

DEP SPECIFICATION

ASSESSMENT AND DESIGN OF THE FIRE SAFETY OF ONSHORE INSTALLATIONS

DEP 80.47.10.30-Gen.

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DESIGN AND ENGINEERING PRACTICE

DEM1



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1. INTRODUCTION

1.1 SCOPE

This DEP specifies requirements and gives recommendations for the determination and selection of fire protection measures for optimising the fire safety of onshore plants.

This DEP is applicable both to new plants and to the modification and extension of existing plants. This DEP contains alternative methods to define the fire protection needs.

This DEP does not include detailed design and engineering requirements of the selected fire protection method; these are covered by the following DEPs:

Fire, gas and smoke detection systems	DEP 32.30.20.11-Gen.
Drainage and primary treatment systems	DEP 34.14.20.31-Gen.
Passive fire protection for onshore facilities	DEP 34.19.20.11-Gen.
Active fire protection systems and equipment for onshore facilities	DEP 80.47.10.31-Gen.
Use of fire fighting agents and movable fire fighting equipment for onshore applications	DEP 80.47.10.32-Gen.
Fire-fighting vehicles	DEP 80.47.10.33-Gen.

This DEP contains mandatory requirements to mitigate process safety risks in accordance with Design Engineering Manual (DEM) 1 - Application of Technical Standards.

This is a revision of the DEP of the same number dated February 2015; see (1.5) regarding the changes.

1.2 DISTRIBUTION, INTENDED USE AND REGULATORY CONSIDERATIONS

Unless otherwise authorised by Shell GSI, the distribution of this DEP is confined to Shell companies and, where necessary, to Contractors and Manufacturers/Suppliers nominated by them. Any authorised access to DEPs does not for that reason constitute an authorization to any documents, data or information to which the DEPs may refer.

This DEP is intended for use in facilities related to onshore oil and gas production, gas handling, oil refining, chemical processing, gasification, distribution and supply/marketing. This DEP may also be applied in other similar facilities.

When DEPs are applied, a Management of Change (MOC) process shall be implemented; this is of particular importance when existing facilities are to be modified.

If national and/or local regulations exist in which some of the requirements could 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 with regards to the 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, the objective being to obtain agreement to follow this DEP as closely as possible.

1.3 DEFINITIONS

1.3.1 General definitions

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

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

The **Principal** is the party that initiates the project and ultimately pays for it. The Principal may also include an agent or consultant authorised to act for, and on behalf of, the Principal.

The word **shall** indicates a requirement.

The capitalised term **SHALL [PS]** indicates a process safety requirement.

The word **should** indicates a recommendation.

The word **may** indicates a permitted option.

1.3.2 Specific definitions

Term	Definition
Active Fire Protection	Dormant fire protection system that needs to be activated in order to perform its function.
Aqueous Film Forming Foam	Synthetic foam consisting of fluorochemical and hydrocarbon surfactants combined with high boiling solvents.
Class A fires	Fires in ordinary combustible materials such as wood, cloth, paper, rubber and many plastics.
Class B fires	Fires in flammable liquids, oils, greases, tars and flammable gases.
Class I products	Liquids which have flash points below 21 °C (70 °F).
Class II (1) products	Liquids which have flash points from 21 °C (70 °F) up to and including 55 °C (131 °F), handled below flash point.
Class II (2) products	Liquids which have flash points from 21 °C (70 °F) up to and including 55 °C (131 °F), handled at or above flash point.
Class III (1) products	Liquids which have flash points above 55 °C (131 °F) up to and including 100 °C (212 °F), handled below flash point.
Class III (2) products	Liquids which have flash points above 55 °C (131 °F) up to and including 100 °C (212 °F), handled at or above flash point.
Class 1A products	Liquids having flash points below 22.8 °C (73.0 °F) and having a boiling point below 37.8 °C (100 °F). Classification used by NFPA
Competent	Person with the skill, knowledge, practical experience and training to carry out fire safety assessment and/or related fire hazard management or fire response duties.

Term	Definition
Deluge System	Sprinkler system in which the water distribution piping is equipped with open spray nozzles for discharging over an area that requires protection.
Drenching System	Fixed “free flowing” water discharge device connected via a piping system to a water source. or System in which water is dumped onto an overflow or underflow weir located on top of the vessel that allows the water to spread over the protected surface.
Escalation	Increase in severity of consequences due to the failure of barriers or mitigation measures intended to prevent fire spread.
Fire Zone	Plant area where a sustained intense fire is considered credible. In line with ISO 23251, a 232 m ² (2500 ft ²) surface on fire may be assumed to be the maximum size of fire to be encountered. (However, a smaller or larger fire size may be determined by hazard consequence modelling)
Fire-Hazardous Product	Butane or lighter product; or Hydrogen plus hydrocarbons when the partial pressure of hydrogen exceeds 0.7 MPa (100 psia); or Hydrocarbons at an operating temperature above the auto-ignition temperature; or Products that pose significant reactive hazards under fire exposure (e.g., ethylene oxide).
Fire Hazard Levels	Hazard levels ranked as Very Low, Low, Moderate and High; used primarily in the USA for ranking fire risks in the design process.
Fire Incident	Event or chain of events resulting in a undesirable combustion process of (a) substance(s) which has caused or could have caused injury and damage to assets and the environment.
Fire Risk	Product of the chance that a specified undesired fire incident will occur and the severity of the consequences of the event.
Fire Safety Assessment	Process of analysing and evaluating fire hazards. It involves both causal and consequence analysis and requires determination of likelihood and risk. This can be both a quantitative as well as a qualitative assessment based upon experienced based rule setting.

Term	Definition
Flammable Product	Any combustible/flammable liquid NOTE: This DEP uses this definition in order to avoid confusion caused by various codes that define flammable/combustible products differently. For example, according to NFPA 30, a flammable product has a flash point < 37.8 °C and a maximum vapour pressure of 276 kPa (abs) at 37.8 °C, whereas other codes define it as a substance having a flash point < 61 °C.
Flammable Range	Range of flammable vapour or gas-air mixture between the upper and lower flammable limits.
Fixed Foam Pourer	Device which discharges foam onto the internal wall of a tank for application to the fuel surface. Systems containing such devices may be designed for full surface application, or for rim seal area foam application in the case of floating roof tanks.
Freeze Areas	Locations where the design ambient temperature ranges to below 0°C (32°F) for prolonged periods.
Hazard	Potential to cause harm, including: ill health and injury; damage to property, plant, products or the environment; production losses or increased liabilities.
Hazard Consequence Modelling (HCM)	Use of mathematical models to estimate the effect of explosions, fires and dispersion.
LASTFIRE	"Large Atmospheric Storage Tank Fires" - Consortium of oil companies reviewing the risks associated with fires in storage tanks and developing the best Industry practice to mitigate the risks.
Master Plan of Fire Safety Systems	Drawing covering the entire installation (location) on which all fire, smoke and gas detection systems, active and passive fire protection systems and fire-fighting equipment (fixed, mobile and portable) are indicated. (This is the same as the fire hazard drawing with the fire and gas detectors on an overlay).
Mitigation	Measures taken to reduce the consequences of a fire incident.
Passive Fire Protection	Fire protection system that performs its function without relying on the requirement of activation. e.g., cementitious coating.
Pre-incident Planning	Emergency planning in which technical, operational and fire fighting response details are described to achieve control of fire, release, dispersion, and explosion incidents in the most efficient and effective way.
Prevailing Wind	The direction from which the wind is most likely to blow, based on local meteorological observations.
Safe	Condition in which all hazards inherent in an operation have either been eliminated or are controlled so that their associated risks are both below a tolerable threshold and reduced to a level which is as low as reasonably practicable (ALARP).

Term	Definition
Semi-fixed Foam System	Permanent foam application system connected to distribution piping that terminates at a safe distance (as determined by HCM). Mobile or portable foam producing equipment are used at the scene and connected to the distribution piping. A foam maker may be part of the portable or permanently installed equipment.
Semi-subsurface Foam Injection	Discharge of foam at the liquid surface in a tank by means of a foldable hose, through a rupture disk from an inlet near the bottom of the tank to avoid intimate contact between foam and the liquid.
Spray Nozzle	Open discharge device directing most of the discharged water in a pattern typical for the particular discharge device.
Sprinkler	Normally closed water discharge device directing most of the discharged water in a downward direction.
Sprinkler System	A fire protection system consisting of at least one automatic water supply and a distribution piping system equipped with sprinklers for discharge over an area to be protected. Sprinkler system types include wet-pipe, dry-pipe, pre-action, deluge, and combined dry-pipe/pre-action.
Subsurface Foam Injection	The discharge of foam into a tank near the tank bottom (above the water layer) allowing the foam to travel through the product to the surface.
Unclassified Products	Liquids with flash points exceeding 100 °C (212 °F).
Very Toxic (Substances)	Substances that are hazardous for the environment or human health, as specified in DEP 01.00.01.30-Gen., which also references databases of "toxic" substances and further classifies very toxic substances as "very toxic - acute", "very toxic - chronic" and "very toxic - environment".
Water Spray System	Fire protection system consisting of a fixed pipe system connected to a reliable water source and equipped with spray nozzles for discharge directed at a specific piece of equipment or surface area to be protected.

1.3.3 Abbreviations

Term	Definition
AFFF	Aqueous Film Forming Foam
AST	Aboveground Storage Tank
BLEVE	Boiling Liquid Expanding Vapour Explosion
BS	British Standard
CCTV	Closed Circuit Television
DEP	Design and Engineering Practice
EDP	Emergency De-pressuring
EIV	Emergency Isolation Valve
ESD	Emergency Shutdown
FAR	Field Auxiliary Room
FGS	Fire and Gas System
FIT	First Intervention Team
FM	Factory Mutual
FPZ	Fireproofing Zone
HCM	Hazard Consequence Modelling
IPF	Instrumented Protective Function, now known as SIF (Safety Instrumented Function)
ISGOTT	International Safety Guide for Oil Tankers and Terminals
LNG	Liquefied Natural Gas
LOC	Loss of Containment
LPG	Liquefied Petroleum Gas
MESC	Material and Equipment Standards and Code
NFPA	National Fire Protection Association
NGL	Natural Gas Liquids
PFP	Passive Fire Protection
PSL	Potential Source of Leak
ROV	Remotely Operated Valve

Term	Definition
UL	Underwriters Laboratories
USA	United States of America

1.4 CROSS-REFERENCES

Where cross-references to other parts of this DEP are made, the referenced section or clause number is shown in brackets (). Other documents referenced by this DEP are listed in (7).

1.5 SUMMARY OF MAIN CHANGES

This DEP is a full revision of the DEP of the same number dated February 2015. The change in this revision are extensive and too numerous to list here however the primary work has been to restructure and clarify requirements, enforced use of shall / should / may for normative statements.

1.6 COMMENTS ON THIS DEP

Comments on this DEP may be submitted to the Administrator using one of the following options:

Shell DEPs Online (Users with access to Shell DEPs Online)	Enter the Shell DEPs Online system at https://www.shelldeps.com Select a DEP and then go to the details screen for that DEP. Click on the "Give feedback" link, fill in the online form and submit.
DEP Feedback System (Users with access to Shell Wide Web)	Enter comments directly in the DEP Feedback System which is accessible from the Technical Standards Portal http://www.shell.com/standards . Select "Submit DEP Feedback", fill in the online form and submit.
DEP Standard Form (other users)	Use DEP Standard Form 00.00.05.80-Gen. to record feedback and email the form to the Administrator at standards@shell.com .

Feedback that has been registered in the DEP Feedback System by using one of the above options will be reviewed by the DEP Custodian for potential improvements to the DEP.

1.7 DUAL UNITS

This DEP contains both the International System (SI) units, as well as the corresponding US Customary (USC) units, which are given following the SI units in brackets. When agreed by the Principal, the indicated USC values/units may be used.

1.8 NON NORMATIVE TEXT (COMMENTARY)

Text shown in italic style in this DEP indicates text that is non-normative and is provided as explanation or background information only.

Non-normative text is normally indented slightly to the right of the relevant DEP clause.

2. FIRE SAFETY ASSESSMENT

2.1 GENERAL

1. The determination of a plant's fire safety shall be based on a risk assessment of a number of selected fire and hydrocarbon leakage scenarios for the plant.

The risk assessment might include quantitative and qualitative methodologies based upon experience-based rule setting.

2. Fire prevention, fire protection and fire fighting measures shall be based on the risk assessment.
3. The extent of fire protection shall be subject to the approval of the Principal and is related to operating manpower levels, personnel safety requirements, environmental concerns, potential for business interruption, and company's reputation.
4. For situations not included in this DEP, NFPA codes or equivalent international standards shall be used.

The relationship of NFPA codes or equivalent international standards and the situations covered in this DEP are discussed in (1.2).

5. For the phases of design, engineering, construction and commissioning of plants, it shall be clearly defined in the project documentation (i.e. BDEP and then later detailed design package) which party is responsible for the design and execution of the fire safety and fire protection.
6. When modifications and extensions to existing plants are envisaged, a fire safety assessment shall be conducted.

2.2 FIRE SAFETY MASTER PLAN

1. For new plants and, where applicable, for extensions to existing plants, a master plan of fire safety systems shall be prepared, unless otherwise specified by the Principal:
 - a. The master plan shall be accompanied by a list to quantify and state the location of the various types of equipment, including hose boxes and fire points.
 - b. The list shall be subject to approval by the Principal.
2. The master plan shall cover the entire plant.
3. The master plan shall show all fire safety related systems (such as general information about fire, smoke and gas detection systems, location of CCTV cameras, location of sirens and beacons, active fire protection systems, fixed, portable and mobile firefighting equipment, etc.) using the graphical symbols and abbreviations given in (Appendix A).

Fire and gas detection systems details are normally displayed in specific drawings (e.g. fire and gas detection layout and zoning drawings).

Instead of a master plan of fire safety systems, the Principal could dictate the development of a fire hazard drawing. See (Appendix E) for further guidance for developing such a drawing.

4. For buildings, the building fire safety assessment shall include:
 - a. fire-spread potential;
 - b. detection;
 - c. fire protection;
 - d. means of escape;
 - e. identification of all possible fire hazards (including combustible or flammable materials and ignition sources);
 - f. identification of people and assets at risk from fire;
 - g. methods of elimination, control or avoidance of fire hazards;
 - h. review of existing fire safety measures and need for improvement;
 - i. preparation of emergency plan and evacuation plan.

2.4 FIRE SAFETY ASSESSMENT - SEQUENTIAL STEPS

2.4.1 Determination of loss of containment and fire scenarios

2.4.1.1 Loss of containment scenarios

1. Loss of containment scenarios to be evaluated should be restricted to equipment failures that are likely to occur and which involve the leakage of flammable, and harmful products (both people and environment, refer to DEP 01.00.01.30-Gen) for which the frequency of occurrence and the severity of the consequences have been evaluated.
 - a. Examples of scenarios that meet the above criteria include:
 - i. small leaks from process equipment and piping, sampling systems, sight glasses, etc. For calculation purposes an equivalent hole size of 6 mm (0.25 in) diameter should be assumed;
 - ii. leaks from failure of an instrument fitting, for calculation purposes an equivalent hole size of typically 10 or 15 mm (0.4 or 0.6 in) in diameter should be assumed;
 - iii. small leaks from flange joints for calculation purposes an equivalent hole size of 1 mm (0.04 in) diameter for ring type joints, 2.5 mm (0.1 in) diameter for spiral wound gaskets and 7 mm (0.28 in) diameter for sheet gaskets, should be assumed;
 - iv. full bore ruptures of process lines up to size DN 20 (NPS 3/4);
 - v. pump and compressor seal failures; for calculation purposes an equivalent hole size of 9 mm (0.35 in) diameter should be assumed;
 - vi. for storage areas, releases into bund areas (e.g., mixer leak, etc.).

2.4.1.2 Fire scenarios

1. Fire scenarios to be evaluated shall include those that may occur at locations such as tank farms/storage areas (to include atmospheric, refrigerated and pressurised storage), process areas and other associated facilities.
2. Typical credible fire scenarios shall include:
 - a. full surface fire scenarios on fixed roof tank in storage areas;
 - b. vent fires on fixed and internal floating roof tanks;
 - c. fires on the roof (partial or full surface) and fires in the rim seal area for floating roof storage tanks the rim seal area;
 - d. jet fires, pool fires and combined jet/pool fires for process areas;
 - e. flash fires (e.g., involving LPGs);
 - f. confined and/or congested Vapour Cloud Explosions (VCEs);
 - g. boiling liquid expanding vapour explosion (BLEVE) for pressurised vessels.
3. Gas and liquid flow rates from holes shall be calculated using HCM for jet/pool fires.

Boil over scenarios, such as escalation of a full surface tank fire incident might need to be included depending the type of tank and location of the storage tank.

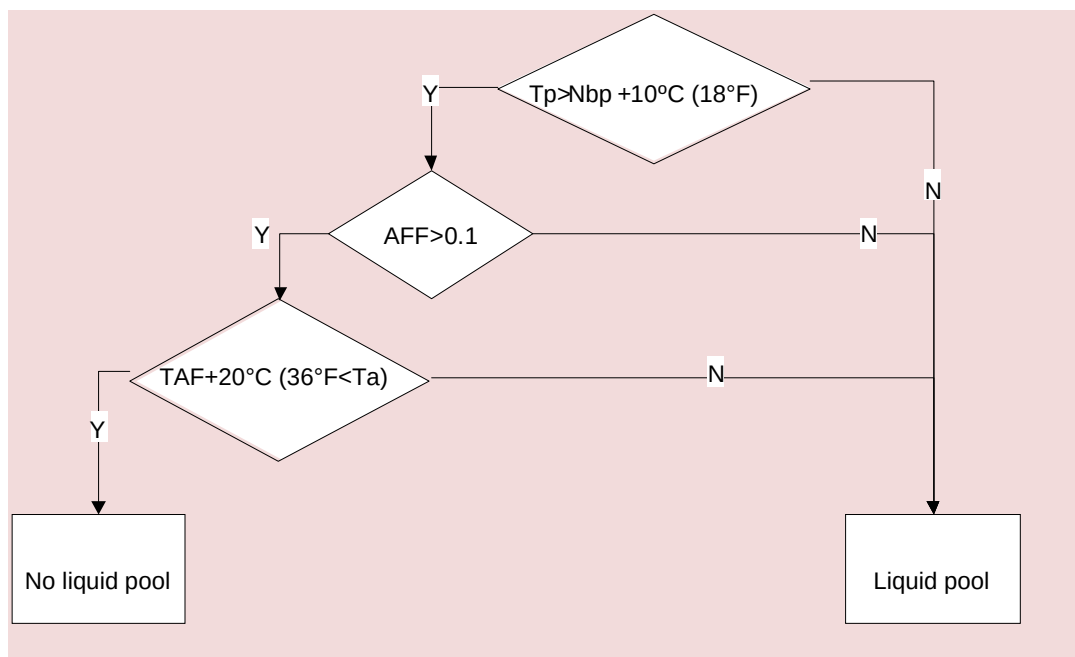
2.4.1.3 Pool fires

1. The assessment shall include the possibility of pool fires for hydrocabons that can form liquid pools.

Liquid pools can be formed by all hydrocarbon products containing pentane and heavier components but also by butanes/butenes at ambient temperatures below 0 °C (32 °F). Additionally, propane and lighter refrigerated/cryogenic liquefied gases (e.g., LNG) may also form liquid pools in the event of accidental leakage while they are handled at temperatures at or near their atmospheric boiling points. In particular, this may be the case during a prolonged leakage if the rate of leakage exceeds the rate of vaporisation.

The formation of a pool is determined by the effects of mechanical break-up of the jet caused by the high velocity and thermal break-up due to flashing of the liquid. The result is an aerosol jet, which might rain out and form a pool.
2. The decision tree in Figure 1 should be used to determine whether rainout occurs.

Figure 1 Rainout Decision Tree



Where: T_p is the temperature of process liquid, $^\circ\text{C}$ ($^\circ\text{F}$)

N_{bp} is the normal boiling point, $^\circ\text{C}$ ($^\circ\text{F}$)

AFF is adiabatic (Isenthalpic) flash fraction. The fraction on a mole base going to vapour when flashed from process conditions to 1 bara (14.5 psia)

TAF is the resulting temperature of the adiabatic flash, $^\circ\text{C}$ ($^\circ\text{F}$)

T_a is the ambient temperature, $^\circ\text{C}$ ($^\circ\text{F}$)

2.4.1.4 Jet fires

Vapour leakage will by nature disperse as a jet. Pressurised liquefied gases that will not form liquid pools upon accidental leakage will disperse as a vaporising liquid aerosol jet.

Ignition of a liquid or a vapour jet results in a jet fire that may cause impinging flames with high radiation intensities. The length and width of unobstructed jet flames vary as a function of the pressure upstream of the leak, the size and geometry of the hole and the wind speed. Levels of radiant heat may be in the order of 250 kW/m^2 ($80,000 \text{ Btu/h}\cdot\text{ft}^2$) – 450 kW/m^2 ($140,000 \text{ Btu/h}\cdot\text{ft}^2$).

Radiation heat level from high pressure jet fires such as those involving LNG, could be above 1 MW/m^2 ($3,414,425 \text{ Btu/ft}^2$).

2.4.1.5 Flash fires

A flash fire can occur when the combustion of a flammable liquid and vapour results in a flame passing through the mixture at less than sonic velocity. Damaging overpressures are usually negligible, but severe injuries can result to personnel if caught up in the flame. Also, a flash fire may travel back to the source of any release and cause a jet fire if the release is pressurised.

2.4.1.6 Vapour cloud explosions

Vapour cloud explosions can result in damaging overpressures, especially when flammable vapour/air mixtures are ignited in a congested area. Personnel may be killed or injured by blast effects, and buildings, plant and equipment could be damaged or demolished.

2.4.1.7 Boiling liquid expanding vapour explosion

A boiling liquid expanding vapour explosion (BLEVE) is usually a consequence of prolonged heating of a pressurised (normally LPG) vessel by an external fire. The vessel may heat up rapidly and fail, spreading burning fuel as it ruptures. The initiating fire may be a pool or jet fire.

2.4.1.8 Atmospheric storage tank fires

2.4.1.8.1 Vent fire

A vent fire is a fire in which one or more of the vents in a fixed roof tank or internal floating roof tank has ignited.

2.4.1.8.2 Fixed roof tank full surface fire

A full surface fire in a fixed roof tank can be caused by static discharge, lightning strike or vapour space explosion. A vapour space explosion can occur if the vapour space is within a flammable range and this is ignited either by hot tank surfaces (fire heated surfaces greater than the auto-ignition temperature) or by a flash back (through tank openings, defective flame arrestor, etc.) If the tank is constructed to have a frangible roof (see API STD 650 for an example of design requirements) then the roof should separate from the tank shell along a weak seam. Depending on the force of the vapour space explosion, the roof may either be partially removed (creating a "fish mouth" opening) or fully removed.

2.4.1.8.3 Floating roof tank rim seal fire

A rim seal fire is a fire in which the seal between the tank shell and roof has lost integrity and the vapour in the seal area ignites. The amount of seal involved in the fire can vary from a small-localised area up to the full circumference of the tank. The flammable vapour can occur in various parts of the seal depending on the seal design.

2.4.1.8.4 Floating roof tank full surface fire

A full surface fire is a fire in which the tank roof has lost its buoyancy and some or the entire surface of liquid in the tank is exposed and involved in the fire. If a roof is well maintained and the tank is correctly operated, the risk of a rim seal fire escalating to a full surface fire is normally low.

2.4.1.8.5 Floating roof tank spill-on-roof fire

A spill-on-roof fire is a fire in which a hydrocarbon spill on the tank roof is ignited but the roof maintains its buoyancy. In addition, flammable vapours escaping through a tank vent or roof fitting may be ignited. It is difficult to prevent a spill-on-roof fire from escalating to a full surface fire because most firefighting systems are designed for fires in the rim seal area.

2.4.1.8.6 Bund fire

A bund fire is any type of fire that occurs within the containment area outside a tank shell. This type of fire can range from a small spill incident up to a fire covering the whole bund area. In some cases (such as a fire on a mixer) the resulting fire could incorporate some jet fire characteristics due to the hydrostatic head.

2.4.2 Assessment of the detection time

1. The assessment shall document how the fire or product leakage can be detected from the following:
 - a. fire/gas detectors;
 - b. CCTV;
 - c. process instrumentation, or
 - d. detection by personnel patrolling the plant.

This allows an estimate to be made of the time elapsed between the onset of the leakage/fire and the moment operating personnel become aware of the abnormal situation.

2. The fire safety assessment shall include:
 - a. detection target setting;
 - b. detector coverage factors of the detection system;
 - c. fire and gas detector positioning methodology;
 - i. the positioning methodology shall be subject to the approval of the Principal in an early design phase (i.e. DEFINE, Basic Engineering).

2.4.3 Determination of the fuel supply reduction measures

1. The available operational measures to isolate and/or reduce the fuel feeding the fire (e.g. manual valves, ROVs or EIVs, EDP and ESD systems, rapid dumping systems) shall be assessed.
2. The operational measures shall be available for use under the emergency (i.e. the use of the operational measures are not impaired).

2.4.4 Quantification of the fire/leakage

1. The consequences in terms of event types, i.e., pool fires, jet fires, flash fires, vapour cloud explosions (deflagrations or detonations), and BLEVEs shall be calculated using HCM.

HCM allows for the effects of such events, in terms of flame impingement, heat radiation, and overpressure levels to which adjacent equipment may be exposed, to be established with acceptable accuracy. The effects constitute the basis for the quantities of water to be applied, see (4.1.2).

2.4.5 Determination of required fire protection measures

The results obtained from the calculations performed during the HCM will reveal which equipment would be most likely to fail causing further escalation of the fire emergency. This provides the basis for the selection of fire protection measures (water spray systems, fixed fire-water monitors, mobile monitors, manual water application by emergency responders, passive fire protection, etc.).

1. Steel equipment and structures should be cooled if exposed to heat radiation levels between 8 kW/m^2 ($2,500 \text{ Btu/h}\cdot\text{ft}^2$) and 32 kW/m^2 ($10,150 \text{ Btu/h}\cdot\text{ft}^2$):
 - a. Such cooling may be provided by mobile firefighting means (e.g., by portable monitor).
2. Fixed fire protection system should be provided for steel exposed to heat radiation above 32 kW/m^2 ($10,150 \text{ Btu/h}\cdot\text{ft}^2$).

Fixed firefighting systems provide the possibility of early stage action which is needed since unprotected steel will quickly exceed the critical metal temperature (just above 400°C [752°F]). Above the critical temperature the equipment if not designed for these temperatures will lose its mechanical integrity causing escalation of the fire emergency.

Water application rates (L/min/m^2 exposed area) required to cool equipment exposed to a range of radiation fluxes (kW/m^2), including water losses due to windy conditions, are discussed in (4.1.2) and illustrated in (Appendix D).

2.5 FIRE PROTECTION OBJECTIVES AND PRINCIPLES

2.5.1 General

Prompt detection of a fire or hydrocarbon leakage in its earliest stage of development is a crucial factor for active fire protection systems to be effective.

1. Detection may be done by personnel or by an instrument:
 - a. Refer to DEP 32.30.20.11-Gen for detection systems.
2. Where firefighting via mobile response is required, access shall be provided in the plant layout for manual fire-fighting operations:
 - a. In the absence of access, fixed exposure protection systems shall be provided.

2.5.2 Passive fire protection (PFP)

Passive fire protection (e.g., fireproofing) performs its function without relying on activation. The prime function of passive fire protection via fireproofing is to retard the rate of temperature increase of a given substrate.

1. Selection of fireproofing (PFP) shall take into account fire type (e.g., pool/jet), fire size, and likely duration.
2. Refer to (3) for the assessment of fireproofing criteria.

2.5.3 Active fire protection (AFP)

An active fire protection system is a dormant system that requires to be activated in order to perform its function (e.g., water spray systems, deluge systems, sprinkler systems, fire-water monitors, and steam rings around flanges). Such systems are activated once the information is received from the scene of the fire that protection is required. Their function is to protect against escalation of the fire emergency and avoid the need for manual intervention in the fire area.

1. Water mist may be used as an active fire protection system under specific circumstances (e.g. turbine enclosures, engine rooms) in indoor plant.
2. For control and extinguishment of flammable liquid pool fires, foam systems may be used.
3. Active fire protection systems may be automatically or manually activated.
4. If fire protection systems are manually activated, actuation points shall be outside any potential fire zone.

2.6 FIRE FIGHTING PREPAREDNESS

2.6.1 Facilities

2.6.1.1 Communication

The speed and effectiveness of the various actions to be taken also depends on the availability of a reliable communications system. This system serves to receive messages from the plant via telephone, radio and alarm systems. It is used to call out duty personnel, fire brigade personnel, the municipal fire brigade, the police and if necessary, ambulances. It is also used to inform key personnel of the development of the incident.

2.6.1.2 Fire-fighting vehicles

1. Acquisition of a foam transport vehicle as well as a general-purpose and or command vehicle for transport of protective clothing, additional hoses, additional portable monitors and tools should also be considered.
2. Dedicated fire intervention vehicles to allow fast response to incidents by trained FIT members should be provided if provision of these vehicles will allow a longer response time from large fire fighting vehicles which could be delayed due to manpower resources.

2.6.1.3 Mobile foam monitors

1. For backing up foam systems on atmospheric storage tanks, mobile or portable foam monitors shall be available as per the outcomes of the fire safety assessment:
 - a. Capacity of these mobile or portable foam monitors shall be per recommended application rates from international standards (e.g. NFPA) or industry best practise (e.g. LASTFIRE), as specified by the Principal.

2.6.1.4 Fire station

1. If specified in the project scope, a fire station should be provided to:
 - a. protect vehicles from degradation due to exposure to the weather;
 - b. provide a maintenance workshop for fire-fighting equipment;
 - c. storage space for fire-fighting agents;
 - d. training space for fire-fighting instruction;
 - e. office space for full-time fire brigade personnel.
2. Bulk foam storage and their logistic arrangements should be located in or near the fire station.
3. Refer to DEP 80.47.10.33-Gen and DEP 80.00.10.11-Gen.

2.6.1.5 Fire fighting training ground

1. Refer to Standard Drawing S 88.030 for first aid or incipient fire-fighting training ground requirements.
2. Refer to Standard Drawing S 88.031 for fire training ground requirements for fire brigade personnel hose team training.

3. ASSESSMENT OF FIREPROOFING

3.1 GENERAL

3.1.1 General

Fireproofing, also known as passive fire protection (PFP), is one of the available options for limiting damage caused by fire. It offers protection against the adverse thermal effects of fire for a limited period and with limited degree of exposure.

1. Equipment protected by active fire protection may also be protected by fireproofing, if the fire safety assessment determines that the active fire protection systems are not capable of providing the required level of protection.
2. In locations where pool of flammable product can collect under or in the vicinity of supporting steel structures and have the potential for escalation, passive fire protection shall be provided.
3. Fireproofing SHALL [PS] be applied to all steel structures whose sudden failure in a fire scenario can lead to danger for personnel or further escalation of the incident.
4. The engineer responsible for the structural design of the plant or unit shall determine which structural members or bracings within the FPZ serve to reduce the effective buckling length of stanchions and therefore need to be fireproofed.
5. Structural members having only a wind bracing function shall not be fireproofed since the maximum wind load case is assumed not to coincide with the fire case.
6. Certain equipment which needs to continue to operate during a fire, such as remote-operated emergency shut-off and depressurising valves and actuators or critical electrical and instrument cables, shall be fireproofed to stay operable for a defined period of time, as specified in the project specification.

Stairways, walkways and platforms designed mainly for live loads and top surfaces of beams supporting floor plates, gratings or equipment are normally not fireproofed.

3.1.2 Fire resistance duration

The length of time during which a steel structure needs to maintain its integrity depends on local circumstances such as type of plant, availability of fire-fighting services, and risk of escalation.

1. For steel structures and equipment requiring fireproofing per the fire safety assessment, a minimum of 30 minutes protection time against a hydrocarbon fire shall be provided:
 - a. The fireproofing fire resistance may be increased to a longer duration than 30 minutes in the project specification.

It is assumed that after 30 minutes structures can be cooled by water or that plant operating staff will have been evacuated.

The need for protection times longer than 30 minutes is assessed using HCM taking into account fire size, duration, extent of flame impingement and availability of fixed/mobile firefighting systems.

3.1.3 Pool fire considerations

1. Fireproofing material to be provided on steel supports and structures within processing facilities for protection against pool fires shall meet the requirement of hydrocarbon fire test as defined in UL 1709, unless otherwise specified by the Principal.
2. Depending on local regulations, a fire test equivalent to UL 1709, such as BS 476 and ISO 834-3 may be specified, subject to the approval of the Principal.

3.1.4 Jet fire considerations

1. Performance of fireproofing material, selected for the protection of structures, against credible jet fire scenarios, shall meet the test requirements of ISO 22899-1.

This test is complementary to other hydrocarbon fire resistance test of fireproofing materials, as specified in UL 1709, BS 476, and ISO 834-3.
2. Fireproofing material to be applied on the exterior of vessels to protect them against jet fire impingement shall be subjected to a hose stream test per the requirements of NFPA 290.
3. Functional explosion resistance requirements of fireproofing material shall be assessed using HCM.

3.2 DEFINING FIREPROOFING ZONE

1. The concept of a fireproofing zone (FPZ) shall be used to specify where, and to what extent, fireproofing shall be applied.

An FPZ is defined as a zone where leakage of a flammable product can give rise to a pool fire of intensity and duration that can cause failure of steel structures and equipment in the zone.

2. An FPZ shall be applied only to a plant or system with an operating inventory of more than 5 tonnes (11,000 lbs) of flammable products that are capable of sustaining a structurally damaging fire.
 - a. The plant system boundary should not include equipment specific manual isolation valves since these might not be accessible during the fire.
 - b. The inventory within a system shall be based on the combined normal liquid volumes in the equipment (excluding volume in piping).

Materials that are not capable of sustaining a fire are liquids that have low vapor pressure such that ignition results in only a flash fire (e.g., Amine/water solutions, glycol mixtures).

In this context, a plant system is a set of equipment (e.g., vessels, heat exchangers, accumulators) with interconnected flow paths that are expected to remain open during the fire. The boundaries of the plant system include:

- *battery limit valves*
- *spring loaded fail-closed basic process control valves*
- *emergency shutdown/isolation valves (if the actuator is specified spring loaded fail closed or is fireproofed)*
- *Dual Class I check valves (a consideration if the upstream system inventory is less than 5 tonnes)*

The base of the FPZ is where liquid pools can collect on impermeable floor surfaces either at grade or on elevated tablespots or other closed surface decks. Such surfaces can sustain a pool fire and are referred to as hazard levels (HLs). The base of the FPZ is typically at the HL located at grade. If there is an additional HL, then an additional FPZ is established with its base at that HL.

3. Each piece of pressure equipment (e.g., vessel, exchanger) that can release more than 5 tonnes (11,000 lbs) of flammable product from the system inventory shall be considered a PSL.
4. Pumps pumping out of PSL equipment shall be considered a PSL unless there is an ROV on the suction to the pump and the ROV is either spring loaded fail closed or fireproofed.
5. Pumps pumping into PSL equipment shall be considered a PSL unless there is either a fail closed control valve or a dual Class I check valves between the pump and the downstream PSL equipment.
6. The height of the FPZ shall be a minimum of 8 m (26 ft) above its base.
 - a. When specifying the FPZ for structures, the FPZ height should be increased to a logical end point (e.g., just below the bottom of the next horizontal beam) in order to maximize fire protection of the vertical member. See (Appendix B) for examples.

7. The radius of the FPZ shall be 9 m (30 ft) around the PSL.

For pumps the PSL is the pump's mechanical seal; therefore, the FPZ is a cylinder with a radius of 9 m (30 ft) and height of 8 m (26 ft). For pressure equipment the PSL will be the surface of the vessel; therefore, the FPZ will be a zone that is 9 m (30 ft) from the edge of the equipment and 8 m (26 ft) high). See (Appendix B) for example.

The 9 m (30 ft) radius is premised that area drainage is provided per DEP 34.14.20.31-Gen. and that paving design moves spills away from structures.

3.3 FIREPROOFING OF EQUIPMENT AND STRUCTURES

3.3.1 Structures supporting equipment

1. Steel structures supporting vessels, columns or exchangers located within an FPZ or fire exposure envelope SHALL [PS] be fireproofed if one or more of the following criteria apply (refer to Appendix C):
 - a. sudden failure of the structure may cause danger to personnel;
 - b. the supported equipment contains a total of more than 2 tonnes (4,400 lb) of flammable product;
 - c. the supported equipment has a total mass (including contents) of more than 10 tonnes (22,000 lb);
 - d. the supported equipment contains "very toxic – acute" substances (refer to DEP 01.00.01.30-Gen for definition);
 - e. failure of the steel structure and supported equipment could lead to escalation beyond the property limit, including environmental damage.

3.3.2 Column/vessel skirts

1. Column and vessel skirts located within an FPZ or fire exposure envelope SHALL [PS] be fireproofed on the outside if one or more of the following criteria apply:
 - a. the column/vessel contains a total of more than 2 tonnes (4,400 lb) of flammable product;
 - b. the total mass of the column/vessel (including contents) is more than 10 tonnes (22,000 lb);
 - c. the column/vessel contains "very toxic – acute" substances (refer to DEP 01.00.01.30-Gen);
 - d. failure of the column/vessel could lead to consequences beyond the site perimeter including environmental damage.
2. If there are flanged pipe connections inside the skirt, then fireproofing shall be applied inside the skirt.
3. Vessels with fireproofed skirts shall be indicated as such on the vessel data sheet.

3.3.3 Saddle supports

1. Saddle supports for vessels and exchangers (even if located within a FPZ or fire exposure envelope) shall not be fireproofed, unless the shortest vertical distance between the concrete pier and the shell of a vessel/ exchanger:
 - a. Exceeds $\frac{1}{2}$ that of the width of the saddle.
 - b. Is greater than 300 mm (12 in).
2. Saddle supports between piggyback exchangers shall not be fireproofed.
3. For the supporting structure of vessels and exchangers, refer to (3.3.1).
4. Fireproofing of extended height saddle supports should be assessed on a case by case basis subject to approval by the Principal.

3.3.4 Pipe rack and pipe supports

1. Steel structures supporting overhead pipe racks and individual pipe supports, located within an FPZ or fire exposure envelope, shall be fireproofed if one or more of the following criteria apply:
 - a. the pipe is a relief/flare line or an emergency depressurising vent line;
 - b. the pipe contains a "very toxic – acute" substance (refer to DEP 01.00.01.30-Gen);
 - c. the pipe is connected to equipment which would be severely damaged by additional nozzle loading in the event of loss of pipe support;
 - d. the pipe runs beneath an air cooler whose steel support structure is fireproofed (including horizontal members);
 - e. the pipe carries fire-fighting water and/or other utilities that would reduce the fire-fighting capability in the event of loss of support;
 - f. the pipe is an instrument airline or hydraulic control line whose loss would interfere with the ability to shut down the plant.
2. If specified by the fire safety assessment, fireproofing blockouts for bolted moment connections in fireproofed main pipe racks shall be fireproofed in the field.

Blockouts are provided to allow steel erection when PFP is applied to steel in the shop. Typically all blockouts are to be repaired (fireproofed) in the field. The intention is to minimise the size and amount of blockouts to be repaired in the field.

3.3.5 Furnace support structures

1. Furnace stanchions shall be fireproofed from grade level to their full height.
2. Structural members incorporated to reduce the effective buckling length of furnace stanchions shall be fireproofed.
3. Structural members that support fireboxes, convection sections, and/or stacks associated with fired heaters shall be fireproofed if exposed to the fire.

3.3.6 Supports of pressurised spheres and bullets

1. Supporting legs of spheres shall be fireproofed from grade level up to 0.20 m (8 in) below the intersection of the leg with the sphere.
2. All stanchions and beams supporting bullets and structural members incorporated to reduce the effective buckling length shall be fireproofed.
3. For skirts, refer to (3.3.2).

3.3.7 Jetties

1. For jetties, fireproofing shall be applied to the main platform steel beams and to the full extent of steel piles under a loading platform.

This requirement applies to all product berths e.g., crude oil, oil products, LNG, LPG.

2. The piles shall be filled with concrete from a level at least 2.0 m (6.5 ft) below low water level up to the underside of the deck:
 - a. Steel reinforcement of the piles to withstand normal operating loads should be considered.
3. Drip trays draining to a sump should be positioned where potential leakage of (flammable) fluids may occur.
4. Where fireproofing could be impractical (e.g., platforms located close to sea level), alternative fire protection measures, such as water spray systems, should be provided.

3.3.8 Valves and valve actuators

1. In all cases where a valve can be engulfed in fire or exposed to high radiation fluxes (above 12.5 kW/m^2 ($3,960 \text{ Btu/(h-ft}^2\text{))$) as a result of a fire, the fire-safe design requirements of the valve shall be determined.
 - a. The exposure of the valve to fire shall not result in escalation of the fire emergency by leakage of product via the gland to atmosphere or leakage through the valve possibly feeding the fire.

Valves are considered fire-safe if, after an engulfment in flames for a certain period of time, their:

- *seat leakage does not exceed a specified requirement;*
- *external leak rate, for example via the valve spindle or valve body joints, remains within acceptable limits.*

2. Isolation valves that are identified as HSSE critical (as per the HSSE Control Framework Managing Risk Manual) SHALL [PS] be specified as fire safe if installed in locations where it is likely that the valve will be engulfed in flames during an emergency.
3. Refer to DEP 31.38.01.11-Gen and the referenced MESC specifications for fire testing and certification.

4. All safety critical valves, including safety related ROVs or EIVs in pump suction and ESD and EDP valves, plus their actuators plus the actuating system, shall remain operable for a duration of 15 minutes, after exposure to fire:

The need for longer operability will be determined in a fire safety assessment based on the potential for escalation in case a valve fails to isolate the flammable inventory after this duration.

- a. longer operability may be achieved by locating the valves plus components outside the fire hazardous zone;
- b. if a valve has to be located in a fire zone, continued operability may, for instance, be achieved by one of the following:
 - i. fire proofing the actuator assembly;
 - ii. applying fire resistant cables;
 - iii. applying a proprietary fireproofing system on cables;
 - iv. putting the whole assembly in a fire resistant enclosure.

Requirement 3 is exempted for actuators or control leads of sectionalizing valves that are designed as "fail close".

5. For detailed valve design requirements for protection against overpressure and sectionalizing, refer to DEP 80.45.10.11-Gen. and DEP 80.47.10.12-Gen.

3.3.9 Cabling

1. Instrument and power supply cabling that is critical for safe shutdown of the equipment/unit during fire exposure (e.g. isolation valves, emergency depressurisation valves) shall be installed in such a way that it is protected against direct heat radiation and flame impingement.
2. Fire heat exposure should be determined using HCM.

Separation distances using fire area rules or FPZ rules will not be effective since cabling cannot withstand high temperatures.
3. If protection via spacing is not possible, then fire-resistant cables shall be used in accordance with IEC 60331-21, i.e., able to withstand temperatures of at least 750 °C (1380 °F) for the period of time necessary to complete the actions of the critical function, up to a maximum of 90 minutes.

3.3.10 Process vessels, storage vessels and piping

1. In exceptional cases where activation of active systems is expected to be inadequate to avoid incident escalation, vessels and piping shall have fireproofing:

An example of such a case is found in large propane refrigerant systems, where the probability of a BLEVE caused by a jet fire is reduced by means of fireproofing.

 - a. The required fire resistance of the fireproofing should be determined by assessing the expected response time of the fire brigade;
 - b. The fireproofing material to be used for this application should be an epoxy-based intumescent or an epoxy-based subliming coating.

This type of material is suitable only if the normal operating temperature of the substrate is permanently between ambient and 60 °C (140 °F).
2. Selection of fireproofing over other fire protection system shall be subject to approval of the Principal:
 - a. For guidance on types and installation of proprietary fireproofing systems, refer to DEP 34.19.20.11-Gen.
3. For fireproofing against jet fire, refer to (3.1.1).