its performance criteria for insulation and integrity for a period in the order of 2 hours. Standard fire tests tend to test materials and certify them for 15, 30, 60 or 120 minutes. It is conceivable that passive protection may have multiple roles - e.g. to withstand a jet fire for 30 minutes and a pool fire for 60 minutes.

- **The ongoing capability of passive protection to achieve its insulating properties should be relevant to the lifetime of the facility.**

  Ongoing performance of passive protection will depend on a number of factors including exposure to physical damage and environmental conditions. It should be proven by long term exposure or fire test. Samples can be made at the time of installation and tested after specific durations such as 5, 10 or 20 years. Site conditions must be reviewed and relevant performance criteria established. Performance in these aspects is usually indicated by weathering tests, impact tests, elevated temperature trials, etc. Often it is necessary to review manufacturers data and check that the test methods used and results are directly relevant to the application.

- **In the case of vapourising liquids, such as LPG, resistance to initial cold and shock.**

5.6 Personnel response

All fire systems require some form of response in terms of operators and/or professional firefighters carrying out some actions during the time the system is operating or immediately after it. This response may be simply to check that the system is performing correctly and achieving its design intent or it could be more onerous. It is important to ensure that performance criteria are available and met for the responders. Critical functional parameters for personnel response include: -

- Availability of personnel
- Numbers of personnel
- Speed of response
- Competency/ongoing training

Considerations must be made of the following: -

- **Responder competency**

  This not only involves the formal technical capability of the responder but also his ongoing training and his access to and opportunity to train against preplanning procedural documentation on his response role to the scenario.

- **Protective clothing and equipment available to facilitate safe response**

- **Post incident procedures**

  In order to ensure that systems are allowed to perform their role it is necessary to provide, as part of the system documentation and responder training, the procedures to adopt after the system has been actuated. An obvious example of this could be the need to allow a gaseous agent system to "soak" for sufficient time to meet performance criteria prior to opening enclosure doors and thus releasing and reducing gas concentrations.

- **Ownership of response preplan**

  It is important to ensure that ownership of the preplan is firmly established so that responsibility for its maintenance is fully understood. It should also be recognised that a preplan should be regarded not purely as a firefighter response aide-memoire but also as one for an operator whose response roles may include initiating or confirming shutdown actions i.e. the preplan should ideally be an integrated document recognising both operator and fire responder actions.

- **Maintenance of personnel response**

  Whilst training of individuals in their role in response is important, it is essential also to have regular exercises to demonstrate the completeness of the response capability. In some parts of the world it is becoming a legal requirement to demonstrate this understanding and implementation of response capability by the holding of regular major incident exercises involving both process operator response and firefighter response.

6 Examination and testing fire systems

6.1 Introduction

It is an unfortunate fact that fire systems, because they make no direct contribution to ongoing production, often tend not to get tested as frequently as they should. Consequently, failures may go undetected for some time. Commissioning of systems to demonstrate that they meet their performance requirements when initially installed, and subsequent routine testing to check that they meet it on an ongoing basis, are essential, especially when the system is intended as a risk management measure for personnel safety.

Therefore a programme must be developed to carry out these tests, detailing the test procedures, the schedules and a record keeping system.

The test procedures should be based on ensuring that the critical performance criteria are met, and the schedules based on ensuring that any system problems will be identified within a reasonable time. Thus the procedures and schedules should reflect consideration of the reliability of system components and the levels of risk reduction that the system is designed to provide (i.e. a life safety critical system may require a more rigorous testing regime than a similar system designed purely for asset protection.) Any system testing should be relevant to the role of the system and either a direct measure of the functional performance standard or a measurement of a parameter which will demonstrate that the functional performance can be achieved.

If no other information is available, initial schedules may be based on manufacturers recommendations and codes of practice such as the NFPA document Fire Protection Systems - Inspection, Testing and Maintenance Manual.

6.2 Direct system testing

Clearly, it is not normally practicable to carry out actual fire tests on site or to simulate exact fire conditions that may be experienced for the identified hazards. The type of system and the design parameters should be confirmed by cross correlations to previous experience or research and development fire testing.

Direct system testing is the testing of the complete system including, where applicable, discharge of extinguishing agent. For example, with detection systems the hot wire test described earlier would be considered a direct system test in a computing or control room because it simulates the condition that the system in its entirety is designed to detect. Testing of individual smoke detector heads using an aerosol spray would not be direct testing, because aerosols do not reproduce actual smoke particle characteristics, and the method only tests an individual component and, possibly, the control panel, but not the ability of the entire system to achieve its performance criteria.

Direct testing of the complete system must be carried out at commissioning and at regular intervals if combinations of indirect tests are not sufficient to guarantee that the performance criteria continue to be met. The relative infrequency of direct tests may mean that the expertise required to carry it out and interpret it properly are not developed in-house.

In general, insufficient direct testing is carried out at facilities. There are many cases where direct testing of systems such as foam systems is not carried out on the excuse that clean up is a problem or the discharge causes corrosion or operational upsets. If such issues are genuinely a problem they should be addressed in performance criteria and the system design modified or system components chosen to minimise the problem. A schedule for direct testing should be developed during detail design.

6.3 Indirect system testing

Indirect system testing is the regular component testing that helps to demonstrate that the overall system is still likely to perform as designed. For example, simulating detector inputs into a control panel can be used to demonstrate that the panel will actuate the relevant alarms and executive actions. As much of the complete system should be tested as possible. For example, a deluge system fitted with a full flow test line should be tested by actuation of the relevant detectors, thus testing detectors, control logic, firewater pump start, ringmain integrity, pump capacity and deluge valve operation. With careful thought going into individual component testing and ensuring that all components are subjected to the testing regime, it may be possible to demonstrate system availability meets the relevant performance criteria with relatively large intervals between direct testing exercises. However, it is unlikely to do away completely with the need for direct testing.

6.4 Interpretation of results

The results of a direct test can, in theory, be relatively easily compared with performance criteria if sufficient thought has been put into the criteria and they include realistic quantified minimum performance data. If the system does not meet the criteria during the test, then remedial action is required. However, direct testing may require special skills or test equipment not normally available to in-house maintenance personnel. In the event that the system does not perform as required, then specialist expertise will probably be required to identify the cause of the problem. This is particularly true in the case of foam systems where any one of several faults can produce the same apparent foam quality failure, and a greater depth of interpretation may be required to identify the key problem.

The results of indirect testing require more analysis because they only demonstrate whether or not discrete parts of the system are functioning correctly. In fact, a testing regime that relies to a large extent on indirect system testing tends to demand a more rigorous and cumbersome record keeping system because the number of tests required to give adequate reassurance of overall system capability is greater.

Note: - The long term testing of passive fire protection is particularly difficult and manufacturers should be consulted to determine the parameters and indicators of system deterioration.

6.5 Impact on maintenance regime

Indirect testing is often the type of testing that is routinely carried out by a maintenance regime which can follow prescriptive procedures without having to have a full understanding of the system's performance criteria. For example, the functional aspects of a control panel can be tested under an instrumentation maintenance regime. Direct tests require a greater understanding of the performance criteria of the system and therefore specialist fire system knowledge is normally required. This, therefore, means that the competency of those persons carrying out the test work has to be appropriate and relevant.

A common solution to this issue is the use of an in-house maintenance department to carry out routine indirect tests, but the use of fire system specialists to carry out and interpret the less frequent direct tests. The direct tests therefore become as much a specialist inspection as a maintenance matter. If competent external specialists are used then this also results in an independent audit trail of system performance as required by legislation in some countries.

If this approach is used it is still important that a common, integrated test regime is developed and implemented. The most important element is that the people testing the system should be competent, understand the system, have, if necessary, specialist or vendor training and certification, and they must understand the role and importance of the system in hazard management. They should also understand the interface with other systems, such as shutdown. In many systems this will require an understanding of both mechanical and instrumentation aspects of system operation.

6.6 Exercises

As part of the integrated approach to system operation, the system testing of personnel response aspects should not be forgotten. To assess these it is normally necessary to develop and implement a programme of regular exercises simulating personnel response as well as system response to an incident.

This integrated approach needs clear identification of system ownership so that all aspects of system functionality assessment can be co-ordinated, and any lessons learnt or faults identified during tests and/or exercises carried through to audited remedial action.

7 Record keeping

As it is quite possible, as described in Section 6, that more than one department is involved in the testing and maintenance of fire systems, it is important to ensure that record keeping is co-ordinated by the system 'owner' and that personnel with full understanding of the system performance criteria review it on a regular basis and assess ongoing system capability.

7.1 Performance trends

For performance criteria it is often the case that a single value for a certain requirement is set at design stage. In fact, for operational purposes, a range of acceptable values should be set as described in Section 4.3 so that test results can be quickly accepted or rejected. Setting of the acceptable range normally requires input from system specialists having the ability to assess the effect on overall system performance of the change in value of particular parameters.

Performance trends can then be analysed and remedial action taken prior to the system performance moving outside of an acceptable range. In some cases it may only be possible to set the acceptable range of parameter values after initial commissioning and a set of base values have been measured. For example, with foam systems, the initial performance specification would include acceptable values for expansion and drainage time. During commissioning and acceptance trials these parameters would be measured. New tolerances could then be set, recognising tolerances in the base values which do not affect the overall system performance to an unacceptable level.

Any future test results falling within the tolerance range would then be acceptable but this does not mean to say that any drifts within the tolerable range should not be analysed in order to see if there is a trend that could lead to early failure.

Appendix 1
Guidance on system inspection/testing procedures, schedules and record keeping – a case history

The most appropriate method of demonstrating the principles of Fire Systems Integrity Assurance is to describe, in a summary form, an example of the process that was carried out in practice.

A major international oil company operating in the UK sector of the North Sea recognised that the procedures to assess ongoing performance of its helideck foam system were not adequate to demonstrate that the systems would perform as required. It should be remembered that the legislative regime involved demands risks to be ALARP and that an auditable track of the performance of safety critical systems is apparent. Helideck foam systems are seen as critical systems for life safety. Also, ICAO have a set of performance based standards which are generally considered to be the most appropriate available for this type of facility.

The production of a new platform gave the opportunity for the operator to develop improved performance criteria and integrity assurance procedures.

It must be recognised that the following example is one for a particular situation considered to be a very critical one. The example is given for guidance on principles only, not as a prescriptive recommendation for all foam systems or even, indeed, all helideck foam systems.

Risk assessment and selection of fire systems

Figure 2 summarises the procedure. The initial steps including review of potential scenarios and selection of fire systems were relatively straightforward as it is generally recognised from experience that the use of foam monitors by competent personnel is the most practicable method of providing appropriate risk reduction.

Set performance standards

The critical performance criteria for such a system are considered to be: -

- Foam concentrate quality
- Time to full operation
- Application rate of foam solution
- Produced foam quality
- Area covered by foam application
- Duration of system discharge

Appropriate values for these criteria have been established by ICAO and published in their series of codes of practice. As the operator considered that ICAO codes of practice were applicable to this situation and were based on sound specialist knowledge, they were adopted as the basis for the performance specifications.

Develop component specifications

It was recognised that in order to meet the critical performance criteria in a reliable and practicable way there was a need to provide detailed foam concentrate and hardware specifications including, in the case of the concentrate, the basis of a testing regime.

Foam concentrate is one of the most critical components of a foam system. To ensure that it is fit for purpose and continues to be so, it is necessary to specify a relevant fire test standard and physical property checks that can be used as indirect testing parameters "on site".

The performance specifications addressed the following issues: -

- Application for which concentrate was intended
- Fuel types involved
- Facility environmental conditions
- Legislative regime
- Containers to be used for delivery
- Container to be used for long term storage on site
- Type of proportioning system to be used
- Fire Test standard to be used (CAP 168 Level B as defined in ICAO documentation) (and witnessed independently)
- Physical property tests required

The supplier was required to provide the following:-

- Physical property test results and tolerance
- Physical property test methods
- Fire test results
- Proportioning rate correction factor (to allow indirect testing with water of the proportioning accuracy on a regular basis)

Figure 2 – Fire System Integrity Assurance example: helideck foam system

Process	Result/solution
Review potential fire incidents as part of Risk Assessment	Liquid spill fires with potential loss of life if not rapidly controlled
Define role required of fire systems in risk reduction	Rapid control of fire to allow safe evacuation or rescue of personnel
Select appropriate system types	Foam monitors operated by trained, competent personnel
Set performance standards	Relevant ICAO standards used as a basis for system performance in terms of time to operation, application rate and coverage
Develop component specifications	ICAO standards used for performance of foam concentrate. System operational experience used for hardware specifications
Develop test, inspection and maintenance procedures and schedules	Direct and indirect testing programme developed incorporating ICAO guidance and system specific procedures
Implement test, inspection and maintenance procedures and schedules	Training in system testing provided with guidance on perfomance trend acceptability. Specialist test programme developed including concentrate properties comparison against retained samples

For information, the physical property tests included:-

- Specific gravity
- pH
- Viscosity at 20°C and -15°C (the operating temperature range of the facility)
- Refractive index
- Film formation speed
- Surface tension
- Interfacial tension
- Spreading coefficient
- Sediment content

Some parameters were directly relevant to performance others indicative of changes occurring in the concentrate which could affect performance.

Similar levels of detail were specified for the hardware aspects of the system.

Develop test, inspection and maintenance programme

The acceptance of the foam concentrate included provision of some test data, the most important of which was the performance based fire test. This was carried through to a routine test programme as described later.

Performance based commissioning tests were carried out as follows:-

- Time to full operation
- Flow rate achieved
- Foam coverage under different wind conditions
- Foam quality and proportioning rate accuracy
- System run time

The opportunity was also taken to take measurements of other parameters which could be used as indirect test parameters allowing performance to be assessed on an ongoing basis without the need for foam discharge on every occasion.

These included:-

- Pressure at monitor outlet
- Proportioning rate calibration factor

Implement test, inspection and maintenance procedures

The programme developed for routine inspection included both direct and indirect testing.

The indirect testing included: -

- Daily movement of monitors and valves to check ease of operations
- Testing of concentrate physical properties and comparison against original values and tolerances on a quarterly basis
- Testing of proportioning accuracy on a weekly basis using water only and the calibration factor derived during commissioning
- Weekly confirmation of pressures achieved at monitors and time to achieve them
- 5 yearly fire test of foam concentrate

The direct system testing included:-

- Annual full system test, independently witnessed by specialists, to assess the critical performance criteria using actual discharge of foam

It was considered that this programme, coupled with daily visual equipment checks, represented a cost effective and environmentally acceptable method of ensuring the safety critical system met its critical performance criteria on a continuing basis. It is emphasised that this testing schedule was developed specifically for the system in hand. In this particular case, the foam concentrate proportioning system had been chosen to provide inherent reliability (such as no moving parts) and so annual testing was considered sufficient. Other types of system may require more rigorous testing schedules to meet availability/reliability requirements.

Full written test procedures were prepared along with guidance on acceptable/ unacceptable results. A documentation package was developed specifically for record keeping, as in this particular case it was considered that the inspection and testing would be carried out by system users rather than a maintenance department, with the maintenance department only becoming involved if repairs or modifications were required to the system following unacceptable test results.

Personnel competency standards

As well as system hardware performance criteria, competency standards were developed for two personnel involved in two aspects of the system: -

(i) System use

The competency requirements included system specific operation as well as helicopter incident fire fighting techniques.

(ii) Testing/maintenance

Competency profiles were developed for the personnel carrying out the routine on-site foam concentrate and routine system tests. In practice, the tests' procedures were very straightforward and the system 'operators' were also tasked with carrying out the tests.

The annual system test witnessed by an external specialist was also used as an opportunity for the specialist to review the system test results and re-assess competency levels of personnel carrying out the test and operating the systems. Regular refresher training was required in helicopter incident response techniques at specialised firefighting schools.

Commercial issues

While, at first sight, the performance specification process, the testing regime and the training requirements may appear onerous and therefore expensive, in reality the overall FSIA process resulted in an auditable track to clearly demonstrate ongoing compliance with regulatory requirements for safety critical systems. This facilitated rapid certification of the installation. The detailed performance based specification also assured reliability and lower maintenance costs.

Another interesting aspect of the whole programme of testing was the requirement for samples of the original foam concentrate to be retained by both manufacturer and facility with permanent labelling showing the physical property values and acceptable drifts. Part of the commercial requirements included as part of the performance specifications was a long term (20 year) guarantee. The retained samples were for use in the event of unacceptable changes in the physical properties of the concentrate. They would be used to help assess whether the deterioration was caused by contamination or misuse at the facility, or if it was caused by general degradation of the product, which would be the responsibility of the supplier.

The well-documented and thorough FSIA process clearly demonstrated the potential commercial value of such a process as well as its contribution to risk reduction.

Appendix 2
Cost benefit analysis equations

A risk reduction option is cost beneficial if:

$$\{(C_{without} \times \gamma_{without}) - (C_{with} \times \gamma_{with})\} \times Pr_{control} > \textit{cost of implementation}$$

where:

$C_{without}$	=	*expected cost of incident without option in place*
C_{with}	=	*expected cost of incident with option in place*
$\gamma_{without}$	=	*expected statistical frequency of the initiating event if option is not implemented*
γ_{with}	=	*expected statistical frequency of the initiating event if option is implemented*
$Pr_{control}$	=	*probability that option will perform as required*

Incident cost elements may include:

- *life safety*
- *environmental damage*
- *asset value*
- *downtime*
- *public image*
- *legislative repercussions*
- *insurance repercussions*

A simplified equation for a mitigation measure is as follows:

A fire hazard management measure is cost effective if:

$$(C_{without} - C_{with}) \times F_i \times P_c > C_{fhm}$$

where:

$C_{without}$	=	*cost of incident without measure*
C_{with}	=	*cost of incident with measure*
F_i	=	*statistical frequency of incident*
P_c	=	*probability of control*
C_{fhm}	=	*cost of measure (Capex and Opex)*

Appendix 3
Reference documents and contact addresses

Reference documents

BFPSA

Code of Practice for Category 1 Aspirating Detection Systems

BFPSA

Code of Practice for Gaseous Fire Fighting Systems

BS 476

Fire Tests on Building Materials and Structures

BS 6266

Code of Practice for Fire Protection of Electronic Data Processing Distillations

EN 54

Fire Detection and Fire Alarm Systems

Health & Safety Executive (UK)

Jet Fire Resistance Test of Passive Fire Protection Materials (OTI 95-634)

Health and Safety Executive (UK)

Prevention of Fire and Explosion and Emergency Response on Offshore Installations

ICAO CAP 168

Licensing of Aerodromes

ICAO CAP 437

Offshore Helicopter Landing Areas

IEC 1508

Guidance on Functional Safety; Safety Related Systems

ISO 7203 - 1

Fire Extinguishing Media - Foam Concentrates

ISO 13702

Control and Mitigation of Fire and Explosions on Offshore Installations

ISO 61508

Functional Safety of Electrical/Electronic/ Programmable Electronic Safety Related Systems

LASTFIRE

A Study into the Risks Associated with Large Open Top Floating Roof Storage Tanks

NFPA 11

Foam Systems

NFPA 15

Waterspray Fixed Systems

NFPA 20

Fire Water Pumps

NFPA 750

Water Mist Fire Protection Systems

NFPA 2001

Clean Agent Systems

NFPA

Fire Protection Systems - Inspection, Testing and Maintenance Manual

OGP

Guidelines for the Development and Application of Health, Safety and Environmental Management Systems (Report No. 6.36/210)

OGP

Incipient Fire Detection (Report No. 6.75/284)

OGP

Inert Gas Extinguishing Agents (Report No. 6.60/259)

Sintef

Handbook for Fire Calculations and Fire Risk Assessment in the Process Industry.

UKOOA

Guidelines for Fire and Explosion Hazard Management

UL 162

Testing of Foam Concentrates

Contact addresses for reference documents

BFPSA

British Fire Protection System Association
48A Eden Street
Kingston Upon Thames
Surrey
KT1 1EE
United Kingdom
Phone: 0208 549 5855
Fax: 0208 547 1564

British Standards
(also for EN and ISO documents)

British Standards Institute
389 Chiswick High Road
London W4 4BR
United Kingdom
Phone: 0208 996 9001
Fax: 0208 996 7001

Health and Safety Executive (UK)

HMSO Publications Centre
PO Box 276
London SW8 5DT
United Kingdom
Phone: 0207 873 0011
Fax: 0207 873 8200

ICAO

Civil Aviation Authority
Greville House
37, Grafton Road
Cheltenham
Glos.
GL50 2B
United Kingdom
Phone: 0242 235151
Fax: 0242 584139

LASTFIRE

Resource Protection International
Suite 6,
Lloyd Berkeley Place, Pebble Lane
Aylesbury,
Bucks. HP20 2JH
United Kingdom
Phone: 01296 399311
Fax: 01296 395669

NFPA

National Fire Protection Association
1 Batterymarch Park
PO Box 9101
Quincy
MA 02269 - 9904
USA
Phone: 617 984 7880
Fax: 508 895 8301

OGP

International Association of
Oil & Gas Producers
25/28 Old Burlington Street
London W1X 1LB
United Kingdom
Phone: 0207 292 0600
Fax: 0207 434 3721

Sintef

Scandpower A/S
PO Box 3
N-2007 Kjeller
Norway
Phone: 0681 4920
Fax: 0681 8822

UKOOA

United Kingdom Offshore
Operators Association
1st Floor
30 Buckingham Gate
London
SW1 6NN
United Kingdom
Phone: 0207 802 2400
Fax: 0207 802 2401

UL

Underwriters Laboratories
333 Pfingsten Road
Northbrook
Illinois 60062 - 2096
USA
Phone: 708 272 8800
Fax 708 272 8129

Appendix 4
Abbreviations

ALARP

As Low As Reasonably Practicable

BFPSA

British Fire Protection Systems Association

BS

British Standards

CBA

Cost Benefit Analysis

CBRA

Cost Benefit Risk Assessment

EN

European Norm

FHM

Fire Hazard Management

FRA

Fire Risk Assessment

FSIA

Fire System Integrity Assurance

HSE

Health, Safety and Environment

ICAO

International Civil Aviation Organisation

IEC

International Electrotechnical Commission

ISO

International Standards Organisation

LASTFIRE

Large Atmospheric Storage Tank Fires

NFPA

National Fire Protection Association

OGP

International Association of Oil and Gas Producers

PFEER

Prevention of Fire and Explosion and Emergency Response

UKOOA

United Kingdom Offshore Operators Association

UL

Underwriters' Laboratories

What is OGP?

The International Association of Oil & Gas Producers encompasses the world's leading private and state-owned oil & gas companies, their national and regional associations, and major upstream contractors and suppliers.

Vision

- To work on behalf of all the world's upstream companies to promote responsible and profitable operations.

Mission

- To represent the interests of the upstream industry to international regulatory and legislative bodies.
- To achieve continuous improvement in safety, health and environmental performance and in the engineering and operation of upstream ventures.
- To promote awareness of Corporate Social Responsibility issues within the industry and among stakeholders.

Objectives

- To improve understanding of the upstream oil and gas industry, its achievements and challenges and its views on pertinent issues.
- To encourage international regulators and other parties to take account of the industry's views in developing proposals that are effective and workable.
- To become a more visible, accessible and effective source of information about the global industry, both externally and within member organisations.
- To develop and disseminate best practices in safety, health and environmental performance and the engineering and operation of upstream ventures.
- To improve the collection, analysis and dissemination of safety, health and environmental performance data.
- To provide a forum for sharing experience and debating emerging issues.
- To enhance the industry's ability to influence by increasing the size and diversity of the membership.
- To liaise with other industry associations to ensure consistent and effective approaches to common issues.

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