MANUAL

WATER-BASED FIRE PROTECTION SYSTEMS FOR OFFSHORE FACILITIES

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DESIGN AND ENGINEERING PRACTICE

PREFACE

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The objective is to set the recommended standard for good design and engineering practice applied by Group companies operating an oil refinery, gas handling installation, chemical plant, oil and gas production facility, or any other such facility, and thereby to achieve maximum technical and economic benefit from standardization.

The information set forth in these publications is provided to users for their consideration and decision to implement. This is of particular importance where DEPs may not cover every requirement or diversity of condition at each locality. The system of DEPs is expected to be sufficiently flexible to allow individual operating companies to adapt the information set forth in DEPs to their own environment and requirements.

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APPENDICES

1. INTRODUCTION

1.1 SCOPE

This new DEP specifies requirements and gives recommendations for the use of water-based fire systems on offshore facilities. It is based on the International Standard ISO/DIS 13702 which should be referenced for further guidance. The DEP includes details on all main elements of a firewater system including firewater pumps, the firewater main system, deluge systems, sprinkler systems, foam systems, water mist systems and ancillary items (monitors, hydrants, etc.). The document assumes the reader has some knowledge of firewater systems design.

The requirements for fire protection are detailed in the Fire and Explosion Strategy (FES) developed during the process of evaluation and risk management within the Hazards and Effects Management Process (HEMP).

This DEP gives guidance on the design of firewater system elements and where prescriptive rules are laid down they represent the best current practice at the time of publication, which could change. This is particularly applicable to new technology developments in firewater mist sprays and the use of deluge systems in explosion suppression. If compliance with the prescriptive rules causes problems, then discussions should be held within the project.

This DEP is applicable to a very wide range of offshore facilities operating in different environments, from simple unmanned structures which may not justify firewater systems to complex platforms where there are many personnel present at all times and a firewater system may have a major role as a life-saving measure.

The decision to use a particular type of firewater system element should be based on the FES rather than information provided in design codes of practice. Industry standards such as National Fire Protection Association (NFPA) codes tend to relate to specific elements of firewater systems. They do not normally give guidance on the overall firewater system as defined here. Such documents may, however, give useful design guidance once a particular firewater system element has been selected on the basis of the hazard assessment.

1.2 DISTRIBUTION, INTENDED USE AND REGULATORY CONSIDERATIONS

Unless otherwise authorised by SIOP and SIEP, the distribution of this DEP is confined to companies forming part of the Royal Dutch/Shell Group or managed by a Group company, and to Contractors and Manufacturers/Suppliers nominated by them (i.e. the distribution code is "F", as defined in DEP 00.00.05.05-Gen.).

This DEP is intended for use in offshore exploration and production facilities.

If national and/or local regulations exist in which some of the requirements may be more stringent than in this DEP, the Contractor shall determine by careful scrutiny which of the requirements are the more stringent and which combination of requirements will be acceptable as regards safety, environmental, economic and legal aspects. In all cases, the Contractor shall inform the Principal of any deviation from the requirements of this DEP which is considered to be necessary in order to comply with national and/or local regulations. The Principal may then negotiate with the Authorities concerned with the object of obtaining agreement to follow this DEP as closely as possible.

1.3 DEFINITIONS

1.3.1 General definitions

The **Contractor** is the party which carries out all or part of the design, procurement, construction, commissioning or management of a project, or operation or maintenance of a facility. The Principal may undertake all or part of duties of the Contractor.

The **Manufacturer/Supplier** is the party which manufactures or supplies equipment and services to perform the duties supplied by the Contractor.

The **Principal** is the party which initiates the project and ultimately pays for its design and construction. The Principal will generally specify the technical requirements. The Principal may include an agent or consultant authorised to act for, and on behalf of, the Principal.

The word **shall** indicates a requirement.

The word **should** indicates a recommendation.

1.3.2 Specific definitions

Active Fire Protection	-	The equipment, systems and methods which, may be used to fight a fire once it has started.
Area Protection	-	Fire protection aimed at covering a complete area rather than specific items or equipment.
Discharge elements	-	Those elements of the overall firewater system that discharge water into a fire-affected area (e.g. deluge systems, sprinkler systems).
Emergency Response Personnel	-	Those personnel who have a designated response role in an emergency.
Equipment Protection	-	Fire protection aimed at specific items or equipment rather than a complete area.
Fire and Explosion Strategy	-	The process that uses an assessment of the hazards of fires and explosions to determine the measures required to manage such hazardous events.
Fire and Gas Panel	-	The control panel at a Central Control Point monitoring and controlling signals from all field detection and protection systems.
Jet fire	-	An ignited release of pressurised, flammable fluid.
Passive Fire Protection	-	A coating, cladding arrangement or free-standing system which in the event of a fire will provide thermal protection to restrict the rate at which heat is transmitted to the object or area being protected.
Pool fire (Spill fire)	-	Combustion of flammable liquid spilled and retained on a surface.

1.4 ABBREVIATIONS

AFFF	-	Aqueous Film Forming Foam
AFP	-	Active Fire Protection
BLEVE	-	Boiling Liquid Expanding Vapour Explosion
BOP	-	Blow-out Preventer
CAA	-	Civil Aviation Authority
EER	-	Evacuation, Escape and Rescue
ESD	-	Emergency Shutdown
ESSA	-	Emergency Systems Survivability Analyses
FES	-	Fire and Explosion Strategy
FFFP	-	Film Forming Fluoroprotein
FGP	-	Fire and Gas Panel
HEMP	-	Hazards and Effects Management Process
HLO	-	Helicopter Landing Officer
HSE	-	Health, Safety and the Environment

HV	-	High Voltage
HVAC	-	Heating, Ventilation and Air Conditioning
LAT	-	Lowest Astronomical Tide
ILBP	-	In-line Balanced Pressure Proportioning
MOPO	-	Manual Of Permitted Operations
NDE	-	Non-Destructive Examination
NUI	-	Normally Unmanned Installation
PEFS	-	Process Engineering Flow Scheme
PFP	-	Passive Fire Protection
P&ID	-	Process and Instrument Diagram
QRA	-	Quantitative Risk Assessment
TR	-	Temporary Refuge

1.5 CROSS-REFERENCES

Where cross-references to other parts of this DEP are made, the referenced section number is shown in brackets. Other documents referenced by this DEP are listed in (13).

2. HAZARDS AND EFFECTS MANAGEMENT PROCESS (HEMP)

2.1 INTRODUCTION

All companies associated with the offshore oil and gas industry shall have an effective management system which addresses the health, safety and environmental (HSE) issues that are relevant to its activities. A key element is a process of evaluation and risk management, called in Shell the Hazards and Effects Management Process (HEMP). This process is described in general in EP 95-0100 with more detailed information given in EP 95-0300. Guidance on fire control and recovery is given in EP 95-0351.

2.2 FIRE AND EXPLOSION STRATEGY

The results of the evaluation process and the decisions taken with respect to the management of fires and explosions are recorded in a FES which summarises the key aspects of the hazardous events, the associated risks, measures to minimise the consequences and measures to prevent fires and explosions arising. The measures required may include elements detailed in (3) and (4).

The level of detail in the FES will vary depending on the scale and complexity of the offshore facility and the stage in the offshore facility's life-cycle when the risk management process is undertaken.

The FES should also describe the role and essential elements (or Performance Criteria, see 2.4) for each of the systems required to manage possible hazardous events on the offshore facility.

2.3 THE ROLE OF FIREWATER SYSTEMS

A number of different systems might be considered as part of the FES to reduce the risk of a fire or explosion. Firewater systems are one such system in the category Active Fire Protection (AFP). They are usually operated only after the initial hazardous event (e.g. hydrocarbon liquid release) and ignition have occurred. They are intended to mitigate the consequences of the event by extinguishing or limiting the spread of fire. Therefore they must be regarded as a **recovery** measure within the FES and so should only be put in place after it is shown that **control** measures cannot reduce risk to a tolerable level and one which is as low as reasonably practicable.

In addition, it should be recognised that other recovery measures such as shut-down, inventory control, plant layout, drainage, Passive Fire Protection or other AFP measures (extinguishers, carbon dioxide systems etc.) may be more appropriate than water-based systems to reduce risk levels. AFP, in general, because of the inherent maintenance requirements and reliability issues, should be regarded as one of the last "lines of defence" of recovery rather than the "first".

The purposes of installing AFP systems on offshore facilities include the following:

- to protect personnel at a Temporary Refuge (TR);
- to minimise fire damage and thus enable the facility to return to operational status as soon as possible after a fire;
- to minimise escalation, which could lead to widespread damage and pollution of the environment;
- to meet legislative or other mandatory requirements.

Water can reduce the potential risk from fire by:

- extinguishing or reducing fire intensity by:
  - cooling of solid combustible material fires or high-flashpoint liquids;
  - excluding oxygen (air) when water is converted to steam in the fire area;
  - excluding oxygen (air) if water is applied as foam to liquid spill fires.
- cooling smoke, flame and hot gases to limit the spread of fire by convection;
- cooling adjacent structures or facilities to prevent fire spread by radiation effects and thus maintain integrity;
- forming a heat absorbing barrier between a fire and facilities, including escape routes, outside the fire area.

2.4 PERFORMANCE CRITERIA

Performance Criteria record the essential features of the measures selected on a particular offshore facility to manage major accidents and any events requiring Evacuation, Escape and Rescue (EER). They provide the basis for monitoring the actual status of the measures throughout the life of the offshore facility.

In order to simplify the development of facility-specific Performance Criteria, templates for firewater-based systems are provided in (Appendix 1) as examples.

2.5 INTERDEPENDENCE WITH OTHER SYSTEMS

In order to make firewater systems more effective, it is sometimes necessary to have other systems or features in place. Typically these may include:

- Shut-down, isolation and blow-down to minimise fuel inventories.
- Ventilation shut-down to prevent removal of atmospheres with reduced oxygen levels (due to consumption of oxygen by the fire or due to steam formation).
- Power-down to reduce risk of electric shock problems, short-circuiting etc. and to remove a potential ignition/re-ignition source.
- Fire and Gas Detection and Control Panel logic including audible and visual alarms.
- Drainage and containment systems to remove product and firewater and/or contain it in one place so that the fire does not spread to other areas.
- Passive Fire Protection measures to contain an incident.

3. FIREWATER SYSTEMS

3.1 DESIGN GOALS

Goal 1: To satisfy the Performance Criteria.

Goal 2: To fulfil their functions during normal operations, maintenance and repair with sufficient reliability and availability.

Goal 3: To be capable of operation under the emergency conditions that may be present when the system is called upon to operate.

Goal 4: To be suitable for their operating environment throughout the required design life.

Goal 5: To be capable of being operated easily, safely and effectively.

Goal 6: To be capable of rapid reinstatement after operation and testing.

Goal 7: To allow easy demonstration of compliance with the Performance Criteria.

Goal 8: To provide sufficient documentation to facilitate safe operation, maintenance, testing, inspection and commissioning of firewater systems.

Goal 9: To provide facilities at a Central Control Point to allow persons to monitor the status of and initiate automatic firewater systems.

Goal 10: To provide adequate drainage within any area where firewater may be discharged to prevent escalation of a fire by carry-over of flammable liquid to adjacent areas.

3.2 SYSTEM OVERVIEW

3.2.1 Elements of firewater systems

Figures 1 and 2 show the different elements that make up a firewater system. Design guidance on specific elements is included in (Sections 4 through 11).

For any given fire scenario, it may be necessary to operate more than one water-based recovery system simultaneously. For example, it may be necessary to operate a foam system to extinguish a contained spill fire while simultaneously operating deluge systems to cool adjacent structures and also to have manually controlled hose lines available for system back-up. Therefore, in developing the FES it is necessary to determine those systems which may be required to operate simultaneously. Certain elements of the firewater system (supply source, pumps and firewater main) are common to all other elements (such as deluge systems).

Thus individual elements may have different availability requirements (see 3.2.2).

3.2.2 Overall system requirements

The justification for provision of a firewater system shall be based upon a formal hazard assessment, as documented in the FES.

The Performance Criteria for each individual firewater system element shall be defined.

Application rates of water and/or foam solution shall be sufficient to meet the functional Performance Criteria.

The firewater system shall be such that when more than one element of it may be required to operate simultaneously, the goals of each operating element shall be met.

The availability of all elements of the firewater system shall be maximised as far as is reasonably practicable.

Equipment specifications including materials of construction shall take into account the operating environment of the firewater system and design life.

Firewater element design shall consider drainage requirements from any discharge area to ensure that the drains are adequate and appropriate.

Firewater shall not be discharged into areas containing significant quantities of water-reactive materials.

3.2.3 Overall system guidance

3.2.3.1 Design intent

As part of the hazard assessment a FES should be developed to justify the need for a water-based active fire protection system. Having established the need for a water-based system, its design intent can be specified. Guidance on the capabilities and limitations of the different systems available is included in (Sections 4-11).

An assessment of the escalation potential within and beyond each fire area should also form part of the hazard assessment.

The results of this assessment should be used to develop the Performance Criteria for the various elements of the firewater system.

Additional guidance on scenario development and assessment of hazardous event recovery measures is provided in EP 95-0300, EP 95-0350 and EP 95-0351.

The design intent for elements that discharge water or foam should include:

- Element purpose: extinguishing, control etc.
- Fire description: type (jet, pool, etc.); size; duration; intensity; over-pressures from any associated explosion.

From this information, detailed performance requirements and specifications for the individual discharge elements can be prepared (Sections 4-11). Application rates of water or foam solution can then be determined either by experiment or from relevant proven data. In the absence of such information, recognised codes of practice such as NFPA can be used provided it is shown that the application rates applied are relevant to the fire scenario.

3.2.3.2 Firewater demand

The Performance Criteria for the firewater pumps and the firewater main should be based on two scenarios as follows:

- **The design firewater demand;** this is the largest firewater demand for a single fire event and should take into account:
  - any requirements for personnel protection during escape and evacuation;
  - the demand of all firewater systems which are likely to be initiated by the initial fire incident;
  - requirements for manual fire-fighting by personnel with hose lines, monitors etc. (e.g. to provide boundary cooling);
  - any firewater requirements for essential users (e.g. drilling make-safe and generator cooling).
- **The maximum reasonably foreseeable firewater demand;** this should **also** take into account:
  - possible escalation to other fire areas (e.g. due to external flaming or due to failure of a fire barrier as a result of an explosion);
  - release of protection systems covering other areas (e.g. due to an explosion or external flaming being detected by flame detectors in other areas);
  - possible manual initiation of additional water-based protection systems or equipment to protect nearby equipment and facilities.

The firewater system should be capable, at its design conditions and integrity, of meeting the design firewater demand. However, the maximum reasonably foreseeable firewater demand may be met by allowing the firewater pumps to run-out beyond their duty point and making use of all sources of firewater which are likely to be available in the emergency.

The purpose of defining a design firewater demand and maximum foreseeable firewater demand is to provide a basis for sizing, but not excessively over-sizing, the firewater pumps (see Section 4) to enable firewater to be used effectively in fire scenarios involving explosions or escalation. The usual underlying philosophy is that the duty point of firewater pump systems is designed to deal with fire incidents which are not preceded by explosions. Firewater systems are likely to have a useful role following an explosion but such an event should not normally dictate the duty point of the firewater pumps.

The above procedure for determining firewater demands applies to both enclosed and naturally ventilated areas. However, for naturally ventilated areas the fire area should be taken as the largest area likely to be affected by a single fire emergency. That area may be one level of an integrated deck because of the likelihood of fire detectors throughout the same level reacting to the fire.

If the firewater demand for such fire area(s) cannot be satisfied, additional physical separation of the decks and/or adjacent compartments can be employed or additional firewater pumping capacity made available. However, if barriers are provided as a means to achieve segregation or prevent the unnecessary simultaneous operation of firewater system elements in adjacent areas, such barriers should not impede the free natural ventilation of the areas nor result in unacceptable explosion over-pressures.

For existing offshore facilities, it may not be reasonably practical to increase the supply of firewater or provide additional physical separation in order to deal with the maximum foreseeable firewater demand. All cases where there may be limited firewater cover should be identified and the impact of these on the offshore facility’s emergency procedures should be considered so that any resultant actions to be taken by Emergency Response personnel can be included in the installation Emergency Response Plan.

If the hazard assessment on an offshore facility indicates that there is no need to provide a water application system, but recommends the provision of hydrants and/or monitors, the possible use of the service water facilities should be investigated. The largest firewater demand in this instance should be based on the numbers of the monitors and hydrants that will be brought into simultaneous operation.

3.2.3.3 Drains

Firewater discharge rates required can be large. Drains should be sized to allow for the flows applied or containment should be such that the water and any other spilled liquids do not spread to other areas. Drains should be designed to prevent fire spread if burning liquids are carried into them by water-based fire systems.

3.2.3.4 Operating environment

The selection of materials for pipework or other firewater system components should take into account the operating environment which is normally highly saline and often has extremes of temperature and humidity. On offshore facilities where temperatures drop below 0 °C and permanently filled firewater system elements are provided, the routing of pipework should be such as to minimise exposure to freezing conditions. Specific measures may be required to eliminate the possible freezing of exposed pipework. The firewater main temperature should be monitored non-intrusively at any exposed locations likely to freeze.

Facilities for injecting additives (chemical or biological) to inhibit corrosion and marine growth within the firewater system should be provided. Any additives may affect foam production and should be checked with the manufacturer. Operation of the flushing system also needs to be considered.

3.2.3.5 Location

The firewater system components should be located so as to minimise the probability of mechanical damage by dropped objects, swung loads, explosion venting, etc.

3.2.3.6 Surge problems

Surge pressures can be induced in a firewater system element by the following causes:

- Starting and stopping the firewater pumps.
- Operation of a firewater system discharge element.
- Closing a firewater system discharge element.
- Failure of a first fire pump to start, resulting in a delay which allows the fire main to drain before a stand-by pump starts.
- Starting the firewater pump against a non-pressurised fire main.

Surge pressures are dependent on:

- Firewater pump characteristics, i.e. run-up time and head generated.
- System design, i.e. length of piping, location of elbows and bends, etc.
- Valve type and location.
- Time of opening and closing of main system valves.

To reduce the effects of surge on the system, a surge study should be conducted upon completion of the firewater main isometric drawings. Corrective measures should be applied to protect the system against surge pressures that are greatly in excess of the system design pressure (see 4.3.2.8).

3.2.3.7 Strainers

To prevent blockage of system elements or components it is normal practice to include strainers in the pump suction line, but it may also be necessary to provide strainers at the inlet to individual system elements.

3.2.3.8 Materials

All water distribution pipework should be designed and constructed from materials suitable for the duty. In addition:

- pipework less than 25 mm nominal diameter should not be used;
- the design velocity should not exceed 10 metres/second;

- pipework should have adequate flanged joints to allow internal inspection.

Materials should be selected that are inherently corrosion-resistant. These may include glass-fibre reinforced epoxy (GRE) and glass-fibre reinforced thermosetting plastic (GRP), as detailed in DEP 31.38.70.24-Gen.

If materials of construction are not specified, the design Contractor should submit proposals for approval by the relevant approval authority.

Piping classes should be selected from DEP 31.38.01.15-Gen.

3.3 OPERATION, CONTROL AND MONITORING

3.3.1 Mode of operation

3.3.1.1 Requirements

All firewater system elements shall be clearly marked with operating instructions easily understood by those required to use them.

All actuation devices or equipment requiring manual initiation or deployment shall be easily accessible and located outside or away from the protected area so that an operator can actuate the systems safely when required.

For manually initiated discharge elements, the time delay before they are actuated and become operational shall not affect their ability to fulfil their intended functions.

For automatically initiated discharge elements, a manual release station which does not rely on the integrity of electrical or pneumatic signals shall also be provided.

Any prior actions required for systems to be effective, such as power or ventilation shut-down, shall be incorporated in the system logic cycle.

3.3.1.2 Guidance

The mode of operation of any firewater system discharge element can be either manual or automatic, triggered by a signal from, for example, a fire detection system.

The means of actuation selected will depend on the time delay acceptable. In general, the faster a discharge element is actuated, the lower the probability of incident escalation. Automatic systems are faster to actuate than manual systems. In addition, the length and size of lines between water source and discharge elements will affect the effective response time.

Automatic systems may be more prone to spurious discharge which, particularly in the case of discharge onto electrical equipment, can cause considerable damage. The FES should therefore address the need for automatic actuation and the consequences in terms of escalation if such automatic actuation or other automatic actions are not provided. In the case of automatic systems, the speed of response should be considered when selecting the most appropriate detection system.

Discharge of water onto live electrical equipment can cause severe equipment damage and provide an electric shock hazard. Energised HV electrical equipment should therefore be isolated prior to any system discharge or designed to prevent water ingress under discharge conditions.

Water-based systems should not be actuated by the detection of gas in the protected area since they may create a potential ignition source by wetting electrical fittings and equipment.

The role of deluge systems in explosion mitigation is discussed in Section (11).

3.3.2 Alarm and annunciation

3.3.2.1 Requirements

The status of all automatic firewater system elements shall be indicated at the Central Control Point. Actuation of an alarm for one system shall not prevent other alarm and annunciation signals.

3.3.2.2 Guidance

All instrumentation associated with the firewater system should interface with the Fire and Gas Panel (FGP). The main objective should be for the discharge of any system and the initiation of actions to be confirmed on the FGP. This should also apply if a system is locally actuated.

Normally, with water-based systems a specific pre-discharge alarm to allow personnel to evacuate an area prior to discharge is not necessary.

As a minimum, the annunciations at the Central Control Point should include the following for discharge systems:

- System Operable;
- System Actuator Fault (e.g. monitoring lines to solenoid valves in actuating systems);
- System actuated;
- System discharged.

3.3.3 Shut-down and reset

3.3.3.1 Requirements

All firewater system elements shall be such that they can be shut down and reset into a fully operable condition as soon as is practicable after the incident.

Automatic shut-down of a system shall not be permitted unless it can be shown that leaving the system running could give rise to a greater risk than shutting it down.

Formal procedures shall be in place for manual response after a system has discharged and for resetting.

System Operable annunciation shall not be possible unless all components are reset.

3.3.3.2 Guidance

Normally only the manual shut-down of an AFP system should be allowed following visual inspection of the incident area to ensure that it is safe to do so.

In some cases automatic shut-down of an AFP system may be allowed if the risk is greater if the system was not shut down (for example, if continued operation of the system could lead to flammable liquids being spread to other areas by the firewater).

The following factors should be considered prior to deciding if automatic shut-down is appropriate:

- Will significant damage to equipment occur if the system is not shut down (e.g. hot machinery, electrical equipment)?
- Will drainage from the area be such that fire spread will occur unless the system is shut down? (e.g. carry-over of hydrocarbon liquid to other areas by firewater due to insufficient containment.)

3.3.4 Emergency response

3.3.4.1 Guidance

A post-discharge emergency response procedure is normally required (as and when it can be conducted safely) to ensure that the system has operated correctly. The formal response procedure should evaluate:

- Safety of personnel;
- Additional shut-down actions required (although shut-down actions in major fires should normally be automatic);
- Back-up fire-fighting equipment required;
- Special equipment required (e.g. gas detection, breathing apparatus);
- Training levels and schedules required including schedules of drills.

Prior to start-up of the offshore facility following a firewater system discharge, electrical equipment that has been within the discharge area should be closely inspected.

Formal training programmes should be in place for all personnel who may be required to operate hydrants or other fire-fighting equipment. The training should include alarm procedures prior to deploying equipment, identification of types and extents of fires that can be attacked with the equipment, the limitations of the equipment fire-fighting strategy and tactics.

3.4 INSTALLATION, INSPECTION, TESTING, COMMISSIONING AND MAINTENANCE

3.4.1 General requirements

The objectives, functional requirements and frequencies of inspection and maintenance shall be determined according to the specific equipment types chosen.

All firewater system components shall carry certification from a recognised relevant approval authority or the Manufacturer/Supplier shall demonstrate that the components have satisfactory performance.

3.4.2 Inspection requirements

All equipment shall be subject to inspection in accordance with project requirements unless this is waived in writing.

Any rejection made by inspectors will be final. However, such inspection shall in no way release the Manufacturer/Supplier from the guarantees covering materials, apparatus and performance of the equipment supplied.

The Principal and/or his authorised inspection agents shall have access to all parts of the Manufacturer/Supplier's works where the equipment is produced or tested. The Manufacturer/Supplier shall provide the inspector with all reasonable facilities to witness tests and to satisfy himself that the materials are being furnished in accordance with this DEP and other relevant documents, and that the workmanship is satisfactory in every respect.

Records of all quality procedures, inspections and tests shall be retained and made available to the Principal and/or his authorised inspection agents as required.

Quality assurance shall comply with specific project requirements.

3.4.3 Acceptance testing and commissioning requirements

Specifications and checklists for the acceptance testing and commissioning of the firewater system and its components shall be prepared. Pre-commissioning checks shall be carried out using the checklists.

All pipework shall be hydrostatically tested in accordance with the project's piping specification. The test pressure and temperature shall be recorded on charts with the starting and completion times noted and signed by the Principal.

Pipework shall be flushed out with clean water and shown to be clear of foreign matter prior to commissioning. After testing it must be demonstrated that all pipework is free from obstruction and test blanks removed.

When testing an installed system the hydrostatic pressure shall be measured at the lowest point of the system being tested. If this is impracticable the recorded pressure should be adjusted and recorded as such. During hydraulic testing, instruments must be removed to prevent damage from excess pressure.

Block valves shall be tested in accordance with project requirements immediately following the system hydraulic test. A test of the valve seats shall be included.

If test blanks are used these should be of the self-indicating type to indicate clearly their presence and should be numbered and their position recorded on the Permit to Work. A final check should be made to ensure that the blanks have been removed prior to closing out the Permit to Work.

If pipework is pneumatically tested, such a test shall be in accordance with the project specifications and full safety procedures undertaken including the display of warning signs.

Full-flow operational tests, including response times for all firewater system elements and pressure measurements, shall be undertaken. Adjustments shall be made to ensure that the elements can cope with expected surges (pump start-up time/closure of overboard dump valve).

Correct annunciation of the alarms at the Fire and Gas Panel and correct operation of all system trip switches, etc. shall be verified.

After testing it shall be ensured that all valves are in the normal operating position and that drain valves are closed.

3.4.4 Maintenance requirements

Deviations from the Manufacturer/Supplier's maintenance and testing procedures shall only be permitted if they do not affect the Performance Criteria for the system. Any such deviations shall be based on a risk-based analysis of maintenance requirements and agreed by the appropriate authority in the Principal's organisation.

Any special tools necessary to assemble, service or dismantle the equipment shall be supplied by the Manufacturer/Supplier as part of the purchase order.

3.4.5 Guidance

Fire-fighting systems require routine maintenance and testing to ensure that the system and its components are in good operating condition.

The Manufacturer/Supplier should supply all the information necessary to enable the equipment to be maintained in good condition. This should include the recommendations for the operating spares to be held, the frequency with which the equipment is to be examined and the procedures to be used to ensure that the equipment is always available for immediate use.

Further guidance on the maintenance of fire-fighting systems is given in NFPA 25 and in the specific NFPA codes relevant to individual firewater system elements.

An example of a checklist for commissioning and routine testing is given in (Appendix 2).

3.5 DRAWINGS AND DOCUMENTATION

3.5.1 Requirements

Drawings, test reports, certificates, quality plan, spare parts data, manuals and all other necessary documentation shall conform to the project requirements.

All appropriate drawings shall contain an arrow indicating the direction of North (a plant North arrow) and a Key drawing showing the location of the area in question.

As-built drawings shall be based on a survey of the completed work.

Hydraulic calculations shall be carried out for all firewater system pipework and discharge systems using a validated and recognised computer program.

Hydraulic calculations shall be based on composite pipework isometric drawings. Isometric drawings shall give all installed pipe lengths, fittings and diameters, and service take-off details. Each pipework intersection point shall be identified as a node point on the isometric drawing. The node number shall be cross-referenced to the hydraulic calculation data file and a summary sheet of hydraulic calculations shall be provided.

A unique data-set shall be submitted for each calculated system. Each data-set should comprise the following:

- one print of the input data-set;
- one print of the input check;
- one print of the pipe table;
- one print of the overall hydraulic isometric;
- one hydraulic calculation print-out including details of any constraints such as flow velocities, minimum and maximum pressures and unacceptable pipe diameters.

When a system is revised during the course of a project, hydraulic calculations shall be re-run and the revised data shall be added to the input data, together with an explanatory text. Previous data shall not be amended or edited. Revised data shall be issued separately.

All drawings and calculations shall be retained on file for the life of the offshore facility.

3.5.2 Guidance

At least the following design and as-built drawings and documentation should be prepared for each element:

- plans, elevation/sectional drawings and flow sheets, including layout of pipework and showing location of isolating valves, deluge or sprinkler valves, nozzles, maintenance access and pump withdrawal requirements, etc.;
- P&IDs and PEFS, including instrument valve tag numbers and unique equipment numbers;
- PES Cause & Effects;
- instrument data sheets and loop diagrams;
- electrical schematics;
- Programmable Logic Controller (PLC) logic diagrams;
- electrical certification schedule;
- schematics/isometrics showing dimensions, node points, etc.;
- performance test requirements/results;
- hydraulic calculations;
- pressure surge calculations;
- schedule of equipment and symbols used.

Dimensions critical to correct installation should also be shown.

Some of the documents and drawings listed above may be required to support a Safety Case submission.

The primary objective of the as-built drawings is to establish the pipe diameters used and any variations in numbers of pipe fittings, and that pipe lengths are within 5% of the original design. Significant variations may influence the system hydraulic performance and may require a re-run of the hydraulic calculations.

The Statutory Authorities may require drawings and calculations to be submitted as part of the re-certification of an offshore facility following any modifications.

Relevant NFPA publications refer to accepted flow formulae. If programs using alternative formulae are used they should be checked to ensure that they are relevant and that the results include sufficient safety margins to allow for changes in pipe characteristics with time and for tolerances within pipework and fittings.

The hydraulic calculations should be supervised by a person experienced in the use of the chosen program and under the direction of an engineer familiar with firewater system element design.

The following should be taken into account when using a computer program to perform the hydraulic calculations:

- flows and discharge pressures from all relevant discharge points should be calculated and shown on the print-out. (Any system discharge valve, e.g. deluge valve should be treated as a pipework node);
- pressure losses through any restriction orifices or strainers should be calculated and shown on the print-out;
- equivalent lengths of valves and strainers should be scaled in accordance with NFPA 15 or based on Manufacturers' validated data;
- changes to system flow and pressure by the operation of a secondary source of supply;
- the need, dependent on the calculated availability of components of the firewater main and on the FES, to carry out the hydraulic calculations with one or more of the sections of the main isolated;
- system calculations should be compared with (or superimposed on) the available firewater supply curve to ensure that the firewater supply is adequate and at the required supply pressure. This comparison should be made at the system control valve at the firewater pump discharge nozzle taking into account the pipework in between and, if the sea is used as the water source, relative to the Lowest Astronomical Tide.

A full hydraulic calculation print-out should be provided at the following stages as a minimum:

- initial system design;
- prior to issue of fabrication tender documents;
- as-built.

4. FIREWATER PUMPS

The firewater pump system comprises one or more pumps drawing water from a supply source (normally the sea in the case of offshore facilities) and supplying it, under pressure, to the distribution system which feeds the various discharge elements, application systems and equipment.

This section shall be read in conjunction with (Section 3).

4.1 GOALS

The overall goal of a firewater pump system is to provide a reliable and secure supply of firewater to the firewater main system at the required pressures and flows for all the firewater dependent equipment or systems on an offshore facility.

Specific goals are:

Goal 1: To supply firewater with the required integrity and reliability to all users.

Goal 2: To provide a secure source of supply of firewater from an area not likely to be subject to hydrocarbon or biological contamination.

Goal 3: To provide an adequate supply of firewater that is immediately available on demand.

Goal 4: To ensure that the supply of firewater to the largest firewater demand does not compromise the ability to supply any other equipment required to operate at the same time.

Goal 5: To ensure that the firewater pump unit will not be adversely affected by the environment.

Goal 6: To provide facilities at the normally manned Control Point to monitor the fire pump unit's status and initiate pump start.

Goal 7: To ensure maintenance and testing of the fire pump units can be carried out without significant impairment to the firewater supply capability/capacity.

Goal 8: To ensure that the pump system is capable of continuous unattended operation, once started, for a period determined in the FES.

4.2 DESIGN

4.2.1 Requirements

The drivers for firewater pump units shall have adequate integrity to allow the firewater pump(s) to fulfil their role.

Electrically driven firewater pump units shall have power available at all times, even under emergency conditions.

The firewater pump system shall be designed to avoid common modes of failure.

The operational and Manufacturer's testing requirements shall at least comply with NFPA 20.

The materials of construction shall comply with DEP 31.38.01.10-Gen and be suitable for operation in a safe and efficient manner in an exposed marine environment. These materials shall be capable of withstanding the environmental conditions and should not deteriorate at a rate which will impair the efficiency of the unit within its specified working life. Materials shall also be appropriate for the type of water that will flow through the system. If dissimilar materials are proposed which could lead to potential electrolytic corrosion, then proposals shall be given for galvanic protection.

The performance characteristics of the firewater pump unit shall ensure that adequate firewater capacity is available and can be maintained to supply all demands that may occur simultaneously as required in (3.2.2).

The firewater pump shall be sized to provide either 100% of the calculated design firewater demand for the largest identified fire area or an appropriate fraction determined by any sparing philosophy adopted. Whatever philosophy is adopted, the firewater pump shall be sized such that the calculated design firewater demand (or fraction thereof) shall be met by the pump(s) operating at their duty points.

The firewater pump discharge head characteristics for each pump unit shall be sufficient to meet all firewater system pressure demands plus pressure losses within the firewater main distribution system.

4.2.2 Guidance

4.2.2.1 Location of water inlet

The water inlet should be located so that it is not affected by hydrocarbon spillage, sewage and other contaminates and does not impede diving operations.

The inlet location should be adequately protected against damage. Firewater pump caissons should be sited inside the jacket structure, wherever practical, to prevent collision damage to the pump caisson and permit the caisson to be supported from the jacket.

4.2.2.2 Firewater pump arrangements

The normally preferred firewater pump type is the line-shaft vertical-lift pump directly driven by a diesel engine, in order to remain independent of the offshore facility's power generation services, especially during emergency conditions. If this cannot be achieved alternative firewater pump types include:

- diesel-hydraulically driven submersible pump;
- diesel-electrically driven line shaft pump;
- diesel-electrically driven submersible pump.

The number of pumps to be installed on an installation will be influenced by the 100% design firewater demand, the maximum reasonably foreseeable firewater demand (see 3.2.3.2) and the capacity and reliability of each pump.

The following firewater pump arrangements/combinations represent different solutions for large normally manned installations:

- 3 x 100% firewater pump units;

- 3 x 100% dual duty firewater/service water pump units;
- 2 x 100% firewater pump units + 1 x 100% dual duty firewater/service pump unit;
- 4 x 50% firewater pump units;
- 3 x 50% firewater pump units + 1 x 50% dual duty firewater/service water pump unit;
- 1 x 100% + 2 x 50% firewater pump units + 1 x 100% or 2 x 50% dual duty firewater/service water pump units.

If sea-water pumps are used either as back-up firewater pumps or for dual purpose, they should be designed to the fire pump standards and should incorporate a high-integrity feature to automatically change over to firewater duty on demand. The sizing of any such sea-water pump should include the demand for all essential service water that must be supported when the transfer to firewater duty takes place.

The combinations listed above each have a spare unit as insurance against start failure and a second spare unit to ensure availability of sufficient pump capacity at all times, even when a unit is taken out for maintenance or repair. Any of the combinations stated above will ensure no facility production restriction upon loss of one unit. However, facility production restrictions may become inevitable if the back-up service water pump units do not meet the required firewater pump design standard, or the integrity of the change-over facility to firewater duty cannot be assured or if that facility cannot supply the full demand.

Alternative pump configurations, such as those listed below, may also be acceptable particularly where firewater is provided mainly to minimise the economic losses arising from a fire. However, such arrangements may lead to facility production restrictions on loss of one of the units in the combination.

- 2 x 100% fire pump units;
- 3 x 50% fire pump units;
- 2 x 50% dual duty firewater/service water pump units + 100% fire pump unit;
- 2 x 100% dual duty firewater/service water pump units.

Final selection will depend on various parameters which include:

- pump size
- pump cost
- weight
- space
- platform arrangement
- operating costs
- availability of back-up systems
- manned or unmanned
- level of risk
- range of actuation
- consequences of fire pump failure on production operations

A firewater pumping contingency matrix should be prepared for the chosen combination at the early stages of the conceptual design to identify the economic impact of the pump unit outage on production operations and so establish an optimum maintenance strategy and help ensure minimum disruption to production operations. The matrix should identify the safety envelope within which production can proceed and highlight specific production and operational restrictions. See (Appendix 3) for typical firewater pumping contingency matrix.

The maximum foreseeable firewater demand (see 3.2.3.2) should be supplied by utilising the run-out of the pump curve or by operation of the second, or further firewater pump units. The numbers of pumps may have to be reviewed to ensure sufficient pump capacity at any given time.

4.2.2.3 Location of firewater pump units

To maximise availability and survivability of the firewater pump units, the drivers and power sources should be located in dedicated enclosures and the pumps located in areas where they are unlikely to be disabled by a fire or explosion and/or a collision incident. This can be achieved by locating the drivers, power sources and pump units at the non-hazardous end of the platform.

For indirect undriven firewater pump units, where the drivers and power sources are located at different points on the platform, detailed attention should be given to the rating and protection of the electric or hydraulic lines between the pump and the power source, including the switchgear, so that they meet the survivability requirements.

Where possible each of the firewater pump units should be installed in a separate location on the offshore facility so that it is extremely unlikely that a single fire or explosion will put all the units out of action simultaneously.

4.2.2.4 Firewater pump unit enclosures

Normally the firewater pump unit should have an enclosure housing the pump's prime mover and all associated services. For direct-drive firewater pump units, the pump should also normally be in the same enclosure. Such enclosures should be made to withstand the effects of weather and, as far as is reasonably practicable, those of fire and/or explosion that may occur or impinge within the area in which the enclosure is located. The enclosure should also have mechanical strength and fire rating adequate to withstand the calculated loading that may be experienced during the fire.

Each enclosure should contain only one prime mover and should be at a separate, non-hazardous location on the offshore facility and as far as possible from any other enclosures. In exceptional circumstances involving low levels of risk and high availability, enclosures may contain more than one prime mover.

Due consideration should also be given to the protection of the pump unit against dropped objects.

Each firewater pump prime mover should be provided with its own fixed fire protection system where necessary. The type of fire protection system required for the different types of firewater pump prime mover should be identified as part of the FES. (Due account should be taken of the effect of extinguishant release on the unit).

The possibility should be minimised of explosion and damage to the firewater pump units if hydrocarbon gases migrate to the pump enclosure. The preferred method is to ensure that the pumps, prime movers, associated electrical services and any hot surfaces are unlikely to be ignition sources.

The ventilation air inlet should be provided with gas detectors if it is shown that a gas cloud could reach the inlet during an event. If gas is detected inside the ventilation air inlet, all non-Zone 1 rated electrical equipment should be isolated and the fire pump electric starter should be inhibited. If the pump has started and is operating, all non-emergency electrical equipment should be isolated. (The pump unit should be capable of continuous stand-alone operation. Overspeed protection should be fitted as detailed in EEMUA 107. Vibration protection, if fitted, should not be allowed to trip the pump under emergency conditions.)

The enclosure's fire and gas detection should be connected to the installation's Fire and Gas Panel for annunciation, alarm and actions. (Refer to Figure 3 for details.)

Fire and gas detection in any other areas of the offshore facility should not affect the status of a firewater pump nor should they inhibit the pump start facility.

Every attempt should be made to minimise the noise envelope generated by any firewater pump unit when running, under all load conditions, so that personnel in the firewater pump enclosures are not subjected to levels of noise that exceed the limits for exposure as defined in local regulations or the Shell Safety Committee Publication “Noise Guide”, whichever is the more stringent. Outside the firewater pump enclosures the noise levels should also be as low as reasonably practicable.

Adequate drains should be fitted to permit general good housekeeping in the enclosure.

Firewater pump unit enclosures should be ventilated during non-operational conditions and the HVAC "normal running" systems should supply air to the enclosure to maintain a maximum temperature of 35 °C and a minimum positive pressure of 50 Pa. Extract ventilation should be via louvered pressure relief outlets to atmosphere.

If a diesel engine package provides engine air for cooling and combustion and is separate from the normal HVAC system, then the fire/gas damper logic should be fully integrated with that of the enclosure system. These separate systems should generally form part of the

Emergency Supply and/or firewater pump package(s) and should be powered from the engine(s). However, the HVAC design may be required to include, in addition to the package supply, engine cooling air inlets with fire/gas dampers interlocked with the engine operation.

Penetrations of the enclosure should not jeopardise its integrity and should use certified type penetrations.

4.2.2.5 Firewater demand (see also 3.2.3.2)

Firewater pump curves of units which comply with NFPA 20 have flat run-out characteristics so it is possible to utilise the water available beyond the duty point to deal with any large firewater demands, including those following explosions. Furthermore, the integrity of firewater pump units should be such that it is reasonable to assume that all units are likely to be available when there is a demand for firewater.

The duty point of firewater pumps for new installations may therefore need to be adjusted from that determined for the design firewater demand to ensure that sufficient water is available to deal with this case.

The calculation or estimation of the design firewater demand, including the adequate contingency figures for the largest fire area, should be in accordance with the requirements of the FES.

4.2.2.6 Firewater pump sizing

Sizing of the firewater pump units should ensure that they are capable of supplying the required flow and pressure effectively during credible simultaneous demands. This should also ensure that excess demands do not damage the pumping equipment or draw down the system's pressure to such an extent that it becomes ineffective.

4.2.2.7 Pump materials

a) Pump materials shall be as specified below.

Alternative materials may be used subject to approval by the Principal. Any alternatives shall be based upon high alloy duplex stainless steels which have proven satisfactory service in similar offshore applications. Evidence of satisfactory service shall be provided by the Manufacturer/Supplier.

Casing and impeller	Aluminium Bronze BS 1400-AB2C (ASTM B148 Alloy 958)
Shaft	BS 3076 NA18 (Monel K500 type)
Rising main and caisson mating flange	Aluminium Bronze BS 1400-AB2C (ASTM B148 Alloy 958) or Ni-resist BS 3468: S-NiCr20-2
Strainer and anti-fouling system mountings	BS 3076 NA18 (Monel K400 type)
Fasteners	BS 3076 NA18 (Monel K500 type)

NOTE: Ni-resist cast iron shall have a minimum elongation property not less than 10% -12% and a corrosion allowance of 3.0 mm.

Detailed material specifications including the wear-ring harness shall be provided by the Manufacturer/Supplier in the proposal, and subjected to review and approval by the Principal.

b) Materials, casting factors and the quality of any welding shall be equal to that required by ASME VIII, Div. 1. The Manufacturer’s data report forms specified in the code are not required.

c) Minor parts not identified (nuts, gaskets, washers, keys and so forth) shall have corrosion resistance equal to that of specified parts in the same environment.

d) Castings shall be sound and free of shrink holes, blow holes, cracks, scale, blisters and other similar injurious defects. The surfaces of castings shall be cleaned by sandblasting, shot-blasting, pickling or any other standard method. All mould parting fins and remains of gates and risers shall be chipped, filed or ground flush.

e) The use of chaplets in castings shall be kept to a minimum. The chaplets shall be clean and corrosion free (plating permitted) and of a composition compatible with the casting.

f) The repair of leaks and defects in pressure casing castings by peening or burning-in, or by the use of plastic or cement compounds is prohibited. Repair by welding or plugging shall be undertaken only when permitted by the material specification and then only in accordance with the procedures detailed below.

Repair by welding

Weldable grades of castings may be repaired by welding, subject to the following criteria:

- Approval by the Principal shall be obtained before any major weld repair is carried out.
- All repairs shall meet the inspection requirements and acceptance standards for the original material.
- For steel castings, the repair welding procedure and the repair welder's qualifications shall both be in accordance with ASTM A 488. Repair procedures are subject to approval by the Principal.
- The total quantity of weld metal deposited shall be less than 10% of the mass of the casting.
- After weld repair, castings shall be suitably heat-treated if this is specified in the relevant material specification.
- Details of all weld repairs, and of the heat treatment where applicable, shall be recorded.

The definition of a major weld repair is to be taken as either a removal of more than 50% of the wall thickness, or a length of more than 150 mm in one or more directions, or a total surface area of all repairs exceeding 20% of the total casting surface area.

Repair by plugging

Ni-resist cast iron may be repaired by plugging within the limits specified in ASTM A278, ASTM A536 or ASTM A395 respectively. The drilled holes for plugs shall be carefully examined by dye penetrant to ensure removal of all defective material.

All necessary repairs not covered by ASTM shall be subject to approval by the Principal. Details of all repairs shall be recorded and reported to the Principal who shall be informed of the need for plugging before any repair is carried out.

Fully enclosed cored voids in castings, including voids closed by plugging, are prohibited.

4.3 OPERATION, CONTROL AND MONITORING

4.3.1 Requirements

A pump start feature shall be provided local to any firewater panel and at the HLO's position if helicopter services are provided.

A pump stop feature shall be local only. Except during testing, any alarms from pump monitoring systems shall not automatically stop the fire pump.

The facilities required to shut down a firewater pump shall not require any external power.

A duty/standby selector switch shall be provided for the firewater pump system when more than one pump is provided in addition to any selection logic from the fire and gas detection system.

Pump control panels shall be provided for each firewater pump unit and the control of each firewater pump unit shall be via its own individual controller.

The control panel shall monitor and annunciate the normal and malfunction status of the firewater pump unit during stationary and operational states.

The control panel shall generate key signals and repeat annunciation at the Fire and Gas Panel at the Control Point and shall accept start-only control signals from remote locations.

Any instrument critical to the safety of the installation shall be in accordance with DEP 32.80.10.10-Gen.

The control requirements shall at least comply with NFPA 20.

4.3.2 Guidance

The following should be provided in the firewater pump system:

4.3.2.1 Utilities: Fuel, cooling water and cooling systems (if fitted) to enable continuous operation for a prolonged period.

Firewater pump units, once started, should have the capacity for continuous stand-alone operation, for the duration of the fire event or a period to achieve safety, or a time consistent with the endurance time of the TR.

Whatever approach is adopted for setting the minimum duration for the operation of the firewater pump units, each diesel-driven firewater pump unit should be designed to incorporate the following:

- Be totally self-contained including all fuel storage, control and starting equipment, to enable stand-alone operation for the duration of the incident, or for a period determined by the results of evaluations.
- Incorporate a water/water jacket cooling system fed by take-off from the firewater pump discharge line. The cooling system should be independent of the diesel engine enclosure ventilation system.
- If gas may reach a firewater pump enclosure a rig-saver device should be fitted to each diesel engine driver for the firewater pumps to prevent the engines overspeeding due to intake of gaseous hydrocarbons.

4.3.2.2 Starting facilities: Manual and automatic starting facilities capable of multiple start attempts.

Each firewater pump should normally be provided with starting facilities and arranged for automatic start under normal operation. The automatic start should be initiated in response to loss of standing pressure in the firewater main, or confirmed fire detection in any area where firewater is required on the offshore facility.

Remote manual start should be provided at key positions such as the Control Point or helideck and, where deemed necessary, via manual break glass stations throughout process areas.

If firewater pumps are located on separate bridge-linked platforms it may be impracticable to start the firewater pumps sequentially, and the start sequencing of the firewater pumps and the location of pressure switches should be carefully considered to ensure reliable start-up. These functions should be checked in detail during the commissioning phase of the project and fully detailed in the Installation Operating and Maintenance Procedures.

For diesel-driven firewater pumps, there are three methods of providing starting facilities as follows:

Battery start: Unless specified otherwise, each set of batteries should be rated for 12 starts. Dual sets of batteries are mandatory and an automatic start sequence should be arranged such that there are 6 starts, at minimum engine cranking speed, interspersed with 6 rest periods each of 8 seconds duration.

Pneumatic start: Unless specified otherwise, engine starting should be from compressed air supplied to an air-driven starting motor. The air receiver should be sized to provide 12 starts without recharging.

Hydraulic start: The accumulator capacity should be sufficient for a minimum of 6 starts. If the hydraulic system is a back-up to the main engine system, accumulator capacity should be sufficient for a minimum of 3 starts.

If pneumatic or hydraulic methods are used, a feature for black start should be incorporated. The speed of response in the event of gas cloud ignition should be considered.

To enable the diesel firewater pump driver to start automatically in response to fire signals from the Fire and Gas Panel, the diesel engine should be provided with primary and secondary starting systems to maximise the probability of starting on demand. If dual battery banks are fitted these may be regarded as the primary and secondary automatic start facilities with as back-up a manually initiated hydraulic or pneumatic start.

For electrically driven firewater pumps, power availability at all times can be achieved by the provision of dedicated power sources such as a diesel-driven alternator. If electric firewater pumps are driven by the main generators these should be dual-fuelled or a standby diesel generator should be available. In any case, automatic change-over to diesel fuel or to a standby generator should be ensured.

4.3.2.3 Duty/Standby selection: Selection switch located in the Control Point and locally at the firewater pump panel.

4.3.2.4 Pump shut-down: There should be no automatic shut-down of firewater pump units. A pump should only be shut down from its local dedicated controller.

4.3.2.5 Pump Control Panels are required to monitor the performance of the pump units during duty and standby conditions and annunciate back to the Control Point for operator information or action.

4.3.2.6 Pump tie-ins: Separate pump tie-ins to a separate section of the firewater ring main are required to prevent common mode failure of supply and to enable off-line management of the pump.

A dedicated overboard dump line and a firewater pump test line should be incorporated as part of each pump tie-in. The open/closed status of the valves in the overboard dump line should be indicated at the Control Point. The overboard dump line and test line may be combined, provided full functions of both duties are achieved.

4.3.2.7 Pressure relief valves: To protect the pump discharge lines from over-pressure if the pump shut-in head exceeds system design pressure.

Relief valves in the firewater pump discharge lines are only required to protect the piping system from over-pressure if the pump shut-in discharge head exceeds the system design pressure. Relief valves should be sized to allow for conditions such as engine overspeeding. Relief valves should discharge overboard and should be accessible for inspection and maintenance.

4.3.2.8 Main surge control: To protect downstream pipework and components from damage caused by the hydraulic shock associated with start-up or shut-down.

If the fire main surge analysis identifies potential problems, surge control measures should be considered for incorporation into the firewater pump tie-in design. A typical surge control measure is as follows:

- installation of a start-up dump valve and overboard piping tie-in in the firewater pump discharge line upstream of the non-return valve. This valve should be designed to divert all or part of the initial start-up firewater discharge overboard. A flow control system is preferred whereby, on firewater pump start-up, all flow is diverted overboard and after a period of time the dump valve closes. A manual override feature should be provided for the valve. Surge alleviation using a fast acting anti-surge roll seal type valve may be considered as an alternative protection device. The flow control valve should be fail-closed, of high-integrity design (see DEP 32.80.10.10-Gen.) and be suitably rated for performance in the conditions expected in an emergency. Also a cooldown mode should be provided to stop overheating of diesel engine after running loaded;
- the above system should be backed-up by a vacuum breaker/air release valve located in the firewater pump discharge piping upstream of the non-return valve and sized for the anticipated airflow requirements without damage. This valve will have the dual function of preventing a vacuum being pulled by riser draining and limiting water velocity in the riser by controlling the rate of air discharge under fire pump start conditions.

Other options, such as a back pressure control valve, have been used.

Consideration should also be given to the possible effects of water hammer on pump shutdown. Diesel engines should incorporate an idle/cooldown cycle before stopping as a means of preventing this effect.

4.4 FIREWATER PUMP TESTING

4.4.1 Requirements

Each firewater pump shall have facilities for testing the control sequences and performance characteristics. These shall be arranged so that testing of a pump unit shall neither inhibit the automatic start of other units nor the ability to deliver firewater if required to do so.

4.4.2 Guidance

The primary purpose of testing the fire pumps is to ensure the reliability and availability of the system and to confirm periodically that the performance characteristics of the system have not significantly deteriorated.

The fire pump should perform at the minimum rated and peak loads as indicated on the Manufacturer’s certified shop test characteristic curve, within the accuracy limits of the test equipment.

A firewater pump test line should be located in an area adjacent to each firewater pump enclosure so that each firewater pump can be tested without affecting the integrity and performance of the firewater main or other firewater pumps. The test line should be adequately sized and incorporate suitable devices to measure the rate of flow, net pump pressures, volts/amperes for electric driven pumps and speed, across the full firewater pump curve. The tests should also include response time.

For test tolerances refer to NFPA 20.

5. FIREWATER MAIN

The firewater main system is the pipework system and associated valving that distributes water from the pumps to the various application systems and equipment.

This section shall be read in conjunction with (Section 3).

5.1 GOALS

The overall goal of the firewater main is to provide a reliable and secure system to distribute firewater to all firewater-dependent protection systems, on demand, at the required pressures and flows.

Specific goals are:

Goal 1: To ensure that firewater is distributed to all end users at the required pressure and flow during reasonably foreseeable fire emergencies.
Goal 2: To maintain the operability and integrity of the firewater main system during maintenance and/or loss of a section of the main system without impairment to the efficiency of the distribution to the end users.
Goal 3: To ensure that the firewater main system is of sufficient integrity that it will survive under fire emergency conditions and any explosion which may precede a fire.

5.2 DESIGN

5.2.1 Requirements

The firewater main shall supply both the fixed firewater systems and manual fire-fighting equipment, i.e. hydrants and hose reels, etc.

Adequate piping capacity shall be provided so that firewater is transported and distributed effectively.

The survivability of the firewater ring main shall be maximised by avoiding areas of high risk, choosing resilient materials and by making use of any form of protective shielding afforded by structural members.

The piping materials shall be capable of operation in a safe and efficient manner when in an exposed marine environment. Refer to 3.2.3.8 for guidance on materials.

The layout of the firewater main shall consider the requirements for access for maintenance of equipment, valves and instrumentation.

If a platform incorporates a drilling package, the package firewater main shall be compatible with the installation's firewater main.

5.2.2 Guidance

5.2.2.1 Layout

The firewater main should generally be designed as a ring or loop so that a firewater-dependent system is supplied with fire-fighting water from two directions.

On multi-platform complexes the firewater main should be run as a separate loop around each individual platform. A single interconnecting line, or lines, may be adequate between adjacent platform firewater mains depending on pump locations. A block valve should be incorporated at each end of each interconnecting firewater main. Provision should be made for connections to allow temporary firewater hoses to run over bridges to provide reduced firewater distribution if the primary firewater bridge link is out of service (e.g. for maintenance).

The routing of firewater mains through the following areas should be avoided wherever practicable:

- Wellhead
- Process plant

- Gas compression
- In the path of explosion venting
- Areas containing electrical equipment.

In addition the firewater main layout should:

- Be designed to allow for the maximum possible amount of onshore fabrication and testing of large-diameter pipework;
- Minimise the number of interconnections and tie-ins that are required during offshore installation activities.

When deciding whether to route firewater main risers inside or outside the accommodation, the need to protect external mains should be weighed against the difficulties of inspecting internal mains and the consequences of leaks in internal mains.

To ensure a reliable supply to all firewater-dependent systems and to minimise common-mode failures, each connection to the firewater main should supply only one system.

However, up to three twin-outlet hydrants or hose-reels in a single area may be supplied from a single branch connection to the firewater main, provided that there are other hydrants or hose-reels which could be used to fight a fire in the same area and that these are supplied by a separate connection to a different section of the firewater main. Up to five hydrants or hose-reels may be supplied from a single connection to the firewater main, if they are in different areas.

Two independent connections from different sections of the firewater main should feed separate sub-main loops for each of the following services. If the sub-mains are within low-risk areas and there are no maintenance concerns, then a single connection is acceptable.

- The helideck firewater hydrant/foam system
- The living quarters sprinkler systems
- The living quarters hose-reel system
- The drilling module firewater supply system.

5.2.2.2 Response time

The firewater distribution system, including the firewater pumps, should normally be capable of supplying effective firewater upon demand within 30 seconds as required by NFPA 15. Longer response times may be acceptable but should be justified by the FES and the relevant Performance Criteria.

5.2.2.3 Standing pressure

To make firewater available immediately upon demand, the firewater main should normally be filled and pressurised. The means and the standard of pressurisation should be determined by the system/platform requirements.

If the firewater main is charged with sea water and maintained at a standing pressure by means of a pressurising line from the service water system, this pressurising line should be tied into the firewater main with isolation valves provided between the tie-ins.

If the service water system is unable to meet the standing pressure requirements, or is not considered suitable for the service, electric-motor-driven jockey pumps should be installed to provide pressurisation.

The capacity of the pressurising line and the pressure available should be such that a drop in pressure caused by the operation of one fire hydrant will not cause the main firewater pump to start. A demand in excess of one hydrant capacity should initiate the automatic firewater pump start sequence.

On Normally Unmanned Installations (NUI) the firewater main may be normally dry providing a rapid response is still possible when firewater is required for hydrants and fixed firewater systems.

5.2.2.4 Sizing

Sizing of the firewater main system should be based on:

- The maximum reasonably foreseeable firewater demand for a single fire event (see 3.2.3.2).

The firewater main should be designed to supply the required volume of firewater with any one section of it inoperative. In the case of a sub-loop or cross-over, it should be assumed that the firewater is only available at one connection to the firewater main so the sub-loop or cross-over should be sized to transfer 100% of the required loop firewater demand.

- Tolerable pressure drop within the system (maximum allowable water velocity for the selected piping material).

The maximum allowable water velocity for such piping is usually based on material erosion considerations for continuous flow duty. Higher velocities may be permitted in view of the exceptional usage of firewater and so smaller pipe sizes may be used. Other considerations such as pressure drop affecting firewater pump head and pipe rating may prevent the use of the maximum allowable velocity.

- The required outlet pressure especially at the most hydraulically remote location.

In the event of a fire in any one area, the pressure and flows available from the firewater pump configuration to hydrants, monitors, deluge and hand hose lines local to the incident should be sufficient to control the fire. A minimum of 7 bar (ga) for monitors and 3.5 bar (ga) for hydrants should be available for equipment in areas not protected by deluge. Flowing pressure requirements for hose lines and deluge systems should be determined by their designed pressure requirements.

The pressure switch is to be set or located high enough such that the firewater pump will start at the duty point of the jockey pump, to avoid unnecessary starting of the firewater pump.

- The hydraulic performance of the system.

The hydraulic performance of the firewater main should be analysed to establish that an hydraulically balanced system has been designed.

The calculated system demand at each tie-in point to the firewater main should be used to analyse the firewater distribution system characteristics.

The hydraulic analysis of the firewater main performance characteristics should be performed in conjunction with the hydraulic analysis of deluge firewater systems and other systems/equipment served by the firewater main.

5.2.2.5 Protection from freezing

One of the methods available to protect the firewater main system from freezing is to provide an overboard firewater dump feature at the opposite end of the firewater main from the sea water pressurisation inlet. The overboard dump should be sized to establish a small flow in the ring main and controlled in such a way that the firewater pump will not kick-in during its operation. It should be arranged for automatic actuation and isolation.

5.2.2.6 Interface with drilling package

Interfaces between the installation firewater and drilling derrick firewater mains may require the use of suitable flexible, fire-resistant and abrasion-resistant hoses.

5.2.2.7 External supply

To provide a source of firewater to the installation firewater main during major maintenance, construction and commissioning work, especially when the fixed firewater pump systems are not available or have reduced capacity, the need for at least one auxiliary tie-in point should be considered. This will allow connection of an alternative firewater supply from a flotel or multi-functional service vessel. Such tie-in point(s) should be full-bore, flanged and blanked.

The tie-in points should be located at a point easily accessible to the external supply units; for example located near the bridge landing point for a flotel.

5.2.2.8 Connection with service water system

If sea water pumps are used either as back-up fire pumps or for dual purpose, a full-bore connection sized for the maximum water demand should be provided between the firewater main and the service water system. This cross-connection should be isolated by a closed block valve which should be automatically actuated on demand and controlled from the Control Point. Its position should also be indicated at the Control Point.

The cross-connection between the service water and the firewater mains should incorporate a non-return valve to prevent the flow of water from the firewater main to the service water main on occasions when the isolation block valve is open. It should be arranged to ensure that contamination of the firewater main from the sea water system is not possible.

5.2.3 Maintenance and monitoring

5.2.3.1 Isolation and valving

Isolation (or sectioning) valves should sub-divide the firewater main into sections to allow for any maintenance work to be undertaken. Position indication and remote actuation may not be necessary if there is a system of work control which provides information on the position of key isolation valves at the Central Control Point. Access for maintenance and inspection should be provided from deck level, if practicable, or alternatively from permanently installed platforms. Extended stems for operation of valves in firewater mains running below a main deck level may be provided where required. Chain-operated valves may be used for valves which only serve a maintenance function.

A second reason for isolation valves is to retain a supply to firewater systems and essential users following damage to a section of the main in an explosion or fire. System performance outside the damaged section should not be seriously impaired. Remote position indication and actuation should be provided for those valves which perform such a safety-critical function. Chain-operated valves should not be used for this purpose.

Use of large numbers of sectioning valves should be avoided in order to minimise maintenance requirements.

Each branch connection to the firewater main should be provided with isolation valves located in an accessible position as close as possible to the firewater main itself. This requirement may be relaxed for branches where an operating valve to a firewater system is installed within approximately 5 m of the firewater main.

5.2.3.2 Corrosion protection

The firewater main system should be designed to minimise external corrosion and inherent internal corrosion/blockage, preferably by using materials that are inherently resistant to external and internal corrosion.

If a metal firewater piping system is used the following points are generally applicable:

- Each section of the firewater main, between sectioning valves, should be bonded to the installation earth system via sacrificial links;
- Dissimilar metal interfaces which will cause galvanic corrosion should be avoided. In cases where dissimilar metal interfaces are unavoidable and one side of the interface is a relatively small component (e.g. sprinkler head), this component should be made of the more noble material. For existing systems with dissimilar metal interfaces between large components, disposable spool pieces of the less noble material shall be incorporated into the system. The spool pieces should be regularly inspected by ultrasonic wall thickness checks and replaced when necessary.

5.2.3.3 Monitoring devices

A minimum of two pressure transmitters should be fitted to monitor the firewater main standing pressure. On bridge-linked installations at least one pressure transmitter should be located on the firewater main on each separate section of the installation. A pressure transmitter should interface directly into the firewater pump panel to start the pump. All transmitters should be monitored at the Control Point.

For pressurised systems, an automatic firewater pump start sequence should be initiated when a pressure drop of typically 1 to 2 bar (ga) from the firewater main standing pressure is detected.

6. FIREFIGHTING EQUIPMENT

The term fire-fighting equipment covers the following manually operated items which have different basic functions:

- Hydrants: water outlets to be used with discharge equipment.
- Hose reels, hose lines: water or foam application by totally manual means.
- Monitors (fixed and portable): water or foam application through devices of which the output can be controlled and directed by manual means.

This section shall be read in conjunction with (Section 3).

6.1 GOALS

The overall goal of fire-fighting equipment is to combat fires by the safe application of firewater or water-based extinguishing media using manually controlled equipment.

Specific goals are:

Goal 1: To locate hydrants and ancillary fire-fighting equipment so that they are accessible during fires.
Goal 2: To provide hydrant outlets and fire-fighting equipment that can be operated safely and efficiently.
Goal 3: To ensure that relevant ancillary equipment for use with hydrants is readily available.
Goal 4: To ensure that personnel are aware of the use and limitations of hydrants and the discharge equipment they serve.

6.2 DESIGN

6.2.1 Requirements

Hydrant outlets shall be provided on an offshore facility so that water is available when required for fire-fighting by means of manually deployed discharge equipment.

Hydrant outlets shall be of a sufficient size and number to provide the required flows and pressures for any manually deployed water discharge equipment to be operated from them.

All hydrant outlets shall be designed so that personnel using them are not compelled to handle equipment at excessive operating pressures.

The hydrant outlets shall be compatible with couplings on hoses and all discharge equipment which may be connected to them.

Personnel who are liable to use hydrants or the equipment served from them shall be trained in their safe, effective operation.

Hose reels, hose lines and monitors shall be provided so that they can be manually deployed safely, quickly and effectively in any areas where they are required.

All discharge nozzles on hose reels, hose lines and monitors shall be specifically designed for firefighting duty and sized for safe handling and appropriate discharge rates.

Discharge nozzles on hose lines, hosereels and monitors shall be of the adjustable type allowing both spray jet and straight stream application of water or foam if unaspirated foam is required.

Portable and/or fixed foam and/or water monitors shall be provided as required to give primary active fire protection where it is impractical to install other suitable systems or to supplement other active fire protection systems (e.g. deluge, sprinklers).

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

6.2.2 Guidance

The normal purposes of fire-fighting equipment are to combat fires in situations that do not justify fixed systems of the types described in the following sections (sprinkler, deluge, foam and water mist) or to provide back-up to those systems.

In some cases fire-fighting equipment can provide a fixed system in its own right (for example, fixed, self-oscillating monitors might be used for helideck protection). In these cases, the equipment also fulfils one of the two purposes listed above.

The major differences between the discharge equipment covered in this section and that described in the others are:

- The equipment is manoeuvrable and has a sufficient throw range to allow the discharge to be directed as required, thus potentially allowing several areas or specific items to be covered by one discharge outlet.
- Because the discharge can be thrown some distance, some of the water will fall out of the stream, thus requiring greater overall water flows to achieve the same application rate onto the protected area. In the case of foam monitors the application required on the fire is usually also higher due to the relatively forceful application method.
- Because the equipment can be manually controlled the requirements for operability from safe areas and training in correct use are more stringent.

6.2.2.1 Hydrants

The following points should be considered when locating hydrants:

- The provision of safe access to and deployment of equipment from hydrants under all fire conditions. As it is often difficult to predict accessibility due to differing fire conditions (wind direction, fire damage limiting access, etc.), it is usually necessary to provide hydrants so that the fire can be attacked from two different locations.
- Typically hydrants should be located so that no more than two hose lengths need to be deployed from any hydrant in order to allow ease of hose handling and speed of response.
- In general, hydrants should be located outside or on the periphery of the area in which the discharge equipment they serve may be used. On mezzanine levels or in large plan areas it may be necessary to provide hydrants within such an area.
- Hydrants should be at a convenient height with outlet valves directed and angled to facilitate hose connection.
- As hydrants are often located on access routes for materials they may require barriers around them to protect against physical damage.

If hydrants and ancillary equipment are designed to back up fixed systems, they should not be supplied from the same section of fire main as the fixed system (deluge/sprinklers, etc.).

Hydrant risers should each be provided with an isolation valve to allow maintenance of an individual hydrant valve.

Valves manufactured specifically for hydrant use should be used.

The discharge flow/pressure that can safely be handled manually depends on the physical strength of the user. Typically it should not exceed approximately 7 bars with 1000 l/min flow. To limit discharge pressures to safe levels, it may be necessary to provide pressure regulation at hydrant outlets. If so, proprietary items developed specifically for this purpose should be used and the speed of response of the device should be fast enough to cope with the surges caused when a main firewater pump starts up. To minimise maintenance, pressure regulating devices which have no moving parts and rely on the supply pressure to deform a cased elastomeric ring are preferred. If equipment with different operating pressures may be used at a hydrant outlet, pressure regulation should be provided by removable rather than in-line units.

Hydrant coupling sizes and types should be standardised throughout a facility.

Normally ancillary equipment (hoses, nozzles, valve keys, etc.) should be located in a cabinet immediately adjacent to the hydrant outlet.

6.2.2.2 Hose reels, hose lines

Hose reels, being fixed units permanently connected to the firewater main, can be deployed more quickly than hose lines from hydrants.

The flow rates available from hose reels tend to be lower than those from hose ines connected to hydrants. Consequently hose reels tend to be used in areas such as accommodation areas where the fire is likely to be small and restricted to domestic materials. However, larger-throughput units are available if larger fires requiring greater water flow are possible. These units tend to be large and difficult to handle, and space restrictions may prevent their use. Typical areas where they might be used are helidecks where they deliver foam to back up foam monitors, or in process areas, again delivering foam.

Typical flow rates achievable are:

Hose reels with 25 mm diameter hose	-	150 l/min
Hose line nozzles on 45 mm diameter hose	-	450 l/min
Hose line nozzles on 65 mm diameter hose	-	1000 l/min

Foam solution can be discharged through hose lines. If aspirated foam is required, special foam nozzles are necessary. For unaspirated foam, normal water application equipment can be used provided a film-forming foam concentrate is used. Typical application rates for hand-held equipment applying foam solution to spill fires are in the range of 4 to8 litres per minute per square metre as required by NFPA 11. The concentrate-proportioning devices suitable for hand-held equipment are usually line proportioners and consequently pressure drops shall be allowed for (see Section 9). Self-inducing nozzles are not normally appropriate because they require a source of foam concentrate at the nozzle itself and consequently reduce manoeuvrability. For additional guidance on the application of foam refer to (Section 9).

Due consideration should be taken of hose weight and manoeuvrability. Typically, reeled hose lengths should be limited to 30 m. Individual hose lengths used from hydrants should be limited to 20 m. If sufficient application rates and pressures are achievable through them, 45 mm hose should be used in preference to 65 mm hose for ease of handling.

The number and type of hoses should take account of the numbers of personnel available to use them.

Pistol-grip nozzles are preferable for larger-throughput equipment. In all cases, nozzles should be selected that allow smooth transition from on to off and from straight jet to straight stream without excessive recoil.

6.2.2.3 Monitors

Monitors can be either fixed in position and served directly from the firewater main, or portable and served via hose lines from hydrants. Deploying and adjusting portable monitors is labour-intensive and time-consuming and should not normally be considered as a primary active fire protection but may be deployed to supplement fixed systems/equipment.

Monitors are available in the following forms:

- Manually controlled;
- Self-oscillating with manual over-ride. Such monitors can be pre-set to oscillate automatically through a sweep pattern unless over-ridden locally. They have the advantage that large areas can be protected without manual control being required initially;
- Remotely controlled from a point (preferably with a clear view of the protected area) away from the protected area itself via hydraulic or electrical power lines. Although such monitors allow operation from safe areas they tend to require high levels of maintenance and it is usually difficult to ensure a clear line of sight to the protected

area. Hence they are not normally appropriate for offshore installations.

In general, monitors can be used to provide protection in open deck areas where deluge systems are impractical or are not considered an appropriate protection method.

The use of fixed and/or fixed automatic oscillating monitors should be considered for applying water to specific targets, protecting fire-fighters and escape routes and cooling areas at the boundary of the fire-affected area. Monitors should have a dedicated supply from the fire main with a manual isolation valve external to the area, accessible in the event of a fire and protected from blast and/or damage from falling objects.

Design and specification considerations include:

- friction loss through unit;
- discharge pattern coverage and range (nozzles should allow both variable straight stream and spray);
- operating pressure;
- flow capacity (typically monitor nozzles have a throughput in the order of 1500 to 2000 l/min at a minimum operating pressure of 7 bar (ga);
- provision of locking mechanism to allow monitor to be pre-set in optimum position;
- horizontal and vertical adjustment;
- requirement for foam discharge capability (see Section 9).

7. SPRINKLER SYSTEMS

Sprinkler systems are closed-head devices which open automatically on reaching a fixed temperature to discharge water or foam solution. Thus water or foam solution is discharged only from those nozzles which have opened instead of from all nozzles in the system as is the case with deluge systems.

This section shall be read in conjunction with (Section 3).

7.1 GOALS

The overall goal of sprinkler systems is to assist fire-fighting by applying firewater to a limited area in suitable quantities to control or extinguish the burning of low-flammability material.

Specific goals are:

Goal 1: To provide an optimally designed distribution system which delivers water at the design rate to those discharge nozzles which have actuated in a fire.
Goal 2: To ensure that the application rate of sprinkler discharge water is appropriate to the quantities of combustible material in the areas protected.
Goal 3: To select and locate "fit for purpose" sprinkler discharge heads.

7.2 DESIGN

7.2.1 Requirements

The sprinkler system type shall be selected with account being taken of environmental conditions and the water damage that it may cause. It shall be designed in accordance with a recognised standard, such as NFPA 13.

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

Where an automatic sprinkler system is connected to an unpressurised fire main, it should have a reliable and sufficient supply of water available to provide protection until the fire main is pressurised.

The application rate of water from sprinkler heads shall be appropriate to the quantities of combustible materials in the area protected.

The temperature rating of individual sprinkler nozzles shall take into account ambient temperatures within the protected area.

7.2.2 Guidance

Sprinkler systems can be used as an incident recovery measure by limiting fire spread by cooling cellulosic materials exposed to fire, reducing smoke generation and hence facilitating evacuation. As the systems are automatically discharged they can be used to initiate a fire alarm. The important difference between sprinkler systems and deluge systems (see Section 8) is that sprinkler systems have individual discharge nozzles that are activated on exposure to high temperatures whereas deluge systems have open nozzles which all discharge simultaneously.

Foam concentrate can be proportioned into a sprinkler system to make it suitable for flammable liquid fires (see Section 9). Standard water sprinklers are not normally suitable for flammable liquid spills as such fires are liable to spread rapidly over large areas, beyond the control of the sprinkler system.

Sprinkler systems used on offshore facilities can be of the following types:

- Wet pipe - if all the pipework to the discharge heads is charged with water.
- Dry pipe - if the pipework to an alarm valve is charged with water but the pipework between the valve and the discharge nozzle is dry. This type of system has a slight time delay between the nozzle opening and water discharge, but is not liable to freeze.

The above two types of sprinkler system are the most commonly used and are typically applied for accommodation area protection. Dry pipe systems are used if there is a risk of freezing. Refer to Figure 4 for a typical schematic arrangement of a wet pipe sprinkler system.

- Pre-action sprinklers - if the pipework is charged by a valve which is controlled by a fire detection system or other signal such as that from manual alarm call points. This means that as well as the nozzle's temperature-sensitive element having to actuate, it is also necessary for another action such as smoke detection to occur before the system will discharge.

  In this way the probability of damage by spurious water discharge is minimised. Pre-action sprinklers may, therefore, typically be used in areas requiring a fire extinguishing system but which contain electrical cabinets where water damage could have serious consequences.

As part of Fine Water Spray (water mist) studies (see Section 10) research and testing is ongoing on an enhanced sprinkler system which uses modified standard sprinklers to produce a smaller water droplet size at higher than normal sprinkler head operating pressures. It is claimed that these "enhanced" sprinklers will give more effective extinguishing capability with less water requirement and hence less water damage. To date, such systems have not been included into recognised design standards but, potentially, they might well offer a more efficient system for offshore facilities where the higher water pressures required are normally available.

The normal type of system for offshore facilities is the wet-pipe type. In order to avoid excessive corrosion and salt crystals build-up at the sprinkler heads, it is normal practice to use a supply of fresh water to charge pipework downstream of the alarm valve with sea water being used only when the fresh water is displaced. Total system flushing is then required after any system discharge. A header tank of fresh water sufficient for system leakage or small discharges should also be considered.

If protected areas are prone to freezing the sprinklers should be of the dry-pipe type, provided time delays between sprinkler actuation and water discharge are acceptable. If not, then other measures such as heat tracing and lagging should be taken.

The use of sprinkler systems in areas containing sensitive electrical or electronic equipment should be avoided and alternative recovery measures sought. However, if no alternatives are available, then pre-action sprinklers should be considered. It is then important to ensure that personnel are trained to respond immediately to fire alarms using portable extinguishers before the heat intensity actuates the sprinklers.

The maximum pressure rating of sprinklers should conform to the design pressure of the fire main. If this is not achievable, pressure relief downstream of the sprinkler valves will be required, as experience shows that sprinkler valves are not tight shutoff and the passing water will increase fire-main pressure.

As sprinklers have long been used successfully for fire-fighting and life-saving purposes, they are often subject to statutory requirements and detailed design rules have been developed for their application.

NFPA 13 should be used as a minimum design standard if no adequate local statutory regulations exist.

Higher pressure "enhanced" sprinklers could be considered in locations where statutory requirements do not prevent this approach. However, currently any specification would have to be validated by testing work.

In some locations and for some types of offshore facilities, "marine" type approvals such as Det Norske Veritas (DNV), United States Coast Guard (USCG), etc. may be required, and consequently it is necessary to meet Safety of Life at Sea (SOLAS) requirements.

The classification or hazard rating for sprinkler design depends upon the quantity and/or the combustibility of the materials in the protected area. Provided good practice is adopted in the selection of generally non-combustible materials for furniture, furnishings and building elements, then an NFPA 13 "Light Hazard Occupancy" would normally apply to accommodation areas and "Ordinary Hazard Occupancy" to other areas often protected by sprinklers such as galleys, workshops etc. This results in water application rates in the order of 5 litres per minute per square metre in accommodation areas and 10 litres per minute per square metre for other areas.

Depending on water quality it may be necessary to use larger than minimum sprinkler head orifices. Generally, heads with a nominal orifice of less than 10 mm and a metric 'K' function of less than 47 should not be used.

In areas of high ventilation air currents, additional sprinkler locations may be required to cover the heat plume/heat travel from the design fire scenarios.

Sprinklers in cooking areas should not impinge directly onto the equipment used for heating cooking oil or fat.

Frangible-bulb-actuated automatic spray sprinkler heads should normally be used in sprinkler systems on offshore facilities.

Fusible-link or fusible-strut type sprinkler heads should normally not be used due to poor experience with them in marine environments.

Generally, sprinkler heads should be upright and located above the branch pipes. However, in areas having suspended ceilings, decorative type pendant heads can be used with connections being taken from the top of the branch pipe and the heads being located in the centre of ceiling tiles where practicable. The sprinkler head should be sited below the tiles with ceiling rosettes around the base of each sprinkler head.

All sprinkler heads should be suitable for use with raw sea water, even though systems may be charged with fresh water.

The temperature rating of frangible bulbs should normally be 68 °C except in areas where high ceiling temperatures occur such as galleys and drying rooms. In these areas frangible bulbs rated at 30 °C above the maximum ambient temperature should be used.

7.3 OPERATION, CONTROL AND MONITORING

7.3.1 Requirements

Actuation of one or more sprinkler heads shall be detected by either a flow switch in the pipework or a differential pressure flow transmitter connected to the firewater shutdown system.

A manual isolation valve shall be provided immediately upstream of the sprinkler control valve. This valve shall have an indicator to show open and closed positions and shall be locked with leather straps or nylon chains and padlocks under normal operating conditions. A key for the padlocks shall be provided in a break-glass type container adjacent to the valve (see Figure 5 for P&ID of typical sprinkler system).

7.3.2 Guidance

If a single sprinkler system protects more than one fire zone, a flow switch should be incorporated in each zone to indicate that zone in which a sprinkler has been actuated.

On installations with large firewater pumps there may be significant surges of pressure in the firewater main when a firewater pump starts up. These surges may be sufficient to trip the sprinkler flow switch. In such cases, a time delay should be provided to allow the sensing element of the flow switch to reset following a surge in fire main pressure before an alarm is given.

7.4 INSTALLATION, TESTING AND COMMISSIONING

7.4.1 Requirements

Installation, testing and commissioning shall be in accordance with NFPA 13.

Facilities shall be provided to enable each part of a sprinkler system to be drained and tested and to remove any air from water-filled systems.

A branch line shall be provided immediately downstream of the sprinkler control valve leading to drain via a normally closed drain valve fitted with a restriction orifice. When water is discharged to drain it shall be possible to see this readily by means of a sight glass or a suitable air break having a funnel to collect the water back into the drain.

Inspector's test connections shall be provided at the hydraulically most remote end of each sprinkler zone (see Figure 4).

Each inspector's test connection shall have an isolation valve and incorporate a cropped sprinkler head and a test gauge connection. The cropped sprinkler head shall have the same size of orifice as the sprinkler spray heads in the system to accurately simulate the operating flow through a single spray head.

The gauge connection shall be readily accessible and shall be used to monitor the flowing water pressure at the test connection point during testing.

The test line shall be permanently connected to the drain system via a sight glass assembly so that the water flow can be visually monitored during testing.

7.4.2 Guidance

To minimise possible water damage, sight glasses (rather than air breaks) should be incorporated in sprinkler valve assemblies within accommodation areas.

7.5 DRAWINGS AND DOCUMENTATION

7.5.1 Requirements

The sprinkler system hydraulic calculations shall be performed for both the hydraulically most remote and least remote areas of each system.

Flows from all relevant sprinkler heads expected to actuate in given scenarios shall be calculated and shown on the hydraulic calculation program print-out.

8. DELUGE SYSTEMS

Deluge systems are arrays of open head nozzles which are fed from a common valve. When the valve opens all nozzles discharge simultaneously. The discharge fluid can be water or foam solution.

This section shall be read in conjunction with (Section 3). For additional information on the use of foam in deluge systems see (Section 9). For guidance on deluge protection of specific facilities see (Section 12).

The role of deluge systems in explosion mitigation is discussed in (Section 11).

8.1 GOALS

The overall goal of deluge systems is to assist fire-fighting by the reliable, secure and effective distribution of firewater to limit escalation, provide cooling to equipment and structures and protect personnel.

Specific goals are:

Goal 1: To provide an optimally designed distribution system which delivers water at the design rate to the spray heads.

Goal 2: To provide a uniform distribution of water at that rate so that the whole area requiring protection is adequately covered.

8.2 DESIGN

8.2.1 Requirements

The speed of response required for a deluge system to fulfil its function shall be determined by the FES.

The spray nozzle selected shall depend on the type of application required.

If the water quality is such that blockage of deluge nozzles may occur, a strainer shall be provided at the inlet to the deluge valve assembly.

A feature shall be provided to enable the deluge valves to be tested without discharging firewater through the pipework or nozzles.

All deluge systems shall be hydraulically balanced and shall be designed for a calculated water requirement not exceeding 115% of that required to achieve minimum discharge density. See (Section 8.2.2.6).

8.2.2 Guidance

8.2.2.1 Application

Deluge systems may be used effectively for one or more of the following purposes:

(a) Extinguishment:

- by surface cooling, by reducing the rate of vapour emission;
- by smothering through generation of steam to displace/exclude air;
- by emulsification by applying water to the surface of flammable liquids to prevent the release of vapours;
- by dilution of water-soluble flammable liquids;
- by making the flame so unstable that combustion cannot continue.

(b) Control of burning:

- by reducing the evaporation rate for pool fires;
- by reducing flame temperatures.

(c) Exposure protection:

- by limiting the transfer of heat to personnel, equipment or structures.

8.2.2.2 Effectiveness

The effectiveness of deluge systems is dependent on:

- type and size of fire;
- type of hazard;
- location of spray heads;
- water application;
- water droplet size and velocity;
- speed of response.

Limited theoretical and experimental work suggests that firewater deluge systems alone cannot be relied upon to extinguish or cool equipment and structures engulfed in the high-momentum region of jet fires.

8.2.2.3 Types of protection

Deluge systems can provide the following types of protection:

Area Protection: Provided by a general array of open sprinklers, to enable a uniform application of water to equipment and pipework within a specified area.

Equipment Protection: Provided by dedicated open directional spray heads to direct water onto specific critical items such as vessels, wellheads, BOPs, pumps, etc.

Structural Protection: Provided by dedicated specialised nozzles directing water onto selected structural members.

Certain risks may require supplementary protection using monitors, e.g. main walkways or escape routes.

8.2.2.4 Deluge valve types

Deluge valves are available in two basic types:

- "Clack valves" where the clack is held closed by pneumatic (or, in some cases, electric) devices and swings open on actuation to rapidly allow full flow through the valve;
- Pressure-regulating valves which control downstream pressure to an optimum level determined by the hydraulic calculations. Such valves are normally of the diaphragm type which opens or closes according to the upstream pressure so that the pressure differential across the valve varies and the downstream pressure remains constant.

The pressure-regulating type allows a more straightforward system design, especially on larger offshore facilities where the firewater main pressure varies considerably from deck level to deck level according to the demand. Such valves help to ensure that discharge nozzles operate at optimum pressure at all times whatever other systems are operating simultaneously from the main. In addition, they are tolerant to surges in the firewater main on start-up of the firewater pumps. However, they are inherently more complicated than clack valve types and consequently normally require additional maintenance and testing. Clack valves carrying recognised certification for deluge valve use are available whereas this is not the case with pressure-regulating types. Local legislation may require such certification.

8.2.2.5 Installation

The deluge valve should be separated from the fire area it is protecting by locating it at a distance, by means of a suitably rated fire wall or by locating it within an enclosure. It should also be protected to prevent freezing or deterioration due to environmental effects.

In order to maintain a firewater supply to a deluge system a secondary supply should be considered, which is connected to the system as shown in (Figure 6.)

The manually operated isolating valves should be suitable for the fire risk area and, where appropriate, may be required to be of fire-safe design.

If the water quality could block the pipework or spray nozzles a strainer should be located immediately upstream of the deluge valve (refer to Figure 6). The strainer should be sized for the full design flow and pressure conditions of the deluge system. A manual bypass should be fitted to allow maintenance of the strainer.

All piping should be self-draining.

8.2.2.6 Sizing

The minimum water application rates are based on those given in NFPA 15.

The conceptual design of a deluge system should allow for the uncertainties involved at this stage in the design process. For preliminary conceptual design sizing, allowing for expansion of the system and hydraulic imbalance, the following contingencies should be used:

General area	25% contingency
Vessels and equipment	50% contingency
Areas under an obstructed spray pattern	50% contingency
Structures	50% contingency

These contingencies should be increased by 15% hydraulic imbalance in the summation of the above water quantities.

Additional guidance on application rates is given in the subsequent sections on types of deluge application. The spray nozzle selected will affect the water droplet size and velocity, and the optimum characteristics for the particular fire conditions and environment should be aimed for.

Applying sufficient water to keep process equipment cool can prevent the equipment from being breached and thus avoid further escalation of the fire. Only short-term protection may be necessary if vessels can be depressurised and liquids removed.

The likelihood of pool fires developing under vessels should also be considered and the drainage system should allow adequate run-off. This should be sized for the full discharge capacity of the deluge system and other fire-fighting equipment required to operate simultaneously.

By introducing a film-forming foam into the water spray discharge the deluge system can be effective in extinguishing hydrocarbon pool fires (see Section 9).

The deluge system should also be designed to protect personnel by means of radiation water screens and/or a water spray system. Water screens/drenchers should be located near natural fire-breaks, e.g. main walkways and/or escape and evacuation routes. Their primary role is to create a water curtain along the fire-break as an exposure/radiated heat protection barrier for personnel. The use of monitors may also be considered although their effectiveness is likely to be limited unless they are used to back up other fixed systems.

8.2.2.7 Piping

(Figure 6) shows a typical Process Equipment Flow Sheet (PEFS) for a complete deluge valve assembly. Single deluge systems delivering more than 1000 m^3/hour via pressure regulating deluge valves are inadvisable as they are slow to reach steady-state operation.

On offshore facilities comprising two or more platforms, incorporating one or more fire pumps per platform, the system design should be based on the longest supply route. It may, however, be based on the shortest route on the platform containing the deluge system, if it can be demonstrated that proceeding from the longest route would impose severe design constraints.

The following criteria (as a minimum) should be taken into account when the computerised hydraulic calculations for deluge systems are performed:

- a 1 bar safety factor should be incorporated in the initial design;
- flows and discharge pressures from each spray head should be calculated and shown on the print-out;
- equivalent lengths of valves and fittings should be scaled in accordance with NFPA 15;
- system calculations should be compared with (or superimposed on) the available water supply (i.e. fire pump) curve at the fire pump relative to LAT.

8.2.2.8 Area protection

In this case, a deluge system provides a uniform application of water to equipment and pipework within a designated fire risk area in order to cool the area, prevent failure of the equipment and pipework therein and prevent escalation of the incident to other areas.

General Area Protection should be provided by means of open sprinklers positioned to achieve a typical minimum discharge density of 10.2 litres per minute per square metre of floor area for uncongested areas. For congested areas and in the vicinity of hydrocarbon pumps and compressors this may have to be increased up to 20.4 litres per minute per square metre based on test data or knowledge concerning conditions similar to those that will apply on the offshore facility in question. Open sprinklers are selected to provide a degree of protection and cooling for the beams, deck head and supporting brackets above the nozzle. Obstructions to water discharge may be caused by various items of equipment and structures and "shadowed areas" created. Such obstructions may include:

- mezzanines;
- walkways (open grating or solid);
- ducts;
- pipework;
- major cable trays.

Where such obstructions would disrupt the overhead general area spray pattern, or are over 1 m in width, then additional deluge nozzles should be provided beneath them.

To produce adequate water screens for personnel protection, limited unpublished test data for pool fires indicate that a rate of water application of 45 l/min to 130 l/min over a 3 metre length would be required.

High-pressure jet fires are very intense, transfer heat at high rates to any object in the high-momentum region of the flame and are difficult to extinguish using water spray or foam deluge systems. The primary extinguishment technique should be to remove the pressure and isolate the fuel source. If gas is involved, extinguishment should not normally be attempted, the fuel being allowed to burn off while the surrounding equipment and structures are cooled. Structures should be protected against jet fires by Passive Fire Protection, to prevent their collapse whereby further flammable material could be added to the fire.

8.2.2.9 Equipment Protection

In this case, a deluge system provides water spray to critical items such as vessels, wellheads, BOPs and pumps to limit absorption of heat, minimise damage and prevent failure. Whilst deluge will provide effective cooling for equipment engulfed in pool fires it is unlikely to prevent escalation of jet fires unless very large quantities of water are used. Dedicated protection of wellheads discussed in (12.1) is one example where Equipment Protection may by used against jet fires.

Specific Equipment Protection should be provided where there is a threat of escalation that cannot be controlled by blowdown or contained by Area Protection using open sprinklers and for equipment in shadowed areas where area protection is deemed ineffective.

(Table 8.2) shows typical sprayers and water application rates for specific equipment and area and additional information is given in (Section 5).

8.2.2.10 Structural Protection

In this case, a deluge system has dedicated nozzles for protection of primary load-bearing structural steelwork to minimise local damage from credible fire risks.

Structural Protection may be considered for all primary load-bearing structural steelwork not essential to the support of the TR and EER facilities in areas where there is a significant fire risk. Structures essential to the support of the TR and EER facilities should be protected by Passive Fire Protection to ensure that they will survive long enough under all foreseeable fire conditions to allow evacuation of the offshore facility.

Spray heads for Structural Protection should be located on the side of the steelwork facing the area protected by the deluge system. If a structural member is located entirely within the protected area, spray heads should alternate on either side of the member.

For additional information (see 12.6).

8.2.2.11 Deluge systems for special hazards

Deluge protection should be considered for specific highly vulnerable equipment and for the protection of equipment in small rooms (e.g. boiler rooms, firewater pump unit and emergency generator rooms). These systems can be referred to as Mini-Deluge Systems.

Each Mini-Deluge System should serve a small group of spray heads or directional spray nozzles and should be controlled by one or more Multiple Jet Control valves. See (Figure 9) for a typical layout of pipes and nozzles of a Mini-Deluge System.

A Multiple Jet Control valve contains a heat-sensitive device (normally a frangible bulb) which, when actuated, allows water to flow to the discharge nozzles. Thus the unit acts as the fire detector and the valve. A Multiple Jet Control valve can also include a device to actuate it from a remote point via an electrical signal (e.g. from a detection system) if required.

Systems operated by Multiple Jet Control valves should annunciate alarms in the same manner as conventional deluge systems (i.e. actuation of a pressure switch on water flow).

Each Mini-Deluge System should be fitted with a manual bypass valve, located outside and nearby the protected areas, to allow manual operation of the Mini-Deluge System.

Multiple Jet Control valves which require fresh water to be introduced immediately upstream of the valve as a "barrier" against sea water should not be used.

Design criteria as regards water flow, pressure, nozzles, minimum discharge density etc. for Mini-Deluge Systems are the same as for deluge systems.

Utility areas should not normally be provided with deluge systems or monitors, except for Mini-Deluge Systems protecting against special hazards.

Water mist systems are viable alternatives for many hazardous situations which have previously been protected by Mini-Deluge Systems (see Section 10).

8.2.2.12 Nozzles and spray heads

The layout and location of nozzles should generally be in accordance with NFPA 15.

The types of spray head which may be used in deluge systems for differing duties will depend on the hazardous situation being protected. (Table 8.1) lists the nozzle type generally used for particular hazards. (Table 8.2) lists the type of sprinkler head typically used for the type of area with the normally recommended application rates and (Table 8.3) lists the characteristics of different types of spray nozzles.

Detailed attention should be given to the location of nozzles, discharge pressures and water droplet sizes to minimise the effect of wind on the distribution spray pattern. In particular, for naturally ventilated modules, special attention should be given to the locations of spray nozzles on the periphery of deluge systems where wind effects will be strongest.

The number of different types of spray nozzles employed on a deluge system should be kept to a minimum to reduce the spares inventory and minimise the possibility of the wrong ones being fitted.

The spray patterns from individual nozzles should overlap to avoid the possibility of dry spots.

Spray heads should not be supplied with integral strainers to minimise the chance of blockage, since they are unlikely to be fouled/blocked by any sediment that can pass the deluge valve strainer. The maximum orifice size permissible in accordance with the hydraulic calculations should be used, to minimise the possibility of blockage.

In general protective caps should not be fitted to spray heads. However, where nozzles are used for dedicated wellhead and BOP protection then protective blow-off caps should be fitted to prevent nozzles being blocked by matter from the operational environment.

All spray heads should normally be approved by a recognised testing authority and suitable for the offshore environment.

If foam is to be introduced into a deluge system, the spray heads should be compatible for use with the specified foam concentrate.

Table 8.1 Nozzle types for particular risks

RISK	NOZZLE TYPE
Area Protection	Open sprinklers
Equipment Protection	Medium velocity open sprayer and high velocity sprayer
Structural Protection	As for Equipment Protection but with specialised narrow spray nozzle
Special Hazards	Medium velocity open sprayer.

Table 8.2 Sprayer selection

EQUIPMENT/AREA	OPEN SPRINKLERS	MEDIUM VELOCITY OPEN SPRAYER	HIGH VELOCITY SPRAYER	MINIMUM WATER APPLICATION RATE
AREA PROTECTION	x			10.2 litres per minute per square metre
WELLHEAD/BOP			x	400 litres per minute per wellhead
PUMPS AND COMPRESSORS		x	x	20.4 litres per minute per square metre
VESSELS AND TANKS		x	x	10.2 litres per minute per square metre
CHEMICAL & AVIATION FUEL STORAGE		x	x	10.2 litres per minute per square metre
PIPELINE		x	x	10.2 litres per minute per square metre
OIL PLATE HEAT EXCHANGERS		x	x	10.2 litres per minute per square metre
STRUCTURAL PROTECTION		x	x	10.2 litres per minute per square metre

Table 8.3 Spray nozzle operating characteristics

TYPE OF SPRAY HEAD/NOZZLE	MINIMUM WATER PRESSURE (bar (ga))	MINIMUM ORIFICE SIZE (mm)	MINIMUM METRIC K FACTOR
OPEN SPRINKLERS	NORMAL AREA: 1.0 OPEN NATURALLY VENTILATED AREA: 1.4	10	57
MEDIUM VELOCITY OPEN SPRAYER	MINIMUM: 1.4	6.5	26
HIGH VELOCITY SPRAYER	WINDAGE AREA: 3.5 ENCLOSED AREA: 2.8	6.5	MANUFACTURER'S RECOMMENDATIONS

8.2.2.13 Types of nozzles and sprayers

Open Sprinklers:
These are the same nozzles as used in automatic sprinkler systems but are not sealed by a temperature-sensitive element. The use of open sprinklers provides a degree of area protection and cooling for the beams, deck head and supporting brackets above the nozzle. These nozzles produce large droplets suitable for penetration of hot plumes.

Medium Velocity Open Sprayers:
These nozzles produce water droplets of 0.4 mm or less, with a velocity of between 15 and 20 m/s. The larger the spray angle the smaller the droplets. Medium Velocity Open Sprayers are primarily used for exposure protection and can be used on equipment containing flammable liquids having flash points below 66 C.

High Velocity Sprayers:
These nozzles produce water droplets with high velocity and a diameter of 1.5 to 2.5 mm over an operating pressure range of 3.5 to 6.0 bar (ga).

Typical uses:
- Exposure protection where long nozzles-to-target distances are involved. They are particularly suitable in naturally ventilated and external areas and where wind conditions are excessive.
- Controlling/extinguishing flammable liquid fires with fuels having flash points higher than 66 °C.
- High-density water application.

Specialised Nozzles:
To reduce water wastage, specialised nozzles for structural protection may be used. These give a narrow spray pattern and operate at a minimum pressure of 2.0 bar (ga).

8.3 OPERATION, CONTROL AND MONITORING

8.3.1 Guidance

8.3.1.1 General

The need for initiation of a deluge system by the following techniques should be considered:

- automatically by the operation of a frangible bulb type detector installed on a pneumatic trigger line;
- automatically by the operation of electrically operated fire detectors;
- the manual operation of electrical or pneumatic shielded push-buttons located, where practicable, at each exit from the protected area;
- the manual operation of a key switch or shielded push-button at the FGP or any mimic panel;
- the manual operation of a local deluge manual release shielded valve at the deluge valve skid/assembly;
- manually by the direct operation of a secondary bypass valve.

Normally two initiation methods are used, one acting directly on the valve and one acting electrically. The FES should determine the required speed of response and performance criteria.

It should be ensured that any pneumatic release system for individual deluge valves remains available on loss of instrument air.

Operators should be made aware of the possibility of steam being generated by the deluging of hot surfaces in some enclosures and should not enter the enclosure until satisfied that the hazard has subsided.

8.3.1.2 Automatic initiation

The following notes are provided for guidance on the detection systems often used to actuate deluge systems. More detailed information on detection systems can be found in DEP 32.30.20.11-Gen.

If deluge is to be initiated automatically, the deluge valves should be maintained in the closed position during normal operation by air pressure. The air pressure should be capable of being released by sensing devices as summarised in the following sub-sections.

Should the installation not incorporate a pneumatic supply then consideration may be given to alternative means of actuation, i.e. hydraulic or electric.

Actuation by flame detectors

The primary means of automatic deluge actuation should be by flame detection. Flame detectors are fast acting devices, relying on a line of sight to a flame. Actuation of two or more flame detectors should provide a signal to the FGP. This in turn actuates solenoid valves on the pneumatic detection line to the deluge valve assembly, leading to loss of air pressure and operation of the deluge system.

Actuation by frangible bulb heat detectors

Frangible bulb detectors are fixed-temperature devices which break at a pre-set temperature. The bulb heads are arranged in a network of pneumatic pipework so that one bulb monitors a maximum of 10 m^2. The pneumatic pipework is connected to the deluge valve as detailed in (Figure 6), which shows a typical PEFS for a deluge valve set. The bulb heads will normally maintain air pressure within the system, which, in turn, keeps the deluge valve closed. Fracture of one or more bulbs will release the air pressure and allow the deluge valve to open, supplying firewater to all the open sprinklers/spray heads in the system. Bulbs should be provided with guards in areas where they may be susceptible to mechanical damage.

'The frangible bulb detection system should be capable of maintaining a deluge valve in a closed position for as long as is needed to fulfill its essential function determined by the FES.

It is important for frangible bulb detector heads to be correctly located within the protected area in order to achieve the response times indicated in the FES. However, they should also be accessible for maintenance and testing. Frangible bulbs should be kept free from paint and dirt.

To initiate deluging as quickly as possible, consideration should be given to the use of frangible bulb detector heads with as low an actuation temperature as practicable, subject to the environmental conditions.

Should an array of frangible bulb detector heads present operational problems (e.g. in connection with area maintenance or removal of equipment), then consideration should be given to alternative means of actuation as detailed below.

Actuation by fusible pneumatic loop

This type of heat detector is commonly termed "Polyflo" tubing and is a fusible plastic pneumatic tubing. This form of detection should normally only be considered for retrofit applications. I should be borne in mind that they can be slow to respond and are prone to mechanical damage.

Actuation by linear heat detection

Linear heat detectors are cables whose properties quickly change on rising temperature. They are prone to damage in congested work areas or where wind causes movement of cables.

Linear heat detectors may be considered where no instrument air is available.

8.3.1.3 Alarm and annunciation

If a deluge system is actuated it should be annunciated both audibly and visually at the FGP as follows:

- low air pressure in the detector line should be annunciated visually and audibly at the FGP only;

NOTE: This alarm should occur at approximately one bar above the minimum pneumatic operating pressure required to keep the deluge valve closed.

- low/low air pressure in the detector line should cause audible and flashing visual alarms at the FGP, initiate the platform alarm sequence, HVAC shutdown and ESD actions, operate the deluge release solenoids via the FGP and initiate the fire pump starting sequence.

The operation of the pressure transmitter positioned downstream of the deluge valve should cause the flashing visual alarm at the FGP to become steady thus confirming discharge.

8.3.1.4 Pneumatic control

During normal operation the deluge valve is maintained in the closed position by air pressure and should automatically open if the air pressure falls below that required to keep the valve closed.

Air is normally the primary means of control. The air should be supplied to the deluge valve assembly from the air supply through a pressure regulator.

If instrument air is not available, the use of nitrogen cylinders with low pressure monitoring for pressurising the pneumatic detection system can be considered.

As deluge valves are opened by air failure it is necessary to ensure that each deluge valve pneumatic system is leak-tight. Typically pneumatic systems should be capable of preventing spurious deluge release for 2 hours after loss of instrument air supply. Alternatively, spurious opening of deluge valves should be allowed for in the calculation to determine the largest credible firewater demand.

An air reservoir may be provided to maintain the deluge valve in a closed position to prevent additional demand on the firewater system due to loss of instrument air during an incident. In determining the size of the air reservoir, the volume of air contained in the pneumatic trigger lines may be allowed for. As a general guide, the maximum leakage rate per joint (excluding threaded connections) following a satisfactory leak test (bubble test) will be less than 2832 litres (100 SCF) per year. A 5 litre capacity air reservoir has been adopted by some Shell companies in the past for the applications discussed in this DEP.

8.4 INSTALLATION, TESTING AND COMMISSIONING

8.4.1 Requirements

As far as possible, all testing and commissioning shall be carried out onshore.

Pre-commissioning checks shall be carried out prior to commissioning. This shall include flushing to show the pipework is clear of foreign matter.

All pipework, excluding air lines, shall be hydrostatically tested and no visible leakage permitted.

Pneumatic pipework shall be pneumatically tested.

Offshore commissioning shall, wherever possible, include full flow operational tests of the system.

8.4.2 Guidance

During hydraulic tests, instruments should be removed to prevent overloading.

Pneumatic testing is potentially hazardous and full safety precautions should be undertaken.

Before connecting the system to the fire main a final check should be made to ensure that test blanks have been removed.

8.5 DRAWINGS AND DOCUMENTATION

8.5.1 Requirements

Manufacturers/Suppliers shall provide information and documentation as follows:-

- plans, elevations and flow sheets showing layout of pipework and location of nozzles;
- PEFS of deluge valve assemblies, etc.;
- isometrics of each Deluge System;
- computer data-sets;
- description of the system and method of operation.

9. FOAM SYSTEMS

The term foam system refers to any system that is designed to discharge foam solution. Foam solution expands to form foam bubbles which float on a fuel surface to exclude oxygen (air). For offshore applications, foam solution can be discharged through variants of sprinkler or deluge systems and through monitors or hand-held nozzles. To achieve the desired foam characteristics it may be necessary to use special foam nozzles but, under some conditions, discharge devices can be dual purpose to discharge either foam solution or water.

This section shall be read in conjunction with (Section 3) and those other sections which are relevant to the foam application methods (e.g. deluge systems in the case of foam deluge systems).

9.1 GOALS

The overall goal of a foam system is to combat hydrocarbon spill fires by the reliable, secure and effective application of foam to prevent escalation, limit damage and prevent formation of smoke which could thwart EER or engulf the TR.

Specific goals are:

Goal 1: To ensure that the foam solution application method is appropriate.
Goal 2: To ensure that foam solution application rates and foam properties are sufficient.
Goal 3: To select a suitable foam concentrate.
Goal 4: To provide a system capable of supplying the required quantity of foam solution at the design concentration for a defined period.
Goal 5: To provide sufficient foam concentrate to allow the discharge system to run for the required amount of time.

9.2 DESIGN

9.2.1 Requirements

The method of foam application to the fire shall be appropriate to the fire type and the design intent.

The foam solution application rates shall be shown to be adequate to meet the design intent under operating conditions. As a minimum they shall meet the requirements of NFPA 11.

The foam concentrate and foam properties shall be proven for the design intent and application method using water having the same characteristics as the type used in the firewater system including any additives such as corrosion inhibitors or biocides.

The foam shall be compatible with any other extinguishing media such as dry chemicals that may be used simultaneously with foam discharge.

The foam concentrate proportioning accuracy shall meet the requirements of NFPA 11.

Sufficient foam concentrate shall be available to ensure that minimum system running times are assured and that foam coverage is available for any areas requiring it.

Pressure losses through any proportioning devices shall be based on Manufacturer's validated data.

Central foam systems shall not be utilised as a primary source of foam solution to hand-held equipment.

9.2.2 Guidance

9.2.2.1 Application

Fire-fighting foam can be used as an incident recovery measure by controlling or extinguishing contained liquid spill fires through the following mechanisms:

- acting as a barrier to prevent fuel mixing with air;
- cooling the fuel surface;
- suppressing flammable vapours (which can also help prevent ignition of unignited spills).

Foam solution may be applied by dedicated systems or by general firewater discharge elements such as deluge, monitors and branch pipes. Elements provided to discharge water or foam solution should be designed to fulfil both functions adequately. Due to the quantity of foam concentrate required it is generally not cost-effective to use foam systems for general firewater discharge elements.

Foam is not suitable as an agent on:

- fires involving gases;
- flowing liquid or liquid jet fires;
- live electrical equipment.

On offshore facilities, the normal foam application methods are hose lines, monitors, sprinklers or deluge systems. For special purposes such as protecting storage tanks which may be on some facilities, other application techniques may be more appropriate as described in DEP 80.47.10.31-Gen.

Typical areas for which foam systems may be considered are:

- helidecks;
- process areas where flammable liquid spill fires may occur;
- flammable liquid stores.

The design intent of a foam system is to extinguish a given hydrocarbon liquid spill fire within a given time dictated by the risk of escalation. In some cases, total extinguishment may not be possible but sufficient control by blanketing may still be achieved.

Application methods suitable for offshore facilities are:

- hand-lines;

- monitors;
- foam sprinkler systems;
- foam deluge systems.

Hand-lines obviously demand manual actuation and hence personnel may be endangered. However, they are versatile in that the operator can direct the foam discharge to exactly where it is required. Consequently, foam hand-lines have two potential applications:

- small spill fires too large to handle with an extinguisher but too small to justify a fixed system;
- back-up to fixed systems.

Monitors are essentially the same type of device as hand-line foam nozzles but with a larger throughput that cannot be controlled in a hand-held manner. In addition, the throw tends to be greater thus allowing operators to apply foam from a safe distance more easily. For guidance on types of monitors available see (Section 6).

Foam sprinkler systems can be used to apply unaspirated foam to small spill fires. As only those nozzles discharge which are actuated by high temperature, rather than all the nozzles throughout an area as in a deluge system, they may only be used in relatively small areas. Typically they can be used in places such as small enclosed flammable liquid stores, paint stores, etc.

Foam deluge systems can provide foam coverage over large areas to control and/or extinguish pool fires. Typically they can be used in process areas or flammable liquid storage areas. If a system is intended to act as a foam system for extinguishing/controlling a pool fire and also as a deluge system for cooling structures/equipment etc. then the application rates of foam solution applied should be based on the deluge application rates given in (Section 8).

9.2.2.2 Application rate

The application rate of foam solution (i.e. foam concentrate in water) determines extinguishing efficiency. NFPA 11 gives guidance on application rates and techniques which apply in general to hydrocarbon spill fires. The application rates quoted in these documents generally assume that all the foam solution reaches the fire area as foam and, in the case of foam deluge systems, that it is applied by nozzles at given regular spacing over the entire spill area. It may therefore be necessary to increase foam solution application rates to allow for losses due to wind effects, thermal currents, etc. Safety factors for such effects should be obtained from proven test data. In addition the documents assume that the foam concentrate used is of a recognised quality (see below). Water-soluble fuels such as methanol require special consideration and application rates. Application rates for such fuels should be derived from relevant proven test data.

9.2.2.3 Foam quality

Foam quality can be assessed by measuring Expansion and Drainage Time. It is important to get the combination of these properties correct for the application. In general:

- the higher the foam expansion the better the vapour suppression but the poorer the flowability and the greater the effects of wind or convection currents;
- the longer the drainage time the more stable the foam blanket but the poorer the flowability.

9.2.2.4 Types of foam

On offshore facilities, the most suitable type of foam is often "unaspirated" foam, particularly in deluge systems. Unaspirated foam allows the use of standard water application equipment such as water spray nozzles.

The types of foam concentrate suitable for offshore applications are:

- Fluoroprotein;
- Film Forming Fluoroprotein (FFFP);
- Aqueous Film Forming Foam (AFFF).

Fluoroprotein foam cannot be used in non-aspirating equipment. Therefore, as it is desirable to standardise the type of concentrate used on board an offshore facility and many systems are of the non-aspirating type, fluoroprotein foam is often not a viable option.

The other two types can be used in both aspirating and non-aspirating equipment. FFFP is currently available as a 3% grade, AFFF in both 1% and 3% grades. Where weight and space is at a premium, the 1% grade offers the most efficient method of providing the required amount of foam concentrate but it may demand special proportioning equipment due to its viscosity (especially at low temperatures) and the relatively low concentrate flow levels.

The concentrates suitable for water-soluble hazards tend to be very viscous and have relatively high freezing points.

Internationally recognised standards for foam concentrate include MIL-F-24385, the UK Defence Standard 42 series, the ICAO standard, CAP 168 and UL 162. Different standards are directed at different applications. For example, MIL-F-24385 is intended as a standard for a foam concentrate to be used in incidents such as aircraft crashes and would be relevant to helideck situations whereas UL 162 is intended for foam spray systems such as foam deluge. The test standard chosen should take into consideration the application method, the system design intent and the operating conditions.

Most foam concentrates work well with sea water but if the water used contains biocides, corrosion inhibitor or hydrocarbon contamination, performance may be affected. The foam concentrate should be tested with water having the same properties and composition as that on board the facility.

9.2.2.5 Foam proportioning and storage

Foam proportioning accuracy plays an important part in ensuring that good quality foam is produced by the overall system. If the foam concentrate is proportioned at too low a percentage, the foam solution will be weak and may fail to form stable bubbles. If the concentration is too high, the foam will be too stiff and may fail to flow across the fuel surface to extinguish the fire completely. Methods for checking proportioning accuracy are detailed in NFPA 11. Correct proportioning rates should be achieved at all possible flow rates and pumping configuration.

There are a number of proportioning systems available. Selection of the most suitable one will depend on the following considerations:

(1) The location of foam concentrate storage.

Central foam systems comprise foam storage, foam pumps and a foam proportioning device for each of the firewater pump units. A central foam system is the preferred system on facilities where foam solution may be required in a number of fire areas and by a range of discharge elements. Whilst this system has a limited speed of response due to the time taken to fill the main with foam solution, its advantages are:

- the relative simplicity of the design;
- the foam system can be matched to the duty of the firewater pump;
- the foam system has the same integrity as the firewater pump units as they are located in the same enclosure or area;
- the fire pump can be used to drive the foam pump independently of the facility’s power supplies in an emergency;
- as foam solution fills the firewater main it can be applied through any firewater discharge element.

An acceptable alternative to providing foam storage at each firewater pump is a single foam tank which supplies foam concentrate to each of the foam pumps and proportioners located at the firewater pump units. This arrangement reduces the number of foam tanks but requires more complex valving which can reduce the overall reliability and availability of the foam system.

Another option for foam system design is centralised foam storage and foam pumps supplying a foam ring main which feeds individual foam proportioners at each discharge element. This option provides for very quick application of foam solution and should be considered where the foam system has a major fire-fighting role. However, the drawbacks of this option include:

- foam solution can only by supplied to those systems with proportioners;
- a foam ring main is required;
- foam proportioners entail a high pressure drop at the discharge element which can have a significant impact on the hydraulic performance of the system;
- very complex and maintenance-intensive.

A further option is to provide dedicated foam concentrate storage and proportioning at each foam system. This should only be used where there are only a very few fire areas on the offshore facility requiring limited quantities of foam solution.

A review of overall foam system requirements should be carried out prior to deciding which type of system is the optimum for a particular facility.

Refer to (Figure 10) for a schematic drawing of a typical centralised foam proportioning system.

(2) Water pressure available

Different proportioner types cause different pressure drops across them. In some cases, these can be significant.

(3) Flow requirements

Some proportioners are variable-flow and can automatically adjust concentrate flows to suit water flow, thus allowing several different systems to be run from one proportioner.

(4) Power source availability

For systems employing foam concentrate pumps, a power source is required. This could be electricity, diesel or water power. Although water-powered pumps are ideal in that they require no outside power source, the amount of water required to drive the foam pump can be considerable and may be difficult to dispose of.

9.2.2.6 Proportioner types

The types of proportioner which can be used offshore include:

(1) Premix

One way of proportioning is simply to mix the foam concentrate with water in a large container to form "premix". This can then be stored ready for pumping to the foam discharge devices when required.

Advantages:
- Low cost system;
- Self contained.

Disadvantages:
- Limited storage life and stability of premix solution;
- Only limited size systems possible.

(2) Line proportioners (Inductors, Eductors)

The line proportioner induces foam concentrate into the water line by means of "venturi" action. Water, at a high pressure, is fed into the inductor inlet and passes through a nozzle into a small chamber built into the device. The nozzle characteristics are designed to ensure that the induction chamber drops to below atmospheric pressure. A foam concentrate container is connected to the induction chamber and the foam liquid is driven into the device by atmospheric pressure.

A non-return valve is installed in the foam concentrate pick-up line to prevent water flowing back from the proportioner into the foam concentrate via the pick-up tube in the event of a downstream valve being closed in the foam solution line.

Self-inducing nozzles which incorporate a proportioner and concentrate pick-up tube use a similar principle. Such devices require a foam concentrate storage feature adjacent to the nozzles.

Advantages:
- Relatively low cost proportioner type;

- Easy to install;
- Ease of maintenance (in its most basic form the only moving part is the non-return valve);
- Concentrate storage tank can be refilled during operation;
- No requirement for external power supplies.

Disadvantages:
- A pressure drop of approximately 35% has to occur over the unit for it to function properly;
- Consequently, the maximum allowable back-pressure on the unit is approximately 65%. Back-pressure is affected by elevation difference and friction losses between proportioner and discharge outlet. High back-pressure will stop the device from picking up foam concentrate;
- It is important to match exactly the flow/pressure characteristics of the proportioner with those of the foam discharge device;
- The device is a fixed-flow device.

(3) Diaphragm tanks

A diaphragm tank consists of a pressure vessel incorporating a flexible "bag" containing foam concentrate. Water under pressure is directed into the tank around the bag, thus pressurising the concentrate. Downstream of the water take-off into the tank, a pressure drop is introduced into the main water line so that the foam concentrate is now at a higher pressure than the water line and so can be injected into it.

Advantages:
- Low pressure drop across device;
- Variable flow capability;
- No external power sources required.

Disadvantages:
- Pressure vessels required;
- Cannot normally be refilled during operation;
- Relatively complex inspection and maintenance procedures;
- Refilling requires great care;
- Diaphragms can rupture without any external sign of a problem occurring until equipment is required in an emergency;
- Water around the concentrate diaphragm may be subject to freezing.

(4) Direct pumping

In this system a pump is used to inject foam directly into the water supply. The pump can be electric, diesel or water driven. As with all pumped foam concentrate systems, the choice of materials of construction and type of pump play an important part in guaranteeing long life and dependability of the system. Normally, positive displacement type pumps are preferable to centrifugal types. Materials of construction are chosen according to the type of foam concentrate.

An orifice plate or a constant flow device in the line between pump and injection point determines, in conjunction with the pump characteristics, the flow rate of foam concentrate.

Advantages:
- Simple system;
- No pressure loss in water line;
- Foam storage tank can be refilled during operation;
- Foam pump can be 'matched' to firewater pump characteristics to achieve reasonable accuracy of proportioning across the full range of the firewater pump curve. The concentration of foam in the firewater tends to be high at low flow rates but as a small quantity of foam is used this may be acceptable.

Disadvantages:
- If pumps are not matched, flow rates of foam solution could differ significantly according to different operating conditions.

The use of a Pelton Wheel or water-turbine-driven pump can cope with pressure variations to some extent as their speed and hence pump output varies according to water pressure. A typical application of this type of system is a helideck foam monitor unit (see 12.7).

(5) Electronic metering system

A flow meter is positioned in the water flow to the system. The output from this is fed to a microprocessor control unit which controls a variable-speed motor driving the foam concentrate pump. The pump speed is thus adjusted automatically to provide the correct amount of foam concentrate and inject it into the water stream. Other control information and functions can also be provided by the control unit (for example, low level alarms, foam volume used signals, etc.).

Advantages:
- Wide variable flow range;
- High accuracy available;
- Minimal pressure drop;
- Very simple to use;
- Foam storage tank can be refilled during operation.

Disadvantages:
- Power supply required;
- No standard large-throughput units available at present;
- Reliability unproven;
- Specialised maintenance requirements.

(6) Back-pressure balanced pressure proportioning

The system comprises three basic components:

(a) A foam concentrate pump.
(b) A "ratio controller" which is positioned in the water line and consists of a venturi-type nozzle.
(c) A pressure balancing valve (usually in the form of a diaphragm valve) which balances the pressure of the foam concentrate from the pump with that of the water supply. The valve is incorporated in a line back to the foam concentrate tank. Sensing lines from the water inlet and the foam concentrate lines are connected to it. The valve opens or closes according to the difference between these two pressures.

When the system is in operation, the pressure balancing valve balances the pressure of the foam concentrate entering the ratio controller with that of the incoming water supply.

This is done by opening or closing the valve back to the storage tank according to whether the foam concentrate pressure is higher or lower than the water pressure.

As the water passes through the ratio controller nozzle, a small pressure drop occurs, so that at the outlet of the nozzle concentrate pressure is slightly higher than the water pressure and so foam injection occurs.

Advantages:
- Low pressure drop;
- Variable flow capability;
- Manual over-ride possible;
- Foam storage tank can be refilled during operation.

Disadvantages:
- Power supply required for pump(s). (N.B. Pump can be water driven. The most common form of pump used is an electrically driven pump);
- Relatively expensive;
- All lines downstream of unit carry foam solution, so cannot normally be connected directly to a site water ring main;
- Relatively more maintenance required than with some other systems.

(7) In-line Balanced Pressure Proportioning (ILBP)

Essentially the operating mechanism for this type of system is exactly the same as for back-pressure balancing proportioners. The only difference is that, in this case, the pressure balancing valve is located in the actual line feeding the ratio controller, not in that returning foam concentrate to the tank.

This means that several units can be run remotely from a centralised foam pumping station. A foam concentrate main can be run parallel to the site water ring main and an ILBP unit can be installed at each location where foam may be required. In theory, there is no limitation to the distance between foam pump and ILBP unit, provided due account is taken of the pressure drop between the two components and a sufficiently large pump is specified to overcome this as well as to provide a higher foam concentrate pressure at the ILBP unit than water pressure. (The ILBP module then balances the concentrate pressure down to that of the water supply). In practice, of course, other considerations such as cost and pump availability will be taken into consideration when deciding system layout.

Advantages:
- Versatility of design;
- No need for separate foam solution main around large offshore facilities;
- Low pressure drop;
- Foam storage tank can be refilled during operation.

Disadvantages:
- Power supplies required;
- Greater care required when designing system;
- Relatively more maintenance required than with some other systems.

9.2.2.7 Foam tank requirements

System running time requirements depend upon the application method and the fire type. Guidance on running times is provided in NFPA 11. It should be remembered that the figures quoted in this document are minimum times and local conditions may dictate additional requirements to:

- allow post-discharge system reinstatement without needing to refill a tank;
- provide a safety factor over and above minimum requirements (typically 20%);
- permit simultaneous operation of systems.

Any foam concentrate tank should be designed to allow for:

- capacity to meet worst case demand. In addition, foam may be required after the fire is extinguished to seal the flammable liquid surface whilst the Emergency Response personnel clear the area. Furthermore, it may be necessary, according to local conditions and the availability of additional foam stocks, to have reserve capacity to allow coverage to be maintained after system discharge. Typical foam storage is for a 30 min. supply at the maximum likely rate plus a contingency of 10% to allow for other discharge elements operating at the same time;
- adequate supply, return and filling facilities for foam concentrate able to handle the maximum rates required;
- adequate ventilation so that filling rates can be achieved and to prevent vacuum conditions in the tank during foam concentrate outflow;
- sampling of the foam solution at normal tank levels;
- low point drain to allow refilling of the tank is large enough to allow entry for inspection purposes;
- necessary instrumentation to provide low level alarm;
- internal inspection.

The foam tank should incorporate a level sensing device to give level indication and a low level alarm. The level indication and alarms shall be given at the FGP. An example of the instrumentation that may be employed is given in (Figure 10).

Any foam tank should incorporate means to reduce the area of contact between air and concentrate. This can be achieved by using an expansion dome and keeping the level of concentrate up to the expansion dome or by using a thin layer of white oil (as approved by the concentrate manufacturer) on the surface of the concentrate.

Different concentrates require different materials of tank construction. The concentrate manufacturer should be consulted regarding suitable materials. The use of tank linings should be avoided because these can easily be attacked by the concentrate and the fragments may block orifice plates, valves, nozzles, etc.

9.2.2.8 Foam concentrate pumps

Foam concentrate pumps should be positive displacement types rather than centrifugal. Foam concentrate pumps may be directly coupled to the firewater pump driver or may be independently driven by electrical, diesel or water power according to the reliability and availability required. Foam concentrate pumps coupled to firewater pump drivers should not use a clutch or equivalent to separate the concentrate pump from the driver, but the concentrate pump coupling should be capable of being easily disconnected to permit uncoupled running for test purposes.

The discharge pressure of the concentrate pump should take due account of all possible firewater system operating pressures.

9.3 OPERATION, CONTROL AND MONITORING

9.3.1 Requirements

Foam tank "Low-Level" indication shall be provided for foam concentrate storage tanks unless it can be shown that manual monitoring of tank levels is sufficient in all systems where automatic foam discharge shut-down is required.

Foam concentrate flow indication shall be provided for all systems where safe visual observation of foam production cannot be relied upon.

9.3.2 Guidance

Manual initiation of a foam system is normally preferred to ensure that foam is not discharged onto jet fires and that it is discharged through deluge systems only when it will be of benefit (i.e. that it is not discharged when the deluge system is required for cooling of equipment/structures only and there is not a pool fire).

Automatic actuation of a foam system may be required to ensure sufficiently fast knockdown of a fire in cases of danger.

Automatic shutdown of a foam system is not usual. If a deluge system is intended to operate with foam concentrate proportioned into it to extinguish/control pool fires and then continue with a discharge of firewater once the foam supplies are exhausted, the effect of the deluge on the foam blanket should be considered.

Post-incident reinstatement procedures should address the problem of foam clean-up and foam solution disposal. Environmental considerations or local regulations may not permit disposal into the sea.

9.4 INSTALLATION, TESTING AND COMMISSIONING

9.4.1 Requirements

System installation, testing and commissioning shall, at a minimum, be in accordance with the requirements of NFPA 11 and shall include foam quality and concentrate proportioning tests.

Foam concentrate samples shall be tested annually for deterioration.

9.4.2 Guidance

Representative foam concentrate samples should be tested at an independent laboratory to check whether their physical properties have changed. If they have and the effectiveness of the foam is in doubt, the foam concentrate should be changed unless fire-fighting tests in accordance with the original test specification demonstrate satisfactory results.

9.5 DRAWINGS AND DOCUMENTATION

9.5.1 Requirements

Prior to system commissioning, for use in assessment of the test results, Manufacturers/Suppliers of foam discharge equipment shall provide data sheets including anticipated values (with tolerances) of foam expansion and drainage time with the foam concentrate to be used.

Full specifications and certification including, at a minimum, the following data with tolerances shall be provided by the foam concentrate Manufacturer:

- proportioning ratio;
- freezing point;
- minimum use point;
- viscosity - over relevant temperature range;
- specific gravity;
- pH value;
- surface tension;
- interfacial tension;
- spreading coefficient;
- minimum shelf life;
- expansion ratio *;
- 25% Drain time *;
- fire performance test results *.

* with test specifications.

10. WATER MIST SYSTEMS

Water mist systems are systems which discharge water droplets of such size and distribution that they are rapidly vaporised to form an inerting atmosphere. When designed correctly they can cause very efficient extinguishment in terms of water quantity used. They are primarily intended for use in enclosures.

This section shall be read in conjunction with (Section 3). It should also be noted that many of the water mist systems available are not fed directly from the firewater main due to water quality requirements. The information provided in this section can be used whether or not the system is fed from the firewater main.

10.1 GOALS

The overall goal of a water mist system is to combat fires by providing a reliable and effective water mist which is designed to extinguish the fires in the area protected.

Specific goals are:

Goal 1: To ensure that the water mist system has been proven for applications directly relevant to the fire scenarios.

Goal 2: To base the system design on relevant tests which determine the effectiveness and limitations for all possible fire scenarios in the protected area under all possible operating conditions.

Goal 3: To provide an optimally designed system which delivers water to spray heads at the appropriate flow and pressure to achieve the required application rate from each nozzle.

Goal 4: To provide an effective distribution of water mist sufficient to extinguish fires in the protected area.

10.2 DESIGN

10.2.1 Requirements

The method of water mist application shall be proven as effective for the area being protected.

The application rate, discharge times and discharge sequence shall be appropriate to the equipment protected, the hazard and the design intent.

A validated basis for system design shall be documented.

The system supplier shall provide a list of additional measures that are required to ensure the effectiveness of the system.

ISO/CD 13702 Clause 11.3.4 provides additional information on relevant requirements and guidance.

10.2.2 Guidance

10.2.2.1 Application

The value of water mist as an extinguishant has been recognised for a considerable time. However, it has found relatively little usage due to the fact that halon gases previously appeared to offer significant advantages. Since recognition of the fact that halon is a major cause of breakdown of the ozone layer, considerable efforts have been made to develop water mist systems in particular for situations previously protected by halon.

Water mist is a water distribution of fine drops having a mean diameter $D_{v0.50}$ of 80-200 µm and a $D_{v0.99}$ less than or equal to 500 µm. $D_{v0.99}$ is defined as a drop size distribution of a liquid spray such that 99% of the volume of the spray is contained in drops with diameters less than the value indicated.

The use of water mist extinguishing systems offers the following significant potential advantages:

•	Efficiency	Relatively small quantities of water are required to gain extinguishment.
•	Speed of extinguishment	Rapid extinguishment can be gained.
•	Availability	Water is normally readily available.
•	Environmentally benign	There are no restrictions on the use of water for extinguishing systems.
•	Safe usage	No toxic by-products from the extinguishing agent (currently available systems do not produce droplets under 10 µm, which are not absorbed into the lungs from fine water spray).
•	Clean extinguishant	Potable water in small quantities is unlikely to damage the protected equipment.

The mechanisms of extinguishment with water mist are complex. The primary mechanisms by which water mist will extinguish fires in an enclosure are identified as:

- cooling of the fuel by the spray;
- cooling of the flame by the spray;
- dilution of the oxygen in the combustion zone by water vapour (steam);
- chemical inhibition of combustion radicals by water vapour.

Although the relative importance of each of these will differ for individual cases depending on a number of parameters including fuel type, in general the first three can be considered the most important. Most of the cooling effect of water comes from the latent heat of vaporisation.

As evaporation takes place only at the surface of a liquid, the greater the surface area achieved by a given volume of liquid, the greater its cooling ability will be.

For a given volume of water, fine water sprays can, on account of their greater surface area, achieve a far greater cooling effect than water in the form of larger drops. As steam is generated as a result of the vaporisation, fine droplets are far better able to support the extinguishing mechanisms than the larger droplets from sprinklers or deluge systems.

A droplet with sufficient momentum to penetrate buoyant fire gases and reach and cool the fuel will be somewhat different from a droplet that is sufficiently light to be entrained in the fire plume and cool the flame. A spray needs to contain droplets with a range of diameters to support both these functions.

When selecting discharge equipment the volumetric flow rate and spray angle of a nozzle are also important. A spray must project a sufficient mass of water into a fire to extinguish it. The spray angle determines the volume of space throughout which the mass of water is dispersed and the net velocity, hence momentum, of the spray. The projection capability of the spray serves to propel the mist into obstructed spaces. Therefore, four factors have been identified as necessary to characterise a water mist for fire suppression in enclosures:

- initial drop size distribution;
- spray mass flow rate;
- spray angle;
- spray protection.

Different manufacturers use different techniques to achieve the desired droplet characteristics. Some systems require a pressurised nitrogen source at the nozzles as well as pressurised water. Such systems are known as dual fluid.

Extinction is most likely when there is dynamic interaction of mist with the flame and fire plume. Flame cooling below the fire point and displacement of oxygen with water vapour appear to be the major mechanisms in extinguishing combustible liquid pool fires. The relative importance of each mechanism depends on conditions within the enclosure.

Water mist adheres to all surfaces in an enclosure, including the back and underside of obstructions. The total suspended mass of water per unit volume therefore decreases as spray moves past obstructions in the compartment. By the time the spray reaches the seat of flame it must have enough remaining momentum and mass density to penetrate to the heart of the flame. These factors will dictate the mass flow rate of each nozzle and the optimum nozzle spacing. Convective flows will also take water into the flame.

Due to the loss of mass and momentum against obstructions, water mist is not equivalent to a gaseous fire suppression agent in an enclosure. Strategic location of nozzles as close as possible to specific fire sources, so that spray can be projected directly into the flame, represents the most efficient design approach for enclosures containing obstructions.

Currently a major problem with the design of fine water spray systems is that there are no published detailed design rules. It is therefore necessary to base the decision to use such systems on empirical data obtained from tests which can be shown to be directly relevant to the situation in question.

Considerable amounts of test work have been carried out on the following hazards:

- ships' cabins and general areas, which may be relevant for accommodation areas;
- ships' engine rooms which may be relevant for enclosures for diesel generators, etc.;
- electrical/electronic equipment cabinet protection;
- turbine enclosures;
- enclosed spaces such as paint stores;
- small hazards such as cooker hoods;
- local equipment protection systems such as pump skids.

Shell operating companies have experience of specifying and installing water mist systems for turbine enclosures and other relatively small enclosed spaces, such as machinery spaces.

10.2.2.2 Selection

As the design of water mist systems relies heavily on the availability of relevant empirical data, this guidance is provided in the form of questions that should be answered by a potential system Supplier to enable the Principal to determine whether or not the system being offered is appropriate and proven:

Effectiveness	(i)	Has the system been tested and shown to be effective against hazards of the type being protected against?
	(ii)	Are test results independently validated?
	(iii)	Has the system been tested under all operating conditions and for all scenarios? (e.g. in the case of a turbine enclosure - vents open/closed; ventilation running/shutdown; lube oil spray/pool fires, lagging fires, gas jet fires, etc.; in the case of open area protection, different wind speeds and directions.)
	(iv)	Do the tests demonstrate that the Supplier can design for different equipment configurations so that water mist can be projected into all fire areas?
	(v)	Are water additives such as foam concentrate required to enhance system effectiveness?
	(vi)	Have tests established discharge sequencing requirements to ensure effectiveness but minimise water damage?
Safety		Can the water mist produced pose a safety hazard under discharge conditions either by loss of visibility, scalding, oxygen depletion or ingestion into the lungs? (droplet sizes less than 10 µm may cause problems.)
Effect on protected equipment		Does water mist cause cold shock problems on protected equipment? Does water mist cause unacceptable damage to electrical components? Do water additives in the system have detrimental effects on the protected equipment? Will discharge into enclosures cause excessive pressure changes in fire situations?

Reliability	Do water mist nozzles get blocked easily? Are maintenance requirements sophisticated? Have independent authorities tested system components and their reliability?
System design	Has sufficient testing been done to extrapolate results and allow system design for actual risks? Have design limitations been established? Has the Supplier provided calculation sheets regarding system design and justifying, in particular, discharge rates, discharge times, nozzle numbers and nozzle locations? Safety margins above minimum application rates should also be documented along with the number of discharge "shots" available in excess of minimum requirements.
Other requirements	Are any other risk reduction measures required to ensure effective operation of the system? (For example, are additional passive protection measures required to handle scenarios not able to be dealt with by the water mist system? One Supplier recommends the use of fire retardants in lagging around turbines).

10.3 OPERATION, CONTROL AND MONITORING

10.3.1 Requirements

Manual over-ride facilities for any automatic discharge sequencing shall be provided and personnel shall be made aware of any potential consequences of over-riding automatic sequencing.

10.3.2 Guidance

The Supplier's detailed operations instructions should include reference to manual over-ride of discharge sequence, recommended back-up response techniques and post-discharge clean-up and reset requirements.

10.4 INSTALLATION, TESTING AND COMMISSIONING

10.4.1 Requirements

Water mist systems shall be given full discharge tests at the commissioning stage and at regular intervals after installation including testing any automatic discharge sequencing provided. The test measurements shall include at a minimum:

- Water quantity used against time;
- Discharge times and sequence.

11. DELUGE SYSTEMS TO MITIGATE GAS EXPLOSIONS

11.1 GUIDANCE

There is a belief by some in the industry that explosion hazards may be effectively mitigated by activation of the water deluge system upon gas detection. Experiments have shown that water droplets can indeed be made to interact with a developing explosion to limit flame speeds and reduce over-pressure. To interact effectively with the flame front of a developing explosion the water must be in the form of very fine droplets. However, such small droplets may get swept ahead of the flame and never interact with it. By contrast, large water droplets, of the size produced by deluge systems, have sufficient inertia to not be swept away rapidly and if flow speeds are sufficiently high they are broken up into small droplets by the accelerating gas flow ahead of the flame front, and are then conveniently placed to interact with the flame front. Thus there is a mechanism by which water deluge systems can mitigate gas explosions but there are disadvantages as well as potential benefits.

(a) Potential benefits:

In modules where high flame speeds can be achieved the resultant over-pressure may be significantly reduced if the deluge operates before the explosion occurs. It should be noted, however, that in experiments the best results have been achieved using nozzles that produce larger droplets and at higher water application rates than are used for general area protection.

In modules where large external explosion over-pressures may occur through venting of unburned gas, followed by ignition from the internal explosion, water deluge in the module may be effective in reducing the severity of the external explosion and hence blast damage to adjacent modules.

All key modules have general area protection deluge systems and gas detection systems that could be used to initiate the deluge in response to a high gas alarm, so the cost of implementation would not be great and the potential Implied Cost to Avert a Fatality (ICAF) would be low.

Mitigation by deluge may be the only option available for very high explosion risk modules.

(b) Disadvantages:

The mitigating mechanism only works for severe explosions with high flame speeds generated by congested layouts and will be ineffective if the over-pressure is largely the result of confinement.

Activating the deluge will increase turbulence of the gas cloud, resulting in higher flame speeds and over-pressures, which in the case of low flame speed explosions will not be offset by the subsequent mitigating effect of the water.

Severe explosions may not occur in the majority of release and ignition scenarios because worst-case conditions are not achieved. Thus in the majority of cases deluge may increase the over-pressure by generating turbulence and result in a net increase in risk.

Operation of the deluge often requires HVAC to be shutdown, greatly reducing ventilation that may otherwise aid the safe dispersion of the gas.

The deluge may result in water ingress into electrical equipment and this will in turn increase the probability of fault conditions that create incendiary sparks. This hazard may, in terms of ignition probability, outweigh the potential explosion mitigation benefits.

The deluge must be operating before the ignition and explosion occurs, and so it must be activated automatically in response to high gas alarms. Even so, the detection and response time will be of the order of 60 seconds, during which time the gas may have ignited already.

Adopting a policy of deluge in response to high gas alarm may result in many spurious releases of the deluge. This may in turn result in increased ignition probabilities due to deterioration of electrical equipment and increased leak probabilities due to corrosion failures (particularly corrosion under insulation for carbon steel and stress corrosion cracking for stainless steel) and cold shock failures, particularly leakage at flanges. Damage created by spurious deluge releases will increase the maintenance workload and its associated risks.

Reliance on the deluge system for explosion mitigation may result in it being re-classified as a safety-critical system, requiring enhanced integrity and more regular testing.

With the deluge operating, the escape of personnel caught in the area may be made more difficult, slowing their retreat time and increasing the possibility of being caught in the explosion. It will also make closed circuit television surveillance of the area impossible and thus operators will be unable to see any trapped personnel or identify the equipment that has failed.

11.2 RECOMMENDATIONS

Deluge activation in response to gas detection, to mitigate a possible explosion, has many disadvantages as well as potential benefits. Therefore the current recommendations are not to rely on deluging to mitigate explosions and to not activate the deluge in response to a high gas alarm.

This topic is the subject of on-going research and specific guidance should be sought if deluge is considered to be the only option available to mitigate severe explosion hazards.

12. SPECIFIC FACILITY PROTECTION

This section describes typical policies that may be adopted in the FES for specific areas.

12.1 WELLHEAD AREAS

The wellhead area including wellheads, flow-lines, manifolds (when located on the wellhead side of the blast division), etc. should be regarded as a single fire area to be covered by a deluge system, unless adequate physical separation is provided to sub-divide it into separate areas.

Dedicated Equipment Protection should be considered for wellheads which are likely to convey hydrocarbons. The objective is to prolong the integrity of wellheads subject to fire to prevent escalation and to contain and possibly extinguish a fire originating from a wellhead. For new projects the numbers and locations of these wellheads may not be known. As the distribution system should cover all wellheads, the deluge valve and supply should be sized for the maximum number of wellheads anticipated to convey hydrocarbons. These nozzle connections should initially be plugged and as wellheads are identified as likely to convey hydrocarbons, the plugs should be replaced with nozzles intended for use as identified in the design.

The types and location of nozzles should be selected to minimise interference with the drilling sequence, work-overs, maintenance, etc.

High-velocity sprayers have been found to be effective in achieving the required water application rate (see Table 8.2). A minimum of 2 nozzles per wellhead should be installed and these should be positioned to spray upwards from low level so as to protect the lower region of the wellhead and lift the water spray, thereby increasing protection to the upper portions of the wellhead and surrounding equipment.

Flow-lines and manifolds not protected by Equipment Protection should be provided with Area Protection.

Fixed and/or fixed automatic oscillating monitors may be used to apply water to specific targets, protecting fire-fighters and escape routes and cooling areas at the boundary of the fire-affected area. Monitors may be used simultaneously with any deluge system to prevent escalation by means of discretionary boundary cooling or to protect personnel.

12.2 FLARE KNOCKOUT DRUM

If protecting the flare knockout drum or associated structures/pipework is identified as vital, Passive Fire Protection should be considered as the primary protection technique.

12.3 RISER ISOLATION VALVING AND PIPEWORK

The need to protect risers, riser isolation valving and cross-platform interconnecting pipework should be carefully evaluated.

Passive Fire Protection is preferred to water deluge for riser elements essential to the integrity of the riser outboard of the ESD valve (including the ESD valve itself).

Deluge or automatic monitor protection of cross-over piping inboard of the riser ESD valve should be considered on all manned platforms except those where a Temporary Refuge is located on an adjacent bridge-linked structure. On these multi-platform facilities it is not usually necessary to provide automatic fixed firewater protection of cross-over piping provided that the specific risk is demonstrated to be tolerable. The basis for such a decision shall be that fire or explosion around the cross-over is not very likely to threaten the main areas used to muster personnel and that manual systems can be applied to contain an incident.

12.4 PROCESS AREAS

Process areas should, wherever practicable, be regarded as a single fire area unless adequate physical separation is provided to sub-divide it into different deluge zones. For modules/areas (e.g. integrated naturally ventilated decks) where a fire is likely to trigger deluge in the adjacent fire areas and hence place additional demand on the firewater system, consideration should be given to sub-dividing the system on each level to allow partial isolation, thus permitting efficient deployment of firewater.

Low-pressure vessels, especially those with a small liquid content, may not contain sufficient inventory to generate a severe fire which can escalate to other areas and equipment when Area Protection is active. However, consideration should be given to providing Equipment Protection to such low-pressure vessels if there is the likelihood of a BLEVE (Boiling Liquid Expanding Vapour Explosion) type failure of the vessel.

Vessels containing a small quantity of flammable liquid or gas may not require Equipment Protection deluge providing there is adequate Area Protection and it is demonstrated that ignited releases of hydrocarbon from the vessel would not jeopardise the integrity of critical safety equipment. For this equipment the use of monitors to supplement the area deluge system should be considered. If it can be demonstrated that blowdown can be achieved within a time deemed sufficient to avoid escalation, then it may not be necessary to protect specific equipment, e.g. compressors.

If pipework or vessels containing hydrocarbons are located in, or pass through, the beam space then additional spray heads should be located above such pipes or vessels.

Deluge systems should not be specified to prevent escalation of jet fires.

12.5 DRILLING DERRICK AND SUBSTRUCTURE

The design philosophy for drilling derrick and substructure should consider the requirements for personnel, structural and equipment protection.

Deluge system and/or fixed monitors should be considered in the drill floor area to provide protection for personnel from radiated heat and for any equipment which may be used to control the well, i.e. BOP control panel, choke/kill manifold, doghouse, etc. Deluge protection may also be considered for the "Poor Boy" degasser on the drill floor.

If provided, automatic deluge systems protecting the drilling module and drilling substructure may be taken out of automatic mode to allow manual operation at the Drilling Supervisor's discretion, either at the local deluge valve or by the actuation of a suitably located electrical or pneumatic shielded push-button.

12.6 STRUCTURAL PROTECTION

All the primary load-bearing structural steelwork (with the exception of that essential to the support of a Temporary Refuge) in process and wellhead areas, or in any area that contains a significant fire hazard, may be protected either by deluge or PFP. If deluge is adopted it should be installed so as to minimise local damage. Structures essential to the integrity of the TR and EER facilities should be protected by PFP.

For structural protection, deluge systems should use either medium/high-velocity sprayers or specialised nozzles (e.g. incorporating a narrow spray pattern to reduce wastage).

The water application rate for plant and primary load-bearing structural steelwork should be at least 10.2 litres per minute per square metre over the surface area of the structural member.

Spray heads should be located on the side of the steelwork facing the area protected by the deluge system supplying the spray heads. In the case of a structural member located entirely within the protected area, spray heads should alternate on either side of the member to achieve the discharge density over the wetted area as specified above and detailed in (Figures 7 and 8.)

12.7 HELIDECK

12.7.1 Overall goal

The overall goal of a helideck fire protection system is to prevent and/or extinguish helicopter/aviation fuel fires that may occur on a helideck by the rapid, reliable, secure and effective distribution of foam solution.

12.7.2 Fire protection systems

If the FES identifies that a fire-fighting capability is required for a helideck it should consist of fixed, self-oscillating monitors with a local dedicated foam system. The number of monitors required should be identified in the FES. In general two or more monitors should be provided.

In addition to this system, the following manual and portable fire-fighting equipment shall be provided:

- carbon dioxide extinguishers with extension applicators with an aggregate capacity of not less than 22.5 kg;
- dry powder extinguishers of an aggregate capacity of not less than 45 kg (100 lb);
- a twin-outlet fire hydrant installed in at least two of the helideck passenger access points;
- a cabinet containing the fire-fighting equipment.

Positions should be allocated on or near the helideck to be called the "HELICOPTER LANDING OFFICER'S (HLO) POSITIONS".

These positions should be the focal point for fire-fighting and control actions during an emergency and should be suitably marked on the Installation Safety Plan.

There should normally be two HLO positions and, wherever practicable, each position should be located adjacent to a helideck foam monitor and may form part of a helideck access platform.

There is normally no requirement to have an HLO position adjacent to each monitor if three or more monitors are installed.

A firewater pump start switch should be located at each HLO position.

A control valve should also be located at each HLO position, to allow the HLO to start and stop all helideck fire-fighting monitors from this location.

12.7.3 Foam system

Foam should be immediately available to the helideck area and allow rapid response to a helicopter crash. Local legislation will determine response time but it should not be more than 30 seconds. The supply arrangements should be such that there will be no interruption in supply during fire-fighting. The system provided should be a dedicated system supplying the helideck area alone and should use a reliable source of firewater.

The system provided should not impede escape or evacuation routes and should not hinder evacuation from the offshore facility in any way.

The system should be suitable for a range of firewater pressures including an allowance for surge immediately after start-up.

The coverage of the foam system should comply with applicable local Civil Aviation guidelines (e.g. CAP 437 in the United Kingdom). The fire-fighting foam system provided should be sufficient for the largest helicopter likely to land.

The application rate of foam should be based on the performance of the foam concentrate provided which should not be less than that required for foams meeting ICAO performance level "B", i.e. 5.5 litres per minute per square metre as detailed in CAP 168.

The size of the foam tanks supplied should provide sufficient foam solution to extinguish or control all credible helideck incident scenarios.

The helideck foam system should be capable of initiation from nominated HLO positions.

Similarly, the firewater pump must also be capable of being started from at least two separate positions including any nominated HLO positions.

The foam storage facilities should preferably be located adjacent to the monitors. The control valve should be a manually operated valve, located immediately upstream of the foam storage skid and suitably sized to permit the effective operation of all the helideck monitors. Control valves should be clearly marked and accessible.

If the foam storage facilities are located remote from the monitors, then the control valve should be a manually operated pneumatic control valve. Wherever practicable however, preference should be given to locating the manually operated in-line control valve at the HLO's positions and the use of pneumatics should be avoided.

As pneumatic control valves are relatively compact, and to minimise corrosion, each pneumatic control valve should be located within a cabinet manufactured from suitable materials. Each cabinet should incorporate a non-lockable front access door and should be clearly marked "FOAM MONITOR CONTROL CABINET".

The duty firewater pump start switch may also be located within the cabinet.

Each helideck foam monitor shall be supplied with firewater/foam solution via a dedicated foam tank assembly. Each dedicated foam tank should be of such size that it is capable of supplying at least 10 minutes foam concentrate to the associated helideck monitor.

To ensure system reliability upon loss of the offshore facility’s air pressure, a stainless steel air reservoir may be incorporated. The air reservoir should be sized to open and close the valve three times and have a minimum volume of 10 litres. The reservoir should be connected to the offshore facility’s instrument air supply and should be designed in accordance with project requirements.

On offshore facilities without an instrument air supply or on unmanned offshore facilities, the helideck foam monitors (where installed) should be locally controlled by the manual operation of a valve located upstream of the foam tank assembly.

To prevent drain-down of the foam tank through the pump when static, the outlet flange from the foam skid should be located at the same elevation as the top of the foam tank.

Immediately after use, the pipework between the monitor and the foam skid should be drained down. Contamination of the foam concentrate by the firewater when static should be prevented by the inclusion of suitable valving.

Foam packages and monitors should be supplied via a firewater sub-main located under the helideck, incorporating adequate isolation valves to ensure firewater supply from two directions.

Block valves that isolate the helideck firewater sub-main from the helideck foam storage facilities may require fire-safe certification. This is to ensure valve operation even after severe overheating so as to guarantee system isolation and prevent foam losses in the event of pipework damage during and after a fire.

It is essential when designing helideck protection systems to ensure that full account is taken of all potential losses of pressure and flow between the firewater pump and the monitor discharge nozzles due to Pelton Wheel demand, friction loss through pipework, fittings and equipment, differences of elevation, etc.

In one method of foam proportioning commonly used on helidecks, a small amount of the firewater supply is used to drive a Pelton Wheel water motor, which in turn drives a pump via a reduction gearbox and coupling.

Such a system should be designed to operate immediately and effectively upon a pressurised firewater stream reaching the Pelton Wheel, despite the assembly having remained unattended, and in an exposed environment for a prolonged period.

The proportioning system is normally dedicated to a single firewater monitor.

A schematic of the above system is given in (Figure 11).

12.7.4 Oscillating monitors

Firewater/foam solution should normally be applied via monitors of water-powered, automatically oscillating, low-profile design. Consideration can be given to other means of applying foam solution if they are fit for purpose and will be at least as effective as oscillating monitors under the prevailing environmental conditions.

The monitors should be spaced equidistantly around the perimeter of the helideck taking into account the orientation of the offshore facility and worst-case wind conditions. If three monitors are installed, each should be capable of projecting a minimum of 50% of the total foam solution demand, with the discharged spray solution reaching to the far side of the helicopter landing area under the worst anticipated wind conditions.

Monitors should be positioned so that when in operation the water jets will not impede the escape of passengers from the helicopter.

Foam monitors should use a constant-flow nozzle to prevent the foam concentrate pick-up rate varying with firewater flow rate. The nozzle "K" factor should therefore match the Pelton Wheel characteristics. Refer to (Figure 12.1) for a typical layout and (Figures 12.2 and 12.3) for typical proportioning and oscillating monitor equipment.

12.7.5 Pipework and fittings

The inlet and discharge flanges of the foam system unit described above should terminate at a common skid edge, suitable for connection to horizontal pipework. The discharge flange should be positioned at the same elevation as the top of the tank, to prevent drainage of the tank through the pump and check valve.

The Pelton Wheel driven pump discharge line should incorporate a suitably sized relief valve arrangement that shall discharge foam concentrate back to the bottom of the tank when pumping against a closed valve.

The pump discharge pipework should incorporate a pressure gauge and check valve. All pressure gauges should be liquid filled, 100 mm face with Monel trim, incorporate an isolation valve and be suitably mounted to minimise the effects of vibration.

The firewater inlet line to the Pelton Wheel should incorporate a pressure gauge, filter and isolation valve.

The pipework between the tank and the pump shall incorporate an isolation valve and a flushing connection.

The Manufacturer/Supplier should incorporate a suitable throttling valve on the pump line to permit minor adjustments. The throttling valve should have a removable handle and should be capable of being locked into position.

12.7.6 Pump and gearbox

The pump should be of the gear-type positive displacement design.

The pump should be of a proprietary design and manufacture and should be suitable for use in an exposed environment when permanently filled with AFFF concentrate.

The pump should be designed to run with the foam tank empty and the Manufacturer/Supplier should clearly state the anticipated operating life of the pump when running under this condition.

The Pelton Wheel should be of proprietary design and manufacture, with a proven record offshore and shall discharge directly onto the deck, externally of the skid. The Pelton Wheel should be suitably sized to minimise water usage but should provide sufficient power to maintain pump accuracy across the system operating range.

The gearbox should be designed to optimise the performance of the Pelton Wheel and pump. The Manufacturer/Supplier should supply design calculations if required to do so in the requisition.

Typical materials of construction are as follows:

- Pump:

Body	-	Gunmetal to BS 1400 (LG2)
Rotors	-	Phosphor bronze to BS 1400 (PB2)
Shaft	-	Stainless steel to BS 970 (320 S17 or 316 S16)
Bearings	-	Steel/PTFE DTD-900-4575A

- Relief valve:

Body	-	Gunmetal to BS 1400 (LG2)
Trim and spring	-	Stainless steel (316S)

- Gearbox:

Case	-	Gunmetal to BS 1400 (LG2) impregnated with polyester resin approved by the Principal
Shafts	-	Stainless steel to BS 970 (320 S17 or 316 S16)

12.7.7 Foam storage tanks

The foam storage tank should typically be constructed of approved glass-reinforced plastic (GRP) such as isophthallic polyester fibreglass. Orthophthallic polyester fibreglass composites and/or room-temperature-cured epoxy systems should not be used. Method of construction and stiffening should be in accordance with local/international codes of practice.

Tank fittings:

- Inspection opening (min. clear inside diameter 150 mm), incorporating lockable hinged cover and vent arrangement. Material of cover to be stainless steel (316) or same as tank body;
- Clear isophthallic polyester strip moulded into tank to act as level gauge;
- 4-inch diameter filling connection with anti-froth tube and quick-release cap in stainless steel;
- Drain connection;
- Relief valve return line (anti-froth).

12.7.8 Skid

The complete assembly should be as compact as possible and should be mounted on a skid. Overall skid height should not exceed 1 m, where practicable, to allow a typical installation position on the access platform adjacent to the helideck.

The Manufacturer/Supplier should ensure that the skid and all ancillary equipment is of sufficient strength to allow installation and withstand motion in a barge at sea. Lifting and fixing eyes should also be provided.

A nameplate/instruction plate of corrosion-resistant material (i.e. austenitic stainless steel or cast bronze) should be provided and secured in a prominent position on the skid. The following information should be displayed:

- manufacturer's name and/or identification mark;
- tank capacity;
- type of concentrate;
- any start-up instructions.

12.8 ACCOMMODATION AREAS

The FES should identify the Active Fire Protection requirement for accommodation areas. The following is a typical methodology for protection of accommodation areas:

(i) Corridors and stairwells - automatic sprinklers are provided in accordance with (Section 7). Additionally water hose reels and water extinguishers are provided.
Fire doors in corridors should have magnetic latches released upon a change in platform status.

(ii) Cabins - automatic sprinklers.

(iii) Offices/Public Rooms/Sick Bay - automatic sprinklers.
Additionally public rooms are provided with water extinguishers.

(iv) Galley - automatic sprinklers. Additional CO_2 extinguishers and fire blankets are provided. The deep fat fryer is provided with a drop-down lid held open by a fusible link.

(v) Galley hood/Extract duct - Local carbon dioxide extinguishing system.

(vi) Radio/Switchgear/Telecom Equipment/HVAC Plant Rooms - CO_2 extinguisher.

See also DEP 37.17.10.10-Gen.

13. REFERENCES

In this DEP reference is made to the following publications:

NOTE: Unless specifically designated by date, the latest edition of each publication shall be used together with any amendments/supplements/revisions thereto.

SHELL STANDARDS

Index to DEP publications and standard specifications	DEP 00.00.05.05-Gen.
Piping classes - Basis of Design	DEP 31.38.01.10-Gen.
EP Piping classes	DEP 31.38.01.15-Gen.
Design and installation of glass-fibre reinforced epoxy and polyester piping	DEP 31.38.70.24-Gen.
Fire, gas and smoke detection systems	DEP 32.30.20.11-Gen.
Classification and implementation of instrumented protective functions	DEP 32.80.10.10-Gen.
Design of offshore living quarters	DEP 37.17.10.10-Gen.
Active fire protection systems and equipment for onshore facilities	DEP 80.47.10.31-Gen.
Health, safety and environmental management systems	EP 95-0100
Hazards and effects management process tools and techniques	EP 95-0300
FIREPRAN	EP 95-0350
Fire control and recovery	EP 95-0351
Shell Safety and Health Committee Noise Guide	

AMERICAN STANDARDS

Low expansion foam	NFPA 11
Installation of sprinkler systems	NFPA 13
Water spray fixed systems for fire protection	NFPA 15
Centrifugal fire pumps	NFPA 20
Inspection, testing and maintenance of water-based fire protection systems	NFPA 25

Issued by:
National Fire Protection Association
470 Atlantic Avenue
Boston, Massachusetts, 02210
USA.

ASME boiler and pressure vessel code,

Section VIII, Division 1 - Rules for construction of pressure vessels	ASME VIII, Div. 1

Issued by:
American Society of Mechanical Engineers
345 East 47th Street
New York NY 10017
USA.

Foam equipment and liquid concentrates	UL 162

Issued by:

Underwriters Laboratories Inc.
333 Pfingsten Road
Northbrook
IL 60062-2096
USA.

Military Specification, Fire Extinguishing Agent AFFF for fresh and sea water	MIL-F-24385

Issued by:
Superintendent of Documents
U.S. Government Printing Office
Washington
DC 20402
USA.

Steel castings, welding, qualifications of procedures and personnel	ASTM A488
Gray Iron castings for pressure-containing parts for temperatures up to 650° F	ASTM A278
Ductile iron castings	ASTM A536
Ferritic ductile iron pressure-retaining castings for use at elevated temperatures	ASTM A395

Issued by:
American Society for Testing and Materials
100 Barr harbor Drive
West Conshohocken, PA 19428-2959
USA.

BRITISH STANDARDS

C.A.A. Document licensing of aerodromes	CAP 168
C.A.A. Document offshore helicopter landing areas: guidance on standards	CAP 437

Issued by:
Civil Aviation Authority
Greville House
37 Gratton Road
Cheltenham
Glocs. GL50 2BN
United Kingdom.

Recommendations for the protection of diesel engines for use in Zone 2 Hazardous Areas (1992)	EEMUA 107

Issued by:
Engineering Equipment and Materials Users Association
14-15 Belgrave Square
London SW1X 8PS
United Kingdom.

UK Ministry of Defence: Foam Liquid, Fire Extinguishing (Fluorochemical Type)	UK Defence Standard 42

Issued by:
Ministry of Defence
Directorate of Standardisation
First Avenue House
High Holborn
London WC1V 6HE
United Kingdom.

International convention for the safety of life at sea	SOLAS

Issued by:
International Maritime Organization
4 Albert Embankment
London SE1 7SR

United Kingdom.

Specifications for copper alloy ingots and high conductivity copper castings	BS 1400
Specification for wrought steels for mechanical and allied engineering	BS 970

Issued by:
British Standards Institution
389 Chiswick High Road
London W4 4AL United Kingdom

INTERNATIONAL STANDARDS

Airport Services Manual, Document 9137 - AN/898, Part 1, Rescue and Fire fighting	ICAO 9137-AN/898-1 Third Edition, 1990

Issued by:
International Civil Aviation Organisation
ICAO
International Aviation Building
1080 University Street, Montreal
Canada.

Petroleum and natural gas industries - Control and Mitigation of Fires and Explosions on Offshore Installations - Requirements and Guidelines	ISO/DIS 13702

Issued by:
International Organization for Standardization
1, rue de Varembé
CH-1211 Geneve 20
Switzerland.
Copies may also be obtained from national standards organisations

FIGURE 1 FIREWATER MAIN SYSTEM ELEMENTS

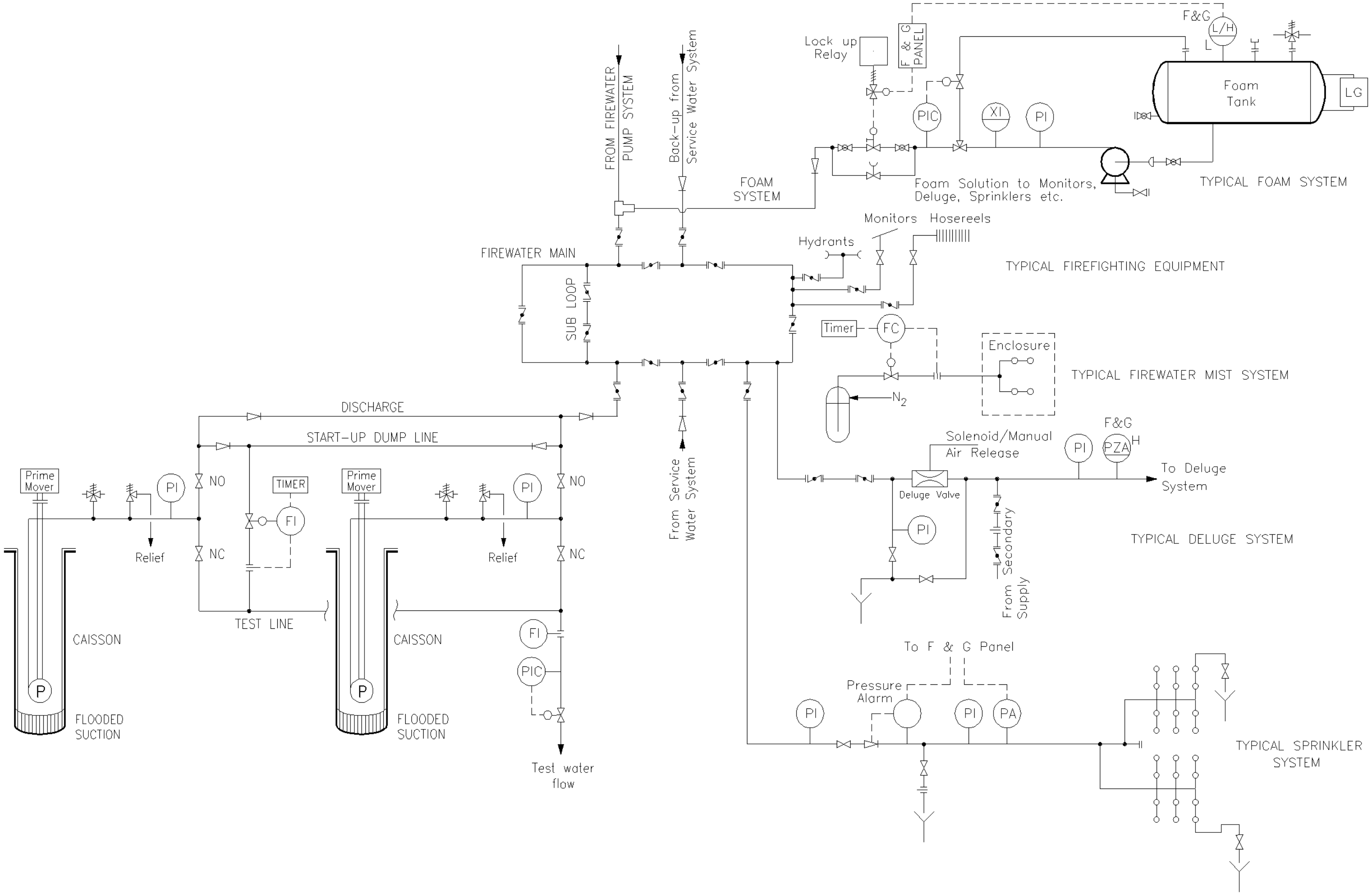


FIGURE 2 FIREWATER PUMP PIPING AND INSTRUMENT DIAGRAM

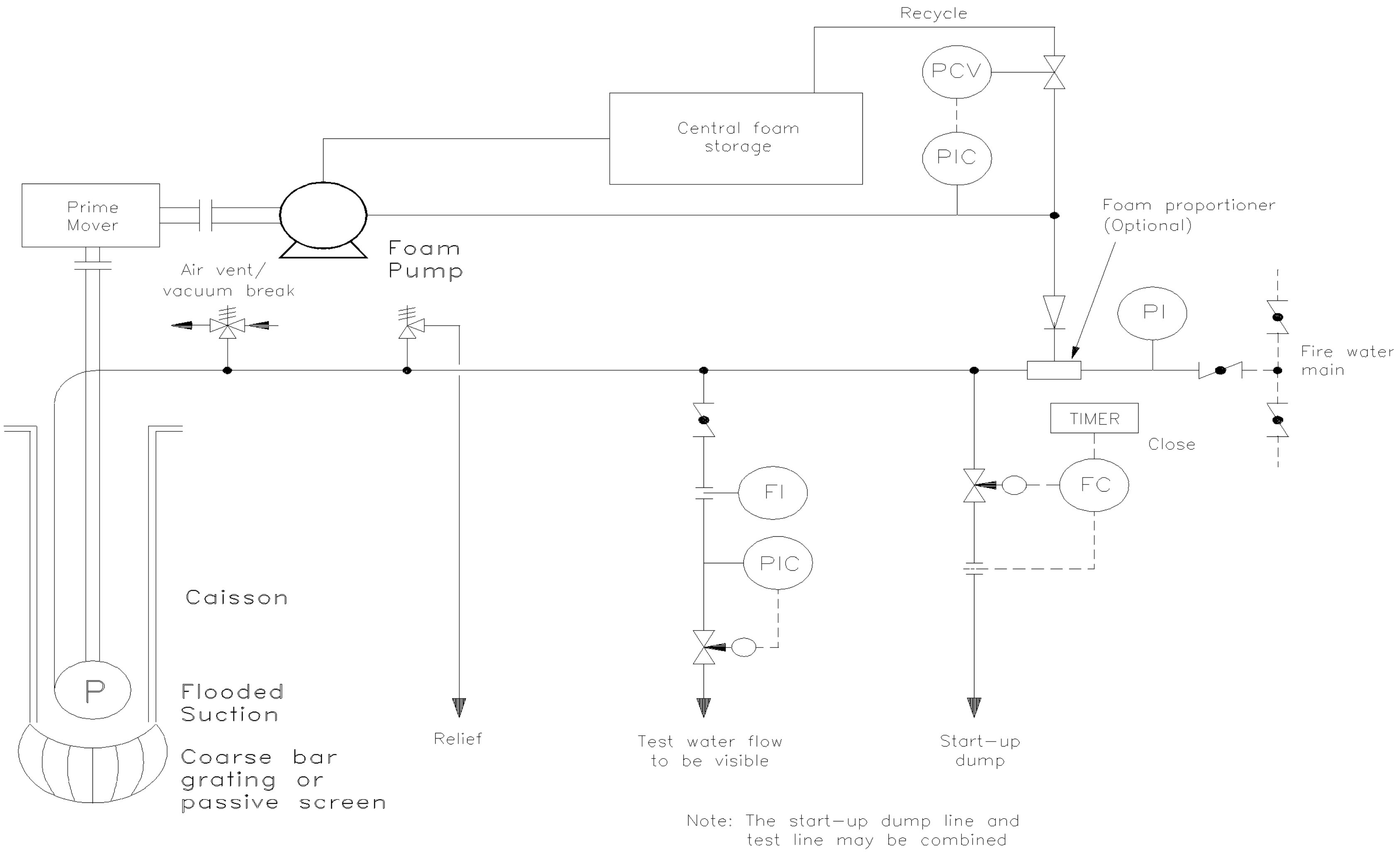


FIGURE 3 FIRE AND GAS DETECTION AND SHUTDOWN LOGIC

		FGP annunciation	Platform alert	Platform hazard	Shutdown HVAC	Close fire damper (normal supply)	Close fire damper (combustion supply)	Inhibit auto/elec pump station	Transfer pump duty to another unit	Isolation non Zone 1 electrics	Operate fire protection	Local manual start available
Fire water pump Running	Any single gas low	×										
	Any single gas high	×										
	Gas 2 out of 3 low duct	×	×									
	Gas 2 out of 3 high duct	×		×	×	×				×		
	Gas 2 out of 3 low enclosure	×	×									
	Gas 2 out of 3 high enclosure	×		×	×	×				×		
	Any single fire	×										
	Fire 2 out of 3	×		×	×	×					×	
Fire water pump Not running	Any single gas low	×										yes
	Any single gas high	×										yes
	Gas 2 out of 3 low duct	×	×									yes
	Gas 2 out of 3 high duct	×		×	×	×		×	×	×		yes
	Gas 2 out of 3 low enclosure	×	×									yes
	Gas 2 out of 3 high enclosure	×		×	×	×		×	×	×		yes
	Any single fire	×							×			yes
	Fire 2 out of 3	×		×	×	×		×	×		×	yes

NOTE:
This logic is applicable to each enclosure housing a diesel engine that powers a fire water pump unit.

FIGURE 4 SCHEMATIC DIAGRAM OF TYPICAL SPRINKLER SYSTEM (SALT WATER FILLED)

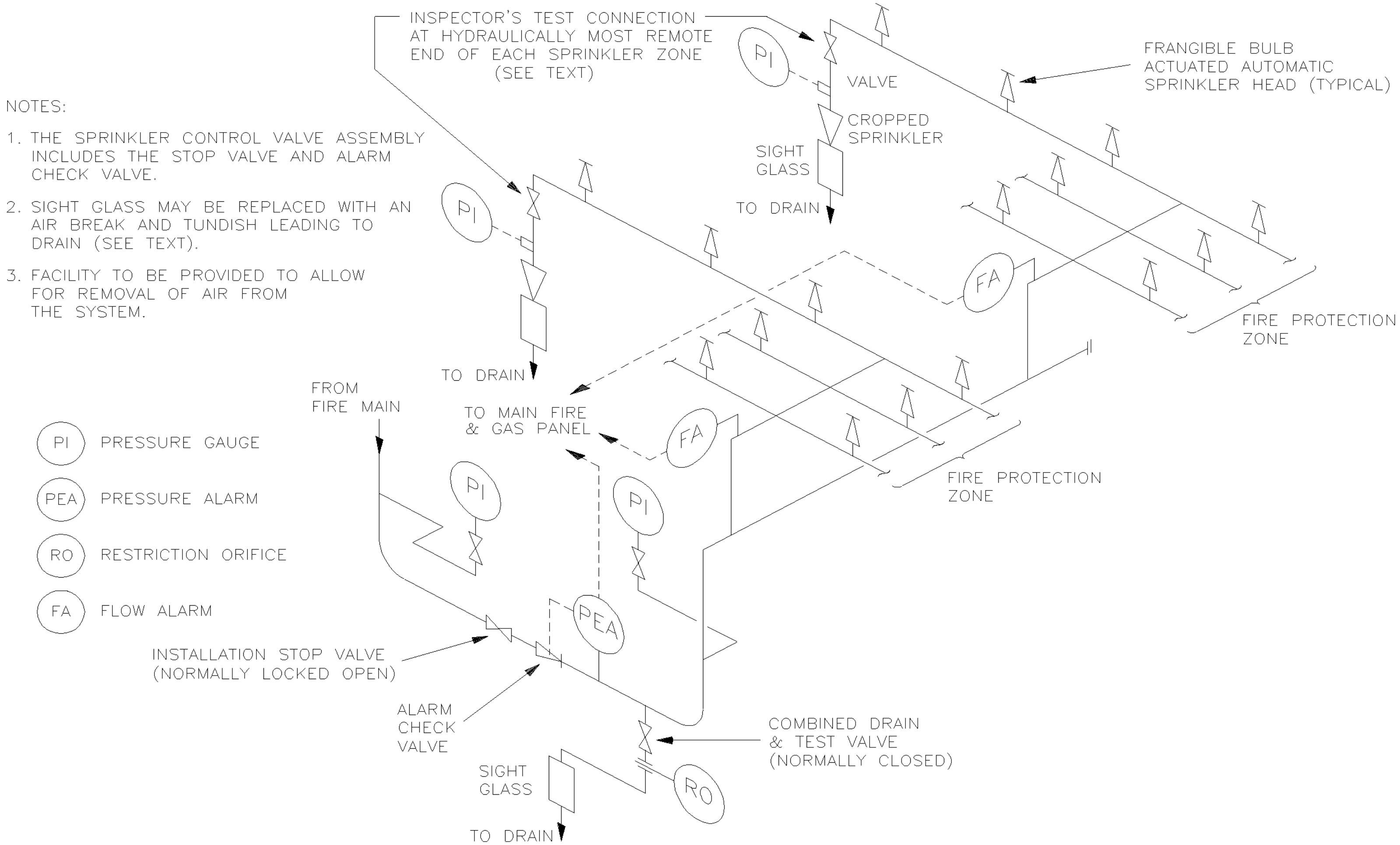
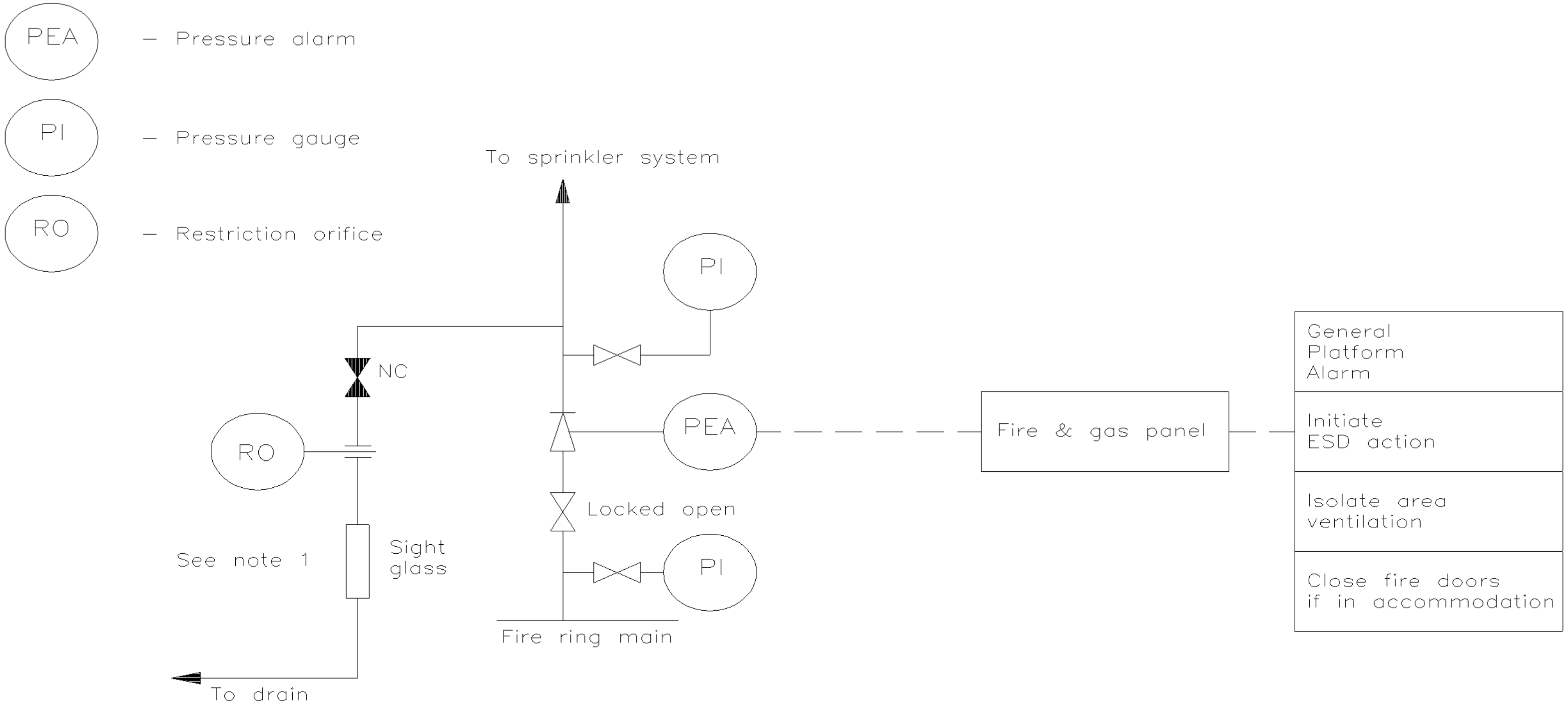
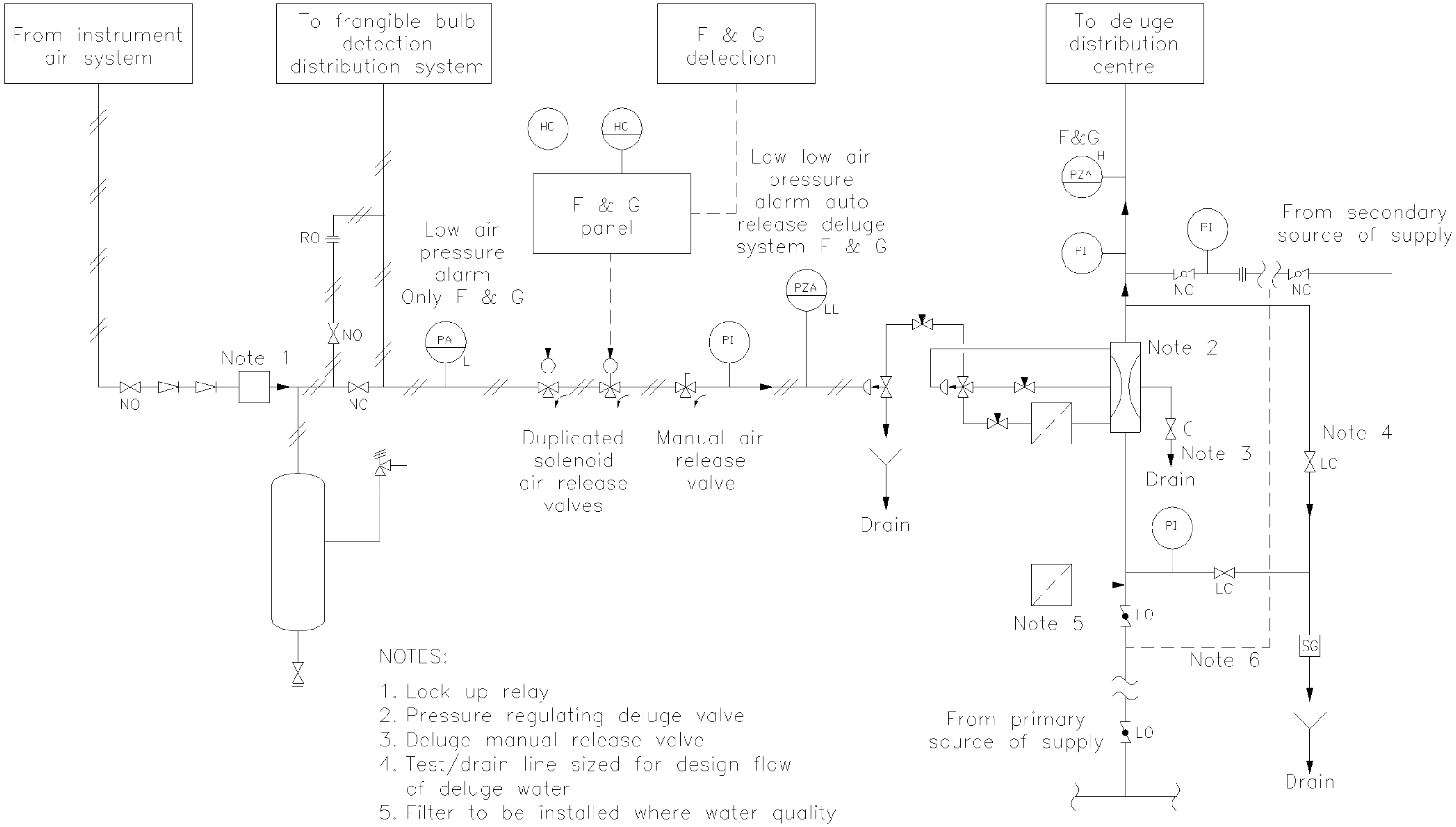


FIGURE 5 P&ID FOR TYPICAL SPRINKLER VALVE ASSEMBLY



NOTE 1: An air–break and tundish to drain may be provided in some cases as an alternative (see text)

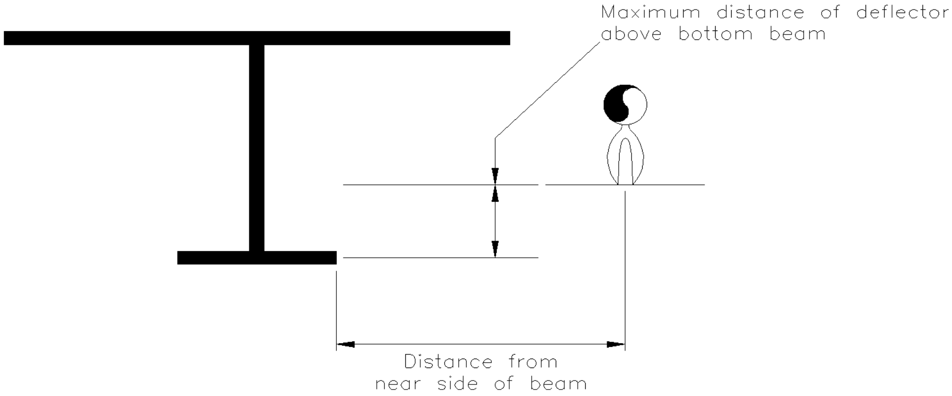
FIGURE 6 PEFS FOR TYPICAL DELUGE VALVE SET



NOTES:

1. Lock up relay
2. Pressure regulating deluge valve
3. Deluge manual release valve
4. Test/drain line sized for design flow of deluge water
5. Filter to be installed where water quality specification cannot be guaranteed
6. By-pass from primary supply only if a secondary supply is not provided

FIGURE 7 SPRAY HEAD LOCATION WITH RESPECT TO BEAMS



DISTANCE FROM SPRAY HEAD TO SIDE OF BEAM	MAXIMUM ALLOWABLE DISTANCE OF DEFLECTOR ABOVE BOTTOM OF BEAM
Less than 300 mm	0 mm
– 300 mm to less than 600 mm	25 mm
– 600 mm to less than 750 mm	50 mm
– 750 mm to less than 900 mm	75 mm
– 900 mm to less than 1050 mm	100 mm
– 1050 mm to less than 1200 mm	150 mm
– 1200 mm to less than 1350 mm	175 mm
– 1350 mm to less than 1520 mm	220 mm
– 1520 mm to less than 1700 mm	270 mm
– 1700 mm to less than 1825 mm	345 mm

FIGURE 8 NOZZLE LOCATION WITH RESPECT TO PRIMARY LOAD-BEARING STRUCTURES

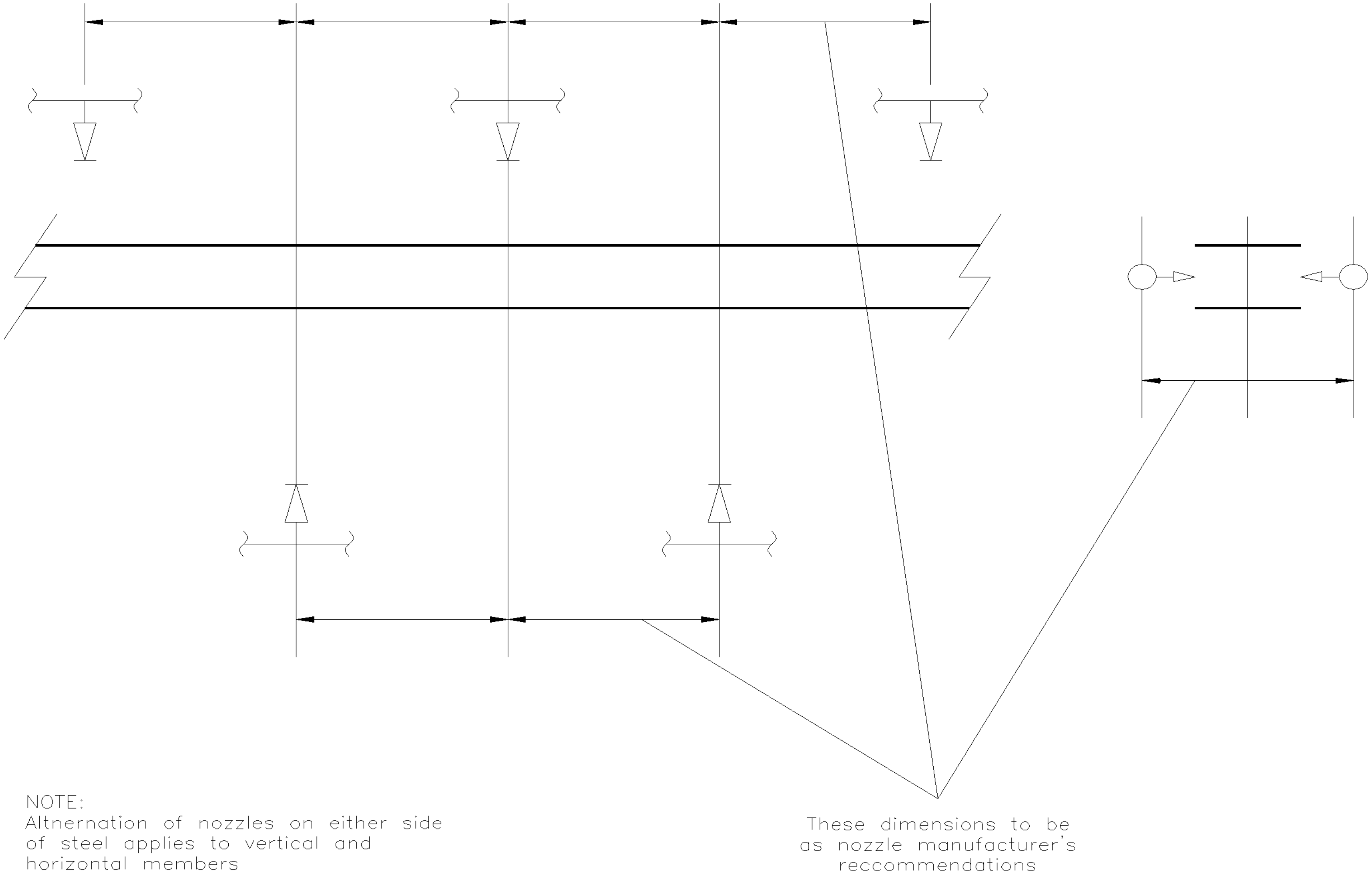
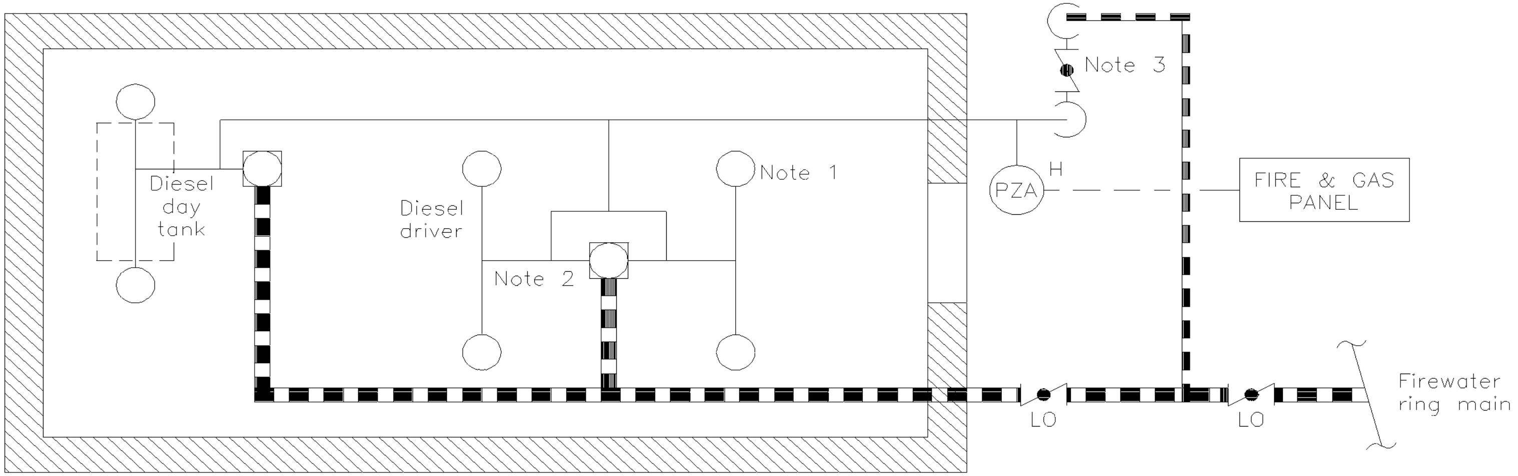


FIGURE 9 SCHEMATIC LAYOUT OF A TYPICAL MINI-DELUGE SYSTEM



NOTES:

1. Nozzle types to suit hazard.
   Number of nozzles operating shall be such that a water velocity of 4.6 m/s through supply pipe to any MJC (Multiple Jet Control) shall not be exceeded.

2. Number and location of MJC units to suit hazard

3. Location of manual by-pass valve to be easily accessible for operation, external to and adjacent to the protected area

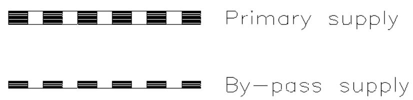
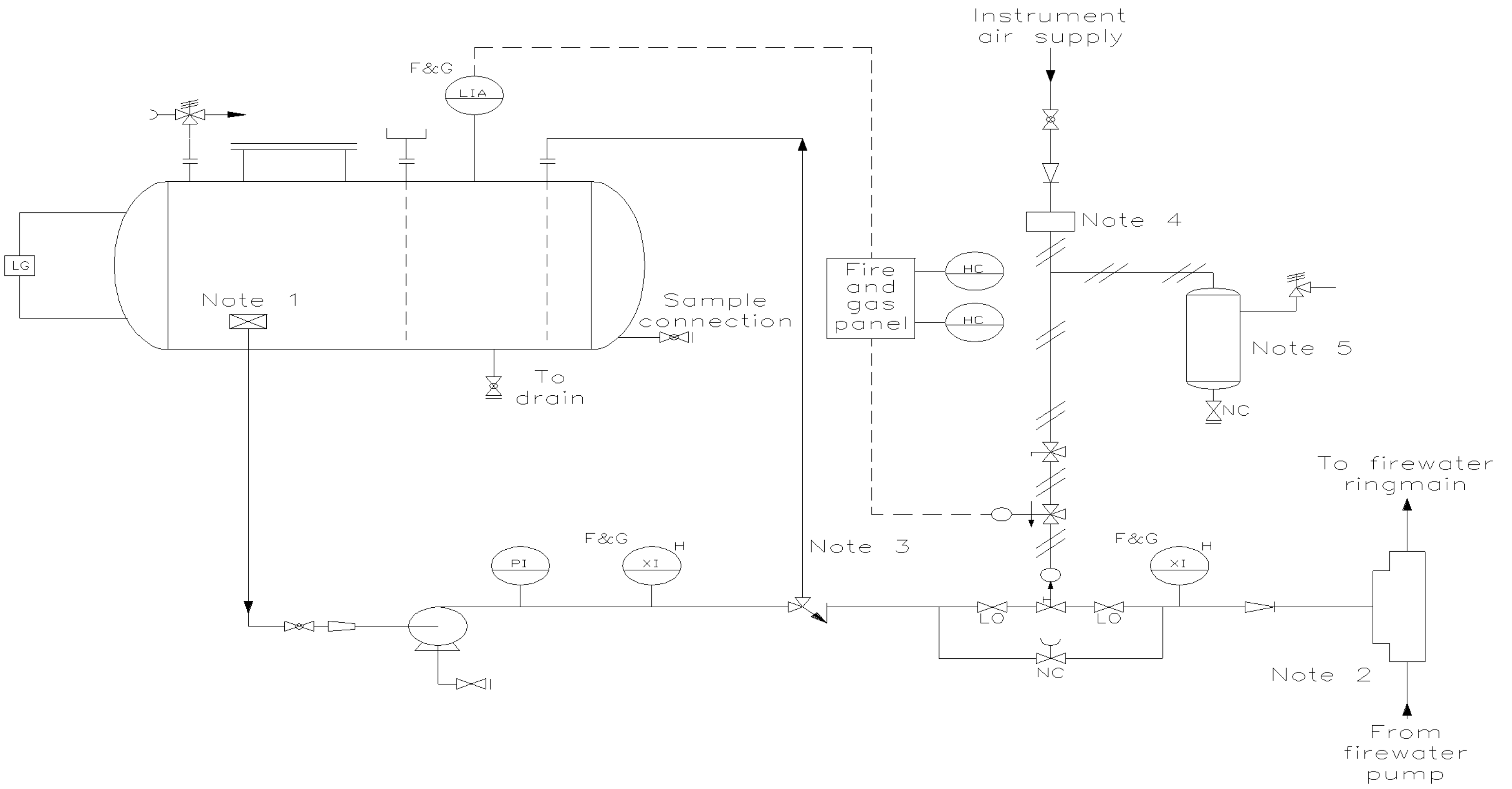


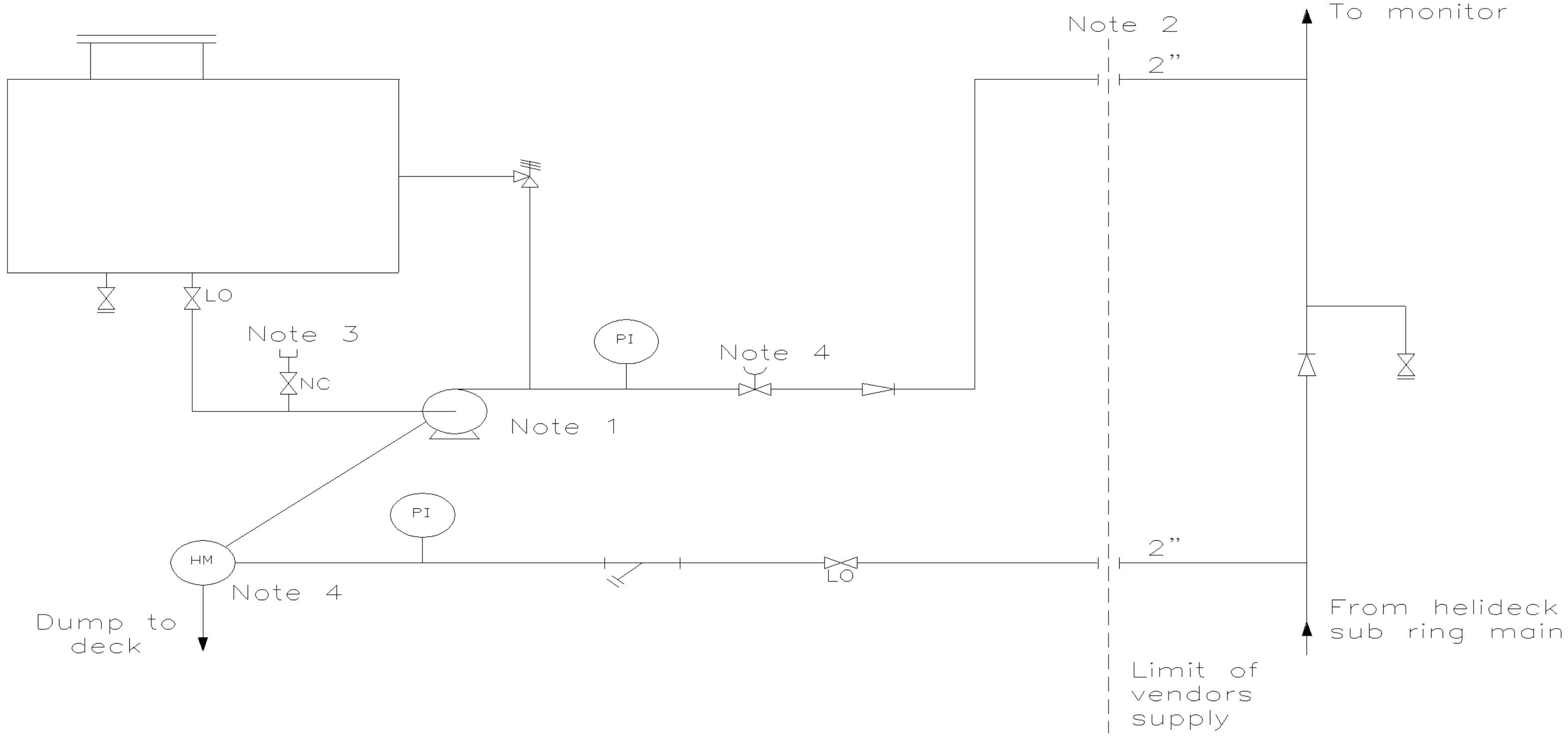
FIGURE 10 TYPICAL CENTRAL FOAM PROPORTIONING SCHEMATIC



NOTES:

1. Vortex breaker
2. Balanced pressure variable flow proportioner
3. Minimum flow bypass valve
4. Lock up relay
5. Backup air reservoir

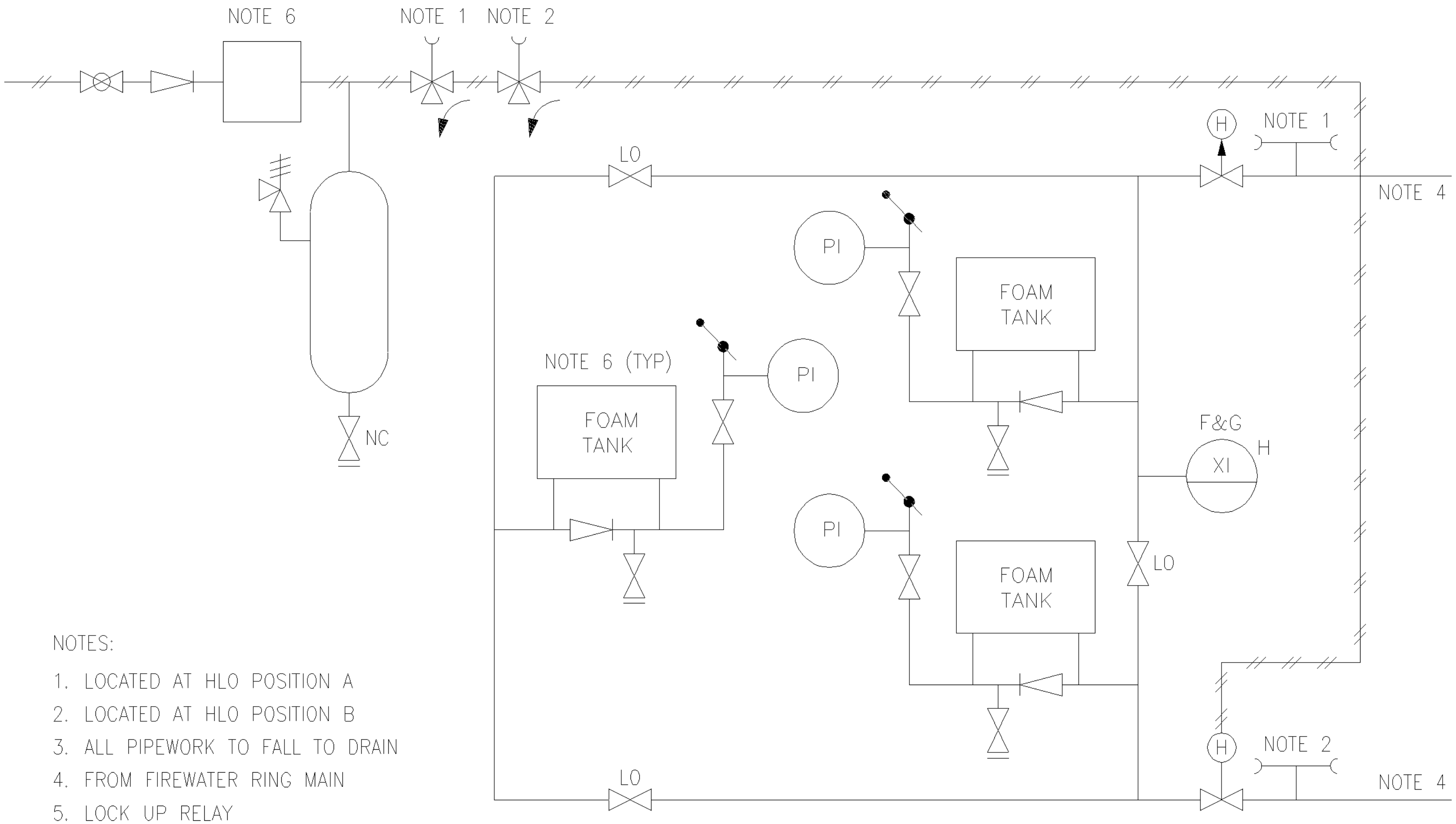
FIGURE 11 HELIDECK FIRE FIGHTING FOAM TANK SCHEMATIC



NOTES:

1. Pelton wheel water drawn motor
2. Skid interface discharge flange to be same elevation as top of foam tank
3. Flushing connection
4. Valve to be located in position after factory calibration

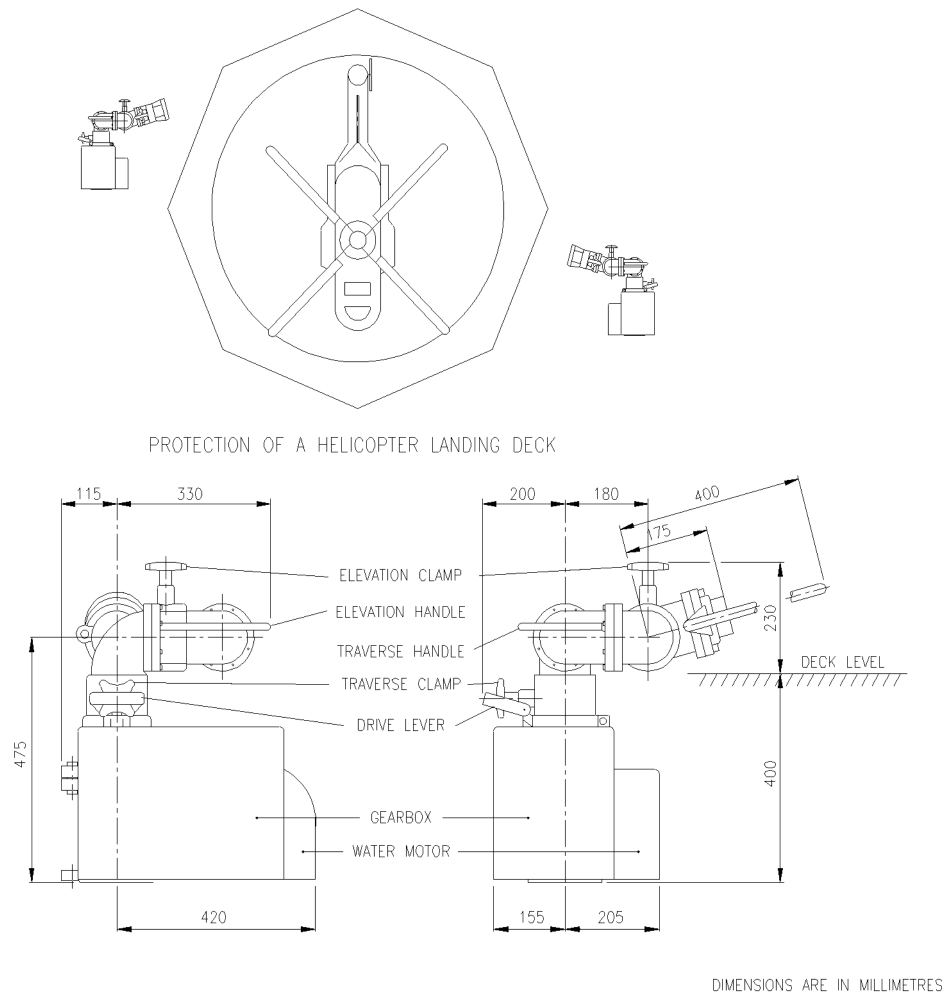
FIGURE 12.1 TYPICAL ARRANGEMENT FOR HELIDECK INCORPORATING 3 FIREWATER MONITORS (WITH REMOTE FOAM STORAGE TANKS) AND 2 HELICOPTER LANDING OFFICER'S POSITIONS



NOTES:

1. LOCATED AT HLO POSITION A
2. LOCATED AT HLO POSITION B
3. ALL PIPEWORK TO FALL TO DRAIN
4. FROM FIREWATER RING MAIN
5. LOCK UP RELAY
6. SEE FIGURE 11

FIGURE 12.2 TYPICAL OSCILLATING MONITORS USED FOR HELIDECK PROTECTION



OPERATION

	AUTOMATIC	MANUAL
SWEEP ANGLE	60° TO 120° IN 15° INCREMENTS	360° FULL ROTATION
ELEVATION	70° ABOVE TO 45° BELOW HORIZONTAL	
NOMINAL OSCILLATING FREQUENCY	6 cycles/min. @ 7 bar	–
NOMINAL FLOW RATE THROUGH WATER MOTOR	120 litres/min. @ 7 bar	–

SPECIFICATION

MAXIMUM WORKING PRESSURE	15 bar
MAXIMUM RECOMMENDED PRESSURE	5 bar
TEST PRESSURE	22.5 bar
WATERWAY INTERNAL DIAMETER	75 mm
MAXIMUM RECOMMENDED FLOW	1500 litres/min.
INLET FLANGE	COMPATIBLE WITH 4" BS 1560 ANSI CLASS 150 RF
OUTLET CONNECTION	2½" BSP MALE (3" BSP OPTION)
APPROXIMATE WEIGHT	117 kg

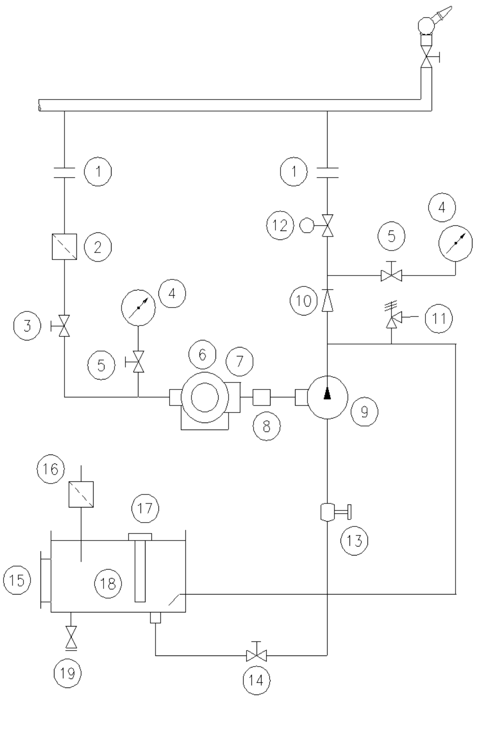
CONSTRUCTION MATERIAL

BODY	GUNMETAL LG4C/ALUMUNIUM BRONZE AB2
GEARBOX	CAST IRON
WATER MOTOR	PHOSPHOR BRONZE/GUNMETAL
FIRINGS	GUNMETAL LG4C
FASTENERS	STAINLESS STEEL

FIGURE 12.3 TYPICAL PROPORTIONING PACKAGE WITH HELIDECK PROTECTION SYSTEMS

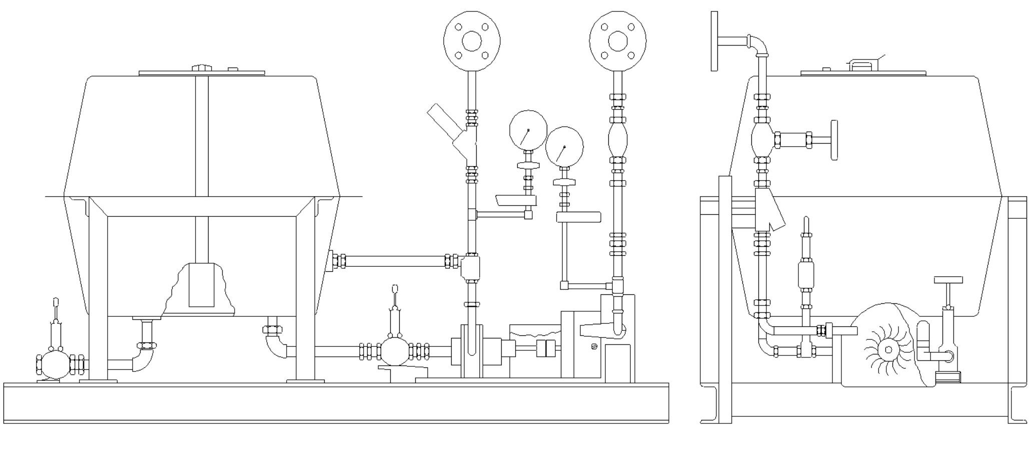
Product	HS 900	HS 1800	HS 2700
Type	Skid	Skid	Skid
Injected flow rate	1% – 10%	1% – 10%	1% – 10%
Injected flow at 7 bar l/min.	9	18	27
Running time min.	33	16	18
Nozzle flow at 7 bar l/min.	900	1800	2700
Injected flow at 5 bar l/min.	7.6	15	23
Running time min.	39	20	21
Injected flow at 10 bar l/min.	10.8	21.5	32.5
Running time min.	27	13	15
Injected flow at 15 bar l/min.	13	26.5	40
Running time min.	23	11	12
Operating pressure range	5 to 15 bar	5 to 15 bar	5 to 15 bar
Materials			
Seawater			
Specification†			
Tank	G.R.P. Isophthalic Based Polyester Resin with clear moulded level gauge and drain valve. Available in either 300 l, 500 l or 1000 l capacities.		
Pump	Gunmetal body, bronze rotors		
Gearbox (if fitted)	Gunmetal body, EN8M gears c\w flexible coupling		
Petton Wheel	Gunmetal		
Valves	Gunmetal body, screwed BSP (F)		
Fittings	Bronze, brazed connections		
Pipe	Cupro-Nickel 90/10		
Pressure gauges (if required)	S.S. case, monel trim c\w isolation valve		
Baseplate	Fabricated carbon steel RS 4360-500 fully qualified welding and N.D.T.		
Painting	To customer offshore specification		
Connections	2" ANSI 150 R.F. flanges		
Dimensions*			
Length m	1.8	2.0	2.0
Width m	1.0	1.0	1.0
Height m	1.2	1.25	1.4
Nett weight kg	220	230	255

† Alternative materials for freshwater are available on request
* Can be altered to suit requirements



SYSTEM SCHEMATIC DIAGRAM

1 Flange connection
2 Seawater filter (if req'd)
3 Isolation valve
4 Pressure gauge
5 Isolation valve for pressure gauge
6 Water turbine
7 Gearbox
8 Coupling (pump/gearbox)
9 Gearpump
10 Check valve
11 Relief valve (full flow)
12 Regulating valve
13 Pump flushing connection
14 Isolation valve
15 Foam sight gauge
16 Breather (foam tank)
17 Foam tank filler cap
18 Foam tank
19 Foam drain connection



APPENDIX 1 TYPICAL PERFORMANCE CRITERIA TEMPLATES

The following templates are given as examples for guidance only. They should be used in conjunction with the main text of this DEP in order to develop Performance Criteria specific to a particular installation in the four areas of Functionality, Reliability/Availability, Survivability and Dependencies/Interactions. It should be noted that any application rate figures for systems such as deluge systems are typical figures that would be applicable in many situations but they should not be used for a specific offshore facility without ensuring that they are relevant.

It is emphasised that these templates are generic in nature. Provision of a template does not imply that the system must be provided and, in any case, the Performance Criteria shall be facility-specific. The process to be adopted in making them applicable to an individual facility involves, for each type of system to be used:

- review of the functions included in the template and revision to reflect the facility-specific basis of design and FES;
- review and, revise of necessary, the appropriate "criteria" which define the design basis of the system;
- review and, if necessary revise, the means for verification of the chosen criteria;
- inclusion of facility-specific targets such as reliability targets identified in the facility’s QRA;
- identification of any fire and explosion loads applicable to the "survivability" elements;
- identification of particular "dependent" systems which are assumed to be available for the main system to function.

The process of review and adaptation requires a knowledge of the overall FES, the role of the firewater system, and its basis of design and an awareness of the contribution it makes to reducing the level of risk on the installation. As such, it is likely that experienced personnel from the following disciplines will be involved in the conditioning process:

- Technical Safety Engineer or Loss Prevention Engineer;
- Lead discipline Engineer for the system;
- Discipline Maintenance Engineer (for existing facilities);
- Operations staff (for new and existing facilities).

PERFORMANCE CRITERIA TEMPLATE		
FIREWATER PUMP		
Goal: To provide a reliable and secure supply of firewater to the firewater main system at the required pressures and flows for all the firewater-dependent equipment or systems on an offshore facility.		
FUNCTIONALITY		
Function	**Criteria/Guidance**	**Analysis/Verification**
Ensure suitable water supply.	No hydrocarbon, biological or foam destructing contaminants.	Inspection. System testing.
Deliver water at appropriate pressure and flow to meet the demands of firewater systems and user.	Firewater requirements in developing the FES.	By review of QRA and FES, use experienced judgement to establish credible scenarios and resulting firewater demand.
Configuration of fire pumps appropriate for water demand.	Minimum of 2 x 100% fire pumps.	Review pump performance to confirm adequacy of arrangements.
To start on demand and on loss of signal from F & G panel.	Automatic start within 30 seconds on loss of pressure, confirmed fire detection, manually from local panel, helideck or Control Point.	Function test.
Prevent pressure surges on start-up.	Requirements determined by surge analysis.	Function test.
Provide pump curve suitable for firewater duty.	Shut-in head max of 140% head at duty point. Head 65% of duty point at 150% duty flow.	Review of supplier's pump curve and certification documents. Function test.
Provide firewater for adequate duration.	3 hours or value determined by assessment.	System review.
Respond in all ambient conditions.	Pipework and valves exposed to low temperature should be trace-heated or other measures taken.	Inspection.

PERFORMANCE CRITERIA TEMPLATE		
FIREWATER PUMP		
RELIABILITY/AVAILABILITY		
Element/Component	**Criteria/Guidance**	**Analysis/Verification**
Tie-in to fire main	Separate tie-in for each pump discharge.	Review of drawings and inspection.
Surge relief function	Required as determined by fire main surge analysis.	Function test.
Entire system	If required by QRA, total system reliability to be determined by calculation.	By calculation, confirmed by monitoring.
System maintenance	Maintenance routines (NFPA)	Maintenance records. Outstanding maintenance routines accepted by system custodian.
System unavailability	MOPO	MOPO available on the offshore facility.
System testing	Test procedures and schedules (NFPA)	Review of maintenance and test records.

SURVIVABILITY			
Event	**Component**	**Criteria**	**Verification**
Fire and explosion	Enclosure for firewater pump prime movers and firewater pumps	Retain integrity against loadings on enclosure of fire pumping system sufficient to meet maximum foreseeable firewater demand.	Loadings identified for scenarios of frequency greater than 10E-4. Analysis or test evidence to confirm construction.
Fire and explosion	Electric cables and hydraulic lines between pump and power source.	Routing to be spatially separated or otherwise protected to ensure maximum foreseeable firewater demand can be supplied.	Loadings identified for scenarios of frequency greater than 10E-4. Experienced judgement used to confirm suitability of arrangements.
QRA Assumptions:-			

DEPENDENCY/INTERACTIONS	
System	**Critical**
HVAC	Yes - Air supply to enclosures
Fire main	Yes - To supply water to discharge elements
Electrical	No - Alternative means of starting
F & G Detection	Yes - To initiate automatic start
Foam	Yes - To provide foam solution in foam discharge elements

PERFORMANCE CRITERIA TEMPLATE		
FIRE MAIN		
Goal: To provide a reliable and secure system to distribute firewater to all firewater dependent protection systems, on demand, at the required pressures and flows.		
FUNCTIONALITY		
Function	**Criteria/Guidance**	**Analysis/Verification**
Distribute firewater at pressures and flows sufficient for all potential end users when a section of fire main is impaired.	100% of firewater demand available from any one section of fire main (i.e. main large enough for demand when one main section isolated).	Hydraulic analysis. Flow tests.
Limit pressure drop to firewater end users with one section of the fire main impaired.	Minimum flowing pressure from calculation of different firewater systems element or 7 bar (ga) whichever is greater; hydrants to be 3.5 bar (ga) or as indicated by calculation.	Table comparing pressure required and delivered. Hydraulic analysis confirmed by commissioning test.
Pressurise main under normal conditions.	Pressurised by electric jockey pump or sea water pump.	Inspection and testing.
Initiate fire pump start in loss of fire main pressure.	Fire pump start initiated by pressure drop of 1 to 2 bar(ga).	Regular function test.
Provide separate connections for independent feeds for firewater users.	Separate connections to main for each monitor, deluge etc.	By review of design. Inspection.
Prevent "hammer" damage to pipework.	Surge possibilities assessed and mitigated, if required.	Surge analysis. Function test.
Respond in all ambient conditions.	Pipework and valving exposed to low temperatures should be trace-heated or other measures taken.	By review of design.

PERFORMANCE CRITERIA TEMPLATE		
FIRE MAIN		
RELIABILITY/AVAILABILITY		
Element/Component	**Criteria/Guidance**	**Analysis/Verification**
Block (isolation) valves provided to isolate any section of main which may be damaged in fire/explosion and to allow maintenance.	Valves to be accessible or operable under conditions when required to operate.	System design. Confirmation by inspection that valves provided in suitable locations for identified hazardous events.
Prevent deterioration of fire main system which would cause blockage of end users.	End user functionality maintained.	Regular function testing and flushing procedures.
Entire system	If required by QRA, system reliability to be determined by analysis.	By calculation and monitoring.
System maintenance.	Maintenance routines (NFPA)	Maintenance records. Outstanding maintenance routines accepted by system custodian.
System unavailability	MOPO	MOPO available on the offshore facility.

SURVIVABILITY			
Event	**Component**	**Criteria**	**Verification**
All fires and explosion	Pipework and isolation valves.	For major accident events, sufficient components are either unaffected (i.e. outside hazard range) or protected, to enable fire main to retain its functionality.	New installations - By review of QRA and using experienced judgement. Refer to ESSA for existing installations.
QRA Assumptions:-			

DEPENDENCY/INTERACTIONS	
System	**Critical**
Fire pumps (and caisson)	Yes - to provide sufficient water supplies.

PERFORMANCE CRITERIA TEMPLATE

FIREFIGHTING EQUIPMENT

Goal: To combat fires by the safe application of firewater or water-based extinguishing media using manually controlled equipment.

FUNCTIONALITY

Function	Criteria/Guidance	Analysis/Verification
Provide monitors in suitable locations	Monitors provided for hydrocarbon process equipment in open deck areas where no deluge installed.	Engineering judgement to confirm that locations are suitable. Inspection.
Provide sufficient hydrant outlets and/or hose reels to enable effective manual fire fighting	Hydrants or hose reels to be located so that at least two jets of water from different locations available for any fire.	Inspection and function tests.
	Outlets standard on installation.	Inspection.
	Maximum working pressure of 15 to 16 bar (ga)	Review of design details and function test.
	Pressure reduction facilities provided to limit maximum flowing pressure to 7 bar (ga) at hand-held branch pipe.	Function test.

RELIABILITY/AVAILABILITY

Element/Component	Criteria/Guidance	Analysis/Verification
System maintenance	Maintenance routines	Maintenance records. Outstanding maintenance routines accepted by system custodian.
System unavailability	MOPO	MOPO available on the offshore facility.

SURVIVABILITY

Event	Component	Criteria	Verification
Fire and explosion	All critical components.	For design events, sufficient components should be provided to allow their use without personnel being subject to unnecessary risk.	By review of assessment and using experienced judgement, confirm that arrangements are satisfactory.

QRA Assumptions:

PERFORMANCE CRITERIA TEMPLATE	
FIREFIGHTING EQUIPMENT	
DEPENDENCY/INTERACTIONS	
System	**Critical**
Fire pumps, distribution pipework and water supply	Yes - to provide sufficient water supplies.

PERFORMANCE CRITERIA TEMPLATE		
SPRINKLER SYSTEM		
Goal: To assist fire-fighting by applying firewater to a limited area in suitable quantities to control or extinguish burning low-flammability material.		
FUNCTIONALITY		
Function	**Criteria/Guidance**	**Analysis/Verification**
Provide sufficient water through network of pipes to control/extinguish small fires involving mainly cellulose material.	For accommodation areas provide 5 litres per minute per square metre. For other areas provide 10 litres per minute per square metre. Design area for water demand 280 m^2. Minimum operating pressure 0.5 bar (ga).	Hydraulic analysis and functional test.
Provide uniform distribution of water over area.	One sprinkler per 10 m^2 minimum. Sprinkler spacing 1.75-4 m apart. Spray patterns not impaired by structure etc.	System design and inspection.
Annunciate confirmation of sprinkler operation.	Pressure switch in valve to report to F & G panel. Flow switch for each fire zone where several zones covered by one sprinkler valve.	Function test.
Respond rapidly to developing fire.	Use 68 °C frangible bulbs, or rated for 30 °C above ambient.	System design and inspection. Certified components.
Respond in all ambient conditions.	Pipework exposed to low temperatures should be trace-heated or other measures taken.	Inspection.

PERFORMANCE CRITERIA TEMPLATE			
SPRINKLER SYSTEM			
RELIABILITY/AVAILABILITY			
Element/Component	**Criteria/Guidance**	**Analysis/Verification**	
System materials	Project specifications	Project documentation/control.	
System maintenance	Maintenance routines	Maintenance records. Outstanding maintenance routines accepted by system custodian.	
System unavailability	MOPO	MOPO available on the offshore facility.	
System testing	Operating standards (NFPA)	Documented in Maintenance System.	
SURVIVABILITY			
Event	**Component**	**Criteria**	**Verification**
Cellulose fire (NOTE: Would not normally be required to survive explosion or jet fire.)	All components in fire area	Need to remain operable until system initiated	Experienced judgement to support design. Certified components.
QRA Assumptions:			
DEPENDENCY/INTERACTIONS			
System	**Critical**		
Fire pump, distribution pipework and water supply	Yes - to provide sufficient water on demand.		
F & G system	Yes - to initiate firewater demand.		

PERFORMANCE CRITERIA TEMPLATE		
DELUGE SYSTEMS		
Goal: To assist fire-fighting by the reliable, secure and effective distribution of firewater to limit escalation, provide cooling to equipment and structures and protect personnel.		
FUNCTIONALITY		
Function	**Criteria/Guidance**	**Analysis/Verification**
Provide water through network of pipes to control rate of burning and/or provide exposure protection to plant/equipment	Minimum discharge density of - general area protection 10.2 litres per minute per square metre nozzles not more than 3.5 m spacing, and one per 10 m^2 for general areas. Obstructions over 1 m wide protected underneath - pumps and compressors 20.4 litres per minute per square metre - vessels, tanks, pipelines etc. 10.2 litres per minute per square metre - personnel exposure 45 to 130 litres per minute per square metre - structural protection 10.2 litres per minute per square metre - For wellheads and BOP supply 400 litres per minute per wellhead via at least two high velocity sprayers Nozzles selected to achieve density without dry spots. Medium-velocity nozzles located within 600 mm of equipment to be protected.	Hydraulic analysis and functional test. Visual inspection under test. Hydraulic analysis programme print-out and test records.

PERFORMANCE CRITERIA TEMPLATE		
DELUGE SYSTEMS		
FUNCTIONALITY (Continued)		
Function	**Criteria/Guidance**	**Analysis/Verification**
Maintain pressure at nozzles	Minimum pressures: Open sprinklers: Normal area - 1 bar (ga). Naturally ventilated open area - 1.4 bar (ga) Medium-velocity open sprayer: 1.4 bar (ga) High-velocity sprayer: windage area - 3.5 bar (ga) enclosed area - 2.8 bar (ga)	Hydraulic analysis and function test.
Respond rapidly to fire	Within 30 seconds of input from F & G panel, water to reach most hydraulically remote nozzle	Function test with pressure and flow meters.
Annunciate confirmation of deluge operation	Indication given at F & G panel	Routine function test.
Suitable for all ambient conditions	External pipework and valve trims exposed to low temperatures that become charged when deluge operated, should be trace-heated or other measures taken.	Inspection.
Means of initiation	- automatic by frangible bulb - automatic by fire detectors - manual electric/pneumatic locally - manual by key switch at F & G panel - manual by release of deluge system - manual by operation of secondary bypass valve.	Function test.

PERFORMANCE CRITERIA TEMPLATE		
DELUGE SYSTEMS		
RELIABILITY/AVAILABILITY		
Component	**Criteria/Guidance**	**Analysis/Verification**
Entire system	If required by QRA, system reliability to be determined by analysis.	By calculation, confirmed by monitoring.
System maintenance	Maintenance routines	Maintenance records. Outstanding maintenance routines accepted by system custodian.
System unavailability	MOPO	MOPO available on the offshore facility.
System testing	No more than 2 adjacent nozzles blocked and still achieve average application rate.	Maintenance records.
Materials selected to minimise velocity, corrosion/erosion effects	Project specifications	Project documentation. Routine testing.

SURVIVABILITY			
Event	**Component**	**Criteria**	**Verification**
Explosion	All components	Valve sets to remain operable under foreseeable explosion.	Analysis of over-pressure loading. Experienced judgement, test evidence or similar to support design or protection provided.
Pool fire Jet fire	All components	Need to remain operable under foreseeable conditions.	Analysis of fire loading. Experienced judgement, test evidence or similar to support design.
QRA Assumptions:			

DEPENDENCY/INTERACTIONS	
System	**Critical**
Fire pump and fire main	Yes - to provide sufficient water on demand.
Air supply to deluge valve and pneumatic detection circuit	Yes - Need to maintain supply for a minimum of two hours to prevent unnecessary valve opening at wrong locations around platform.
F & G System	Yes - to initiate executive actions.

PERFORMANCE CRITERIA TEMPLATE		
FOAM SYSTEMS (See also relevant water system/equipment template)		
Goal: To combat hydrocarbon spill fire by the reliable, secure and effective application of foam to prevent escalation, limit damage and prevent formation of smoke which could thwart EER or engulf the TR.		
FUNCTIONALITY		
Function	**Criteria/Guidance**	**Analysis/Verification**
Introduce foam concentrate into the firewater supply	Central Foam Systems: Foam concentrate supplied into discharge of each firewater pump. Helideck systems: Foam concentrate supplied to three evenly spaced helideck oscillating monitors.	System design. Inspection.
Provide suitable foam solution application rate	4 to 6.5 litres per minute per square metre depending on foam type and fire risk.	System design. Function test.
Provide suitable foam concentrate type	1% type concentrate suitable for method of application and fire risk.	Certification. Fire testing.
Provide correct proportioning rate	For designed foam systems providing aspirated foam, proportioning accuracy of +/- 10%. For firewater discharge elements not specifically designed for foam application, minimum proportioning rate within 10% of concentrate design rate (i.e. 0.9% for a 1% concentrate).	System design. Function test.
Allow manual initiation of the system	Central Foam Systems: - key switch on F&G Panel - direct opening of foam control valve - direct opening of foam control bypass valve. Helideck foam systems: - manual initiation from HLO position.	System design. Function test.

PERFORMANCE CRITERIA TEMPLATE		
FOAM SYSTEMS (See also relevant water system/equipment template)		
FUNCTIONALITY (Continued)		
Function	**Criteria/Guidance**	**Analysis/Verification**
Provide sufficient foam concentrate to meet demand	Minimum of 10 min. supply for helideck foam systems. Capacity of Central Foam System to be sufficient for 30 min. foam application or the time determined in the FES.	System design. Inspection.
Annunciate status	Status of Central Foam system displayed on F&G panel	System design. Function test.
Winterisation	Foam concentrate selected suitable for minimum ambient temperatures. Pipework that becomes charged when operated should be self-draining or winterised.	Certification. Periodic foam concentrate tests. System design. Inspection.
RELIABILITY/AVAILABILITY		
Component	**Criteria/Guidance**	**Analysis/Verification**
Entire system	If required by QRA, system reliability to be determined by analysis.	By calculation, confirmed by monitoring.
System maintenance	Maintenance routines	Maintenance records. Outstanding maintenance routines accepted by system custodian.
System unavailability	MOPO	MOPO available on the offshore facility.
System testing	In accordance with manufacturer's recommendations. 6-monthly testing of concentrate and annual testing of foam system performance.	Inspection of test records by system custodian. Test laboratory. Recognised fire tests.

PERFORMANCE CRITERIA TEMPLATE			
FOAM SYSTEMS			
SURVIVABILITY			
Event	**Component**	**Criteria**	**Verification**
Explosion	All components (i.e. storage tanks, foam pumps, supply lines and discharge elements)	To remain operable after an explosion.	Analysis of over-pressures. Experienced judgement, test evidence or similar to support design or protection provided.
Pool fire	All components (i.e. storage tanks, foam pumps, supply lines and discharge elements)	To remain operable under fire conditions.	Analysis of fire loadings. Experienced judgement, test evidence or similar to support design or protection provided.
Jet fire	All components	(Foam of limited value in jet fires but survivability may be required for use in secondary fires.).	
QRA Assumptions:			

DEPENDENCY/INTERACTIONS	
System	**Critical**
Instrument air	Yes - to actuate foam control valves and to prevent unnecessary opening of deluge valves.
Firewater pump and firewater main	Yes - to supply sufficient firewater to helideck monitors and to convey foam solution to discharge elements.
Fire and Gas System	Yes - to initiate firewater pump start and open foam control valves.
Drainage/containment	Yes - to ensure a contained spill and hence optimise foam effectiveness.

PERFORMANCE CRITERIA TEMPLATE		
WATER MIST SYSTEMS		
Goal: To combat fire by providing a reliable and effective water mist which is designed to extinguish a fire in the area protected.		
FUNCTIONALITY		
Function	**Criteria/Guidance**	**Analysis/Verification**
Provide a system with suitable water droplet size distribution	$D_{v0.50}$ - less than 200 µm $D_{v0.99}$ - less than 500 µm	Test data. Certification.
Provide sufficient water of suitable quality	System to have capacity for 4 timed discharges of 15 seconds each or as required by manufacturer of equipment to be protected. System filled with potable water and foam concentrate where enhanced extinguishment capability is required.	System design. Inspection. System design. System tests.
Provide discharge nozzles located to effectively extinguish all fires that may occur in the area	Relevant test data representative of the fire risk to be protected	System design.
Respond rapidly to fire	Water storage located close to protected area with minimum pipe runs.	System design.
Means of initiation	Automatic discharge by fire detectors installed in the protected area. Manual release at the water mist skid and by key-switch at FGP	System design. Function test.
Annunciate system operation	Indication given at FGP	Function test.

PERFORMANCE CRITERIA TEMPLATE		
WATER MIST SYSTEMS		
RELIABILITY/AVAILABILITY		
Component	**Criteria/Guidance**	**Analysis/Verification**
System materials	Project specifications	Project documentation/control
System maintenance	Maintenance routines	Maintenance records. Outstanding maintenance routines accepted by system custodian.
System unavailability	MOPO	MOPO available on the offshore facility.
System testing	Discharge time Discharge sequence Nozzle blockage	Maintenance records

SURVIVABILITY			
Event	**Component**	**Criteria**	**Verification**
Explosion	All components	Not required	
Fire	All components in area protected	Need to remain operable under foreseeable conditions.	Experienced judgement, test evidence or similar to support design.
QRA Assumptions:			

DEPENDENCY/INTERACTIONS	
System	**Critical**
F & G Panel and detection system	Yes - to provide actuation and control logic (Discharge time and sequencing).
Air supply	Possibly according to system type for operation of pneumatic valves.
HVAC	Yes - to close down HVAC system.

APPENDIX 2 SYSTEM CHECKLIST FOR COMMISSIONING AND ROUTINE TESTING

The following is given as guidance for the items that should be included in commissioning and routine testing procedures and schedules for Firewater System elements. The list should not be taken as a prescriptive or totally comprehensive list, as specific lists should be developed to suit a particular offshore facility.

1. PIPEWORK

(i) Check that all pipework is installed according to the latest 'approved for construction' drawings. Record all deviations on a punch list and pass back to Construction Department. Update latest flow sheet and attach 'AS BUILT' marked-up drawing.

(ii) Check piping for signs of damage.

(iii) Check and inspect NDE records and attach NDE clearance certificate from quality control.

(iv) Check that lines are correctly marked with flow direction.

(v) Check that any junctions of dissimilar metals liable to cause galvanic corrosion are correctly insulated.

NOTE: Instrument connections, orifice plates in lines. Record insulation specifications and types used.

(vi) Check and inspect that piping systems do not obstruct escape ways and emergency exits/accesses.

(vii) Check and inspect all piping penetrations and ensure that:

- they are in accordance with approved design drawings;
- the correct stiffening rings are fitted and welding quality is good and in accordance with the structural procedures;
- the correct type of packing is fitted and sealed correctly;
- bolting is of correct specification and correctly tightened.

(viii) Check that all couplings are in accordance with project specifications.

(ix) Check that all vents and drains are in accordance with project specifications.

(x) Check that all hangers and supports are in accordance with project specifications.

(xi) Carry out system flushing. (See Section 6 of this Appendix).

2. VALVES

(i) Check and inspect all valves in the system and ensure that:

- they are the correct type;
- they are the correct rating;
- they are certified fire-safe where stipulated;
- they are in line correct to the direction of flow;
- the position indicators are correctly orientated and, where remote signalling of position is included, that the correct signals are displayed.
- they have the correct type of hand-wheel or activation lever and locking devices are fitted where required;
- they operate smoothly through the designated limits and are lubricated with the correct lubricant for their particular application;
- the valve schedule and checklists are complete and accurate;
- there is no visible external damage;
- there is adequate access for operation and maintenance;
- purpose and operating instructions are provided.

(ii) Check location and operation of all pressure-reducing valves.

3. FLOW AND PRESSURE SWITCHES

(i) Check flow and pressure switches are installed in accordance with latest issue of approved construction drawings.

(ii) Check that flow switch is installed in line with flow direction.

(iii) Check flow switch/pressure switch indicates open circuit for no-flow condition and closed circuit for flow condition.

(iv) Check sensitivity of flow switch and damper action to suit.

(v) Check there is no visible external damage.

(vi) Check that access is adequate for inspection and maintenance operations.

4. INSTRUMENTS

(i) Check that they are in accordance with project specifications.

(ii) Confirm the correct annunciation and resultant executive action of all remote signals at the main Fire and Gas Panel.

5. ELECTRICAL

(i) Check that installation is in accordance with project specification.

6. PIPEWORK SYSTEM FLUSHING AND PRESSURE TESTING (GENERAL)

(i) Remove gauges which are liable to be damaged at test pressure and during flushing operations and store in instrument store.

(ii) Carry out system flushing in accordance with flushing procedures.

(iii) Check flow at drains and any test connections.

(iv) Complete Certificate of Flushing after performing flushing operation.

(v) Carry out hydrostatic testing in accordance with project specifications and record details on the hydrostatic test report. Attach copies of:

- Isometric sketch showing as-built condition, test limits and scope;
- Test equipment Calibration Certificates;
- Certificate of pressure test;
- Pressure chart and temperature chart;
- Test report;
- Certificate of acceptance of system from contractor.

7. PUMPS

(i) Check that installation is in accordance with project documentation.

(ii) Check starting logic sequence and operation.

(iii) Check discharge pressure of each pump speed at 0%, 25%, 50%, 75%, 100%, 125%, and 150% flow.

8. FIREFIGHTING EQUIPMENT

(i) Check flow capability at each hydrant.

(ii) Check contents of each hose box.

(iii) Check couplings of each hose and any equipment to be connected with them.

(iv) Check monitors, hose reels and hand-held nozzles located in accordance with project specifications.

(v) Check rotation and elevation capability on monitors.

(vi) Check oscillating mechanism of oscillating monitors or remote control capability on any remote control monitors.

(vii) Check straight stream/spray and throw range on all monitor and hand-held equipment nozzles.

9. SPRINKLER SYSTEMS

(i) Check sprinkler heads and ensure the frangible bulbs are of the correct temperature rating for the system.

(ii) Check and ensure that sprinkler heads are correctly installed. Check orientation of sprinkler heads and orifice size. Check and ensure that sprinkler heads are in serviceable condition.

(iii) Check ceiling rosettes are correctly installed.

(iv) Check and ensure that the entire sprinkler and/or spray head (particularly the frangible bulb) is completely clean and free of paint or other coatings other than the original manufacturer's finish.

(v) Ensure spare sprinkler heads are available prior to any tests being performed on the sprinkler system.

(vi) Open sprinkler valve and inspect the condition of its interior and ensure that the movement of the valve clapper is free and that the clapper hinge is lubricated with the approved lubricant. Re-install the sprinkler valve.

(vii) Check operation of audible alarm signals.

10. DELUGE SYSTEMS

(i) Check and ensure that spray heads are correctly installed.

(ii) Check and ensure that spray heads are in serviceable condition.

(iii) Check that spray heads have correct orifice size and spray angle.

(iv) Ensure that spare spray heads are available prior to any tests being performed on the system.

(v) Check that all nozzles are clear from blockage during flow test.

(vi) Check that pressures at most remote nozzles conform to hydraulic calculations.

(vii) Check that no dry areas occur on protected equipment during discharge.

(viii) Check that the air supply is installed in accordance with the latest approved construction drawings and taken from the instrument air supply.

(ix) Carry out air supply leak test in accordance with project specifications.

(x) Check that pneumatic control systems are correct.

(xi) Check that pneumatic reservoirs are free of damage.

(xii) Check that filter-regulators are installed and are of correct size.

(xiii) Check the minimum pneumatic pressure required to open the deluge valves.

11. FOAM SYSTEMS

(i) Check quantity and type of foam concentrate.

(ii) Check operation of foam concentrate proportioning system.

(iii) Check proportioning accuracy at operating flow rates.

(iv) Check foam expansion and drainage time in accordance with specifications.

(v) Ensure foam concentrate tank is full after system testing.

12. WATER MIST SYSTEMS

(i) Check quantity and quality of water in system.

(ii) Check location and flow rate of all nozzles.

(iii) Check presence of nozzle caps if specified.

(iv) Check time and sequence of discharge.

(v) Check that all nozzles flow freely.

(vi) Check that discharge patterns of nozzles overlap.

APPENDIX 3 EXAMPLE OF FIREWATER PUMPING CONTINGENCY MATRIX

PLATFORM																				
	PUMPS																			
	UA: UNAVAILABLE																			
	A: AVAILABLE																			
	DFP: DIESEL FIRE PUMP																			
	EFP: ELECTRIC FIRE PUMP																			
	SWP: SERVICE WATER PUMP																			
	PUMP NUMBER AND TYPE					ACTIONS REQUIRED ON LOSS OF FIREWATER PUMPING CAPACITY														
SCENARIOS	P7001 DFP	P7002 DFP	P7003 DFP	P5001/2/3 SWP		SW CROSSOVER DIAMETER	STOP AND SECURE ALL DRILLING AND WE SERVICES ACTIVITIES WHERE THERE IS COMMUNICATION WITH THE RESERVOIR A SOON AS IT IS SAFE TO DO SO	SHUT DOWN ALL HYDROCARBON PROCESSING AND DEPRESSURISE	STOP AND SECURE ALL OTHER DRILLING AND WELL SERVICE ACTIVITIES AS SOON AS IT IS SAFE TO DO SO	STOP ALL CATERGORY "ONE" HOT WORK	TEST START REMAINING FIRE WATER PUN AS PER NOTE. PROVE SERVICE WATER PUMPS AVAILABLE ON MANUAL START	GENERATOR (ON DIESEL FUEL) RUN ON LOAD	REVIEW WORK ACTIVITIES IN AND AROUN HYDROCARBON PROCESSING/TRANSMISSION AREAS	STOP ALL CROSSOVER OF HYDROCARBONS, AND IMPORT/EXPORT	STOP ALL CATEGORY "TWO" HOT WORK	REDUCE P.O.B. TO ESSENTIAL PERSONNE	INSTIGATE SERVICE WATER/FIRE MAIN CROSSOVER AND SERVICE WATER PUMP(TO BE IMMEDIATELY AVAILABLE	START MAIN GENERATOR(S) (ON DIESEL FUEL)	STOP ALL LOADING OR UNLOADING OF HYDROCARBONS	
1	UA	A	A	A		14"	YES	NO	NO	*YES	YES	N/A	*YES	NO	NO	NO	YES	YES	N/A	
2	A	UA	A	A		14"	YES	NO	NO	*YES	YES	N/A	*YES	NO	NO	NO	YES	YES	N/A	
3	A	A	UA	A		14"	YES	NO	NO	*YES	YES	N/A	*YES	NO	NO	NO	YES	YES	N/A	
4	UA	UA	A	A		14"	YES	YES	YES	YES	YES	N/A	YES	YES	YES	YES	YES	YES	N/A	
5	UA	A	UA	A		14"	YES	YES	YES	YES	YES	N/A	YES	YES	YES	YES	YES	YES	N/A	
6	A	UA	UA	A		14"	YES	YES	YES	YES	YES	N/A	YES	YES	YES	YES	YES	YES	N/A	
7	UA	UA	UA	A		14"	YES	YES	YES	YES	YES	N/A	YES	YES	YES	YES	YES	YES	N/A	
NOTES										A	B		C		D	E		F		

NOTES:

GENERAL NOTES FOR APPENDIX 3:

1. **The matrix in Appendix 3, and these notes, are typical and have been provided by an actual Shell Operating Unit. The terms and departments mentioned may be different in other Operating Units.**
2. These arrangements for supply of firewater in event of total or partial loss of offshore facility's firewater pumping capacity are for short term applications only.
3. Any deviation from the above combinations of pumping to be used in the event of a pump failure and any consequential restrictions on installation/field operations must be agreed by the Head of Asset Integrity Support and the HSE Offshore Division.
4. In the event of a fire pump being unavailable for up to 4 hours for essential maintenance, the Installation OIM may carry on full hydrocarbon processes and inter-field crossover. However, if during this period, it becomes evident that the downtime of the pump will extend beyond 4 hours, guidance should be sought from the Operations Support Section.
5. Planned outages of a firewater pump unit should not be undertaken on producing installations if, at the time of the outage, drilling or well services activities will involve communication with the reservoir.
6. Service water pumps have not been designed to meet all requirements for a fire pump unit.

NOTES ON MATRIX IN APPENDIX 3:

A. All category 1 Hot-work should be limited to the designated fabrication/welding workshop area together with any pressurised modules classified as non-hazardous modules. There is no constraint on category 1 Hot-work if both the following conditions are achieved:

   1. Hydrocarbon process are shutdown, hydrocarbon containing equipment has been de-pressurised, water flushed and purged with nitrogen until free of hydrocarbon gas.
   2. There is no communication with the reservoir. No drilling or Well Services activities which could lead to reservoir communication.

   Category 1 Hot-work relates to all work specified in the Operating Unit Information Manual, Permit to Work System sections.

B. Alternative means of starting should be tested alternately, i.e. manual, dropping pressure, HLO station, etc.

C. This primarily applies to all hydrocarbon/handling/transmission areas, and relates to any work activity which could result in loss of containment and/or fire starting.

D. This relates to all work specified in Operating Unit Information Manual, Permit to Work Sections.

E. Non-essential personnel can be regarded as those staff unable to work during the period of limited firewater cover at the OIM's discretion. Helicopter operations should be conducted when convenient and safe to do so.

F. The main generator(s) should be capable of supplying as a minimum P5001/P5002/P5003. The emergency generator and both battery and upstart systems should be confirmed as being available for black start capability. No work should be carried out, other than essential maintenance, on UPS power supplies, emergency generator, fire and gas detection of ESD systems, that could cause shutdown input to the control system for the sub-main generator.