

DEP SPECIFICATION

**ASSESSMENT OF THE FIRE SAFETY OF ONSHORE
INSTALLATIONS**

DEP 80.47.10.30-Gen.

September 2013

ECCN EAR99

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 projects and to the modification and extension of existing plants. When modifications and extensions to existing plants are envisaged, fire protection aspects shall be considered and existing facilities improved where necessary.

This DEP contains for some situations alternative methods to define the fire protection needs. This is mainly done to make the DEP applicable to be used for design inside and outside the USA.

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

- | | |
|---|----------------------|
| a) Fire, gas and smoke detection systems | DEP 32.30.20.11-Gen. |
| b) Drainage and primary treatment systems | DEP 34.14.20.31-Gen. |
| c) Passive fire protection for onshore facilities | DEP 34.19.20.11-Gen. |
| d) Active fire protection systems and equipment for onshore facilities | DEP 80.47.10.31-Gen. |
| e) Use of fire fighting agents and movable fire fighting equipment for onshore applications | DEP 80.47.10.32-Gen. |
| f) Fire-fighting vehicles and fire stations | 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 2013; see (1.5) regarding the changes.

1.2 DISTRIBUTION, INTENDED USE AND REGULATORY CONSIDERATIONS

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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.

1.3.2 Specific definitions

Term	Definition										
Active fire protection	A "dormant" system that needs to be activated in order to perform its function.										
Fire safety assessment	The process of analysing and evaluating hazards. It involves both causal and consequence analysis and requires determination of likelihood and risk. This can both be a quantitative as well as a qualitative assessment based upon experienced based rule setting.										
Aqueous film forming foam	Synthetic foam consisting of fluorochemical and hydrocarbon surfactants combined with high boiling solvents.										
Classification of fires	In accordance with NFPA, as follows: <table> <tr> <td>Class A fires</td><td>Fires in ordinary combustible materials such as wood, cloth, paper, rubber and many plastics.</td></tr> <tr> <td>Class B fires</td><td>Fires in flammable liquids, oils, greases, tars and flammable gases.</td></tr> </table>	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 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.										
Classification of crude oils and derivatives	In accordance with the IP Code Part 3, as follows: <table> <tr> <td>Class 0 products</td><td>Liquefied Petroleum Gases (LPG).</td></tr> <tr> <td>Class I products</td><td>Liquids which have flash points below 21 °C (70 °F).</td></tr> <tr> <td>Class II (1) products</td><td>Liquids which have flash points from 21 °C (70 °F) up to and including 55 °C (131 °F), handled below flash point.</td></tr> <tr> <td>Class II (2) products</td><td>Liquids which have flash points from 21 °C (70 °F) up to and including 55 °C (131 °F), handled at or above flash point.</td></tr> <tr> <td>Class III (1) products</td><td>Liquids which have flash points above 55 °C (131 °F) up to and including 100 °C (212 °F), handled below flash point.</td></tr> </table>	Class 0 products	Liquefied Petroleum Gases (LPG).	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 0 products	Liquefied Petroleum Gases (LPG).										
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.										

Term	Definition
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	A classification used by NFPA for liquids having flash points below 22.8 °C (73.0 °F) and having a boiling point below 37.8 °C (100 °F).
Combustible product	The term combustible product is not used in this DEP. For this DEP, all liquid hydrocarbon products handled in plants shall be classed as flammable product .
Competent	In relation to this DEP - a 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.
Deluge system	A sprinkler system where the water distribution piping is equipped with open spray nozzles for discharging over an area.
Drenching system	A fixed "free flowing" water discharge device connected via a piping system to a reliable water source. Another definition is A system where 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	An increase in severity of consequences due to the failure of barriers or mitigation measures intended to prevent fire spread.
Fire area	A 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 can 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 control	A reduction in fire intensity of approximately 90%.
Fire-hazardous product	Butane or lighter product; Hydrogen plus hydrocarbons when the partial pressure of hydrogen exceeds 0.7 MPa (100 psia); Hydrocarbons at an operating temperature above the auto-ignition temperature; 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-safe valves	Metal-seated valves that meet leakage criteria specified in fire test protocol. (e.g., provide critical tight shut-off during fire and which remain operable for a period of at least 15 minutes under these test fire conditions)
Fire incident	An 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	The product of the chance that a specified undesired fire incident will occur and the severity of the consequences of the event.

Term	Definition
Flammable product	For this DEP, all liquid hydrocarbon products handled in plants shall be classed as flammable product . See also combustible product and flammability . NOTE: This DEP uses the above definition in order to avoid confusion caused by various codes that define flammable 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.
Flammability	NFPA 704 defines flammability as the degree of susceptibility of materials to burning.
Flammable range	The range of flammable vapour or gas-air mixture between the upper and lower flammable limits. Also, incorrectly, referred to as Explosive Range. e.g., methane between 5 % and 15 % at STP
fluoro-protein foam	A protein based foam with selected fluorinated surfactants that are loosely bonded to the protein to provide the foam with fuel resistance properties.
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.
Fixed foam system	Permanent, complete installation including the foam station, distribution piping and foam application system. (See also semi-fixed foam system, below.)
Hazard	The 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)	The use of mathematical models to estimate the effect of explosions, fires and dispersion.
LASTFIRE	"Large Atmospheric Storage Tank Fires" - a 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	A 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. (<i>This is the same as the Fire Hazard Drawing with the Fire & Gas detectors on an overlay</i>).
Mitigation	Measures taken to reduce the consequences of a fire incident.
Passive fire protection	A 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	A 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 installation consisting of a foam application system connected to distribution piping that terminates at a safe distance. Mobile or portable foam producing equipment shall be transported to 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	The 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.
Sprayer (spray nozzle)	An open discharge device directing most of the discharged water in a pattern typical for the particular discharge device.
Sprinkler	A normally closed 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	A 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
ANSI	American National Standards Institute
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 Shut-Down
FAR	Field Auxiliary Room
FGS	Fire and gas system

Term	Definition
FIT	First Intervention Team
FM	Factory Mutual
FRED	Fire, Release, Explosion, Dispersion
HBPG	High Back Pressure foam Generator
HCM	Hazard Consequence Modelling
IPF	Instrumented Protective Function
ISGOTT	International Safety Guide for Oil Tankers and Terminals
LNG	Liquefied Natural Gas
LPG	Liquefied Petroleum Gas
MESC	Material and Equipment Standards and Code
MIL	Military Standard (USA)
NFPA	National Fire Protection Association
NGL	Natural Gas Liquids
ROV	Remotely Operated Valve
TSO	Tight Shut Off
UL	Underwriter's Laboratories

1.4 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 (7).

1.5 SUMMARY OF MAIN CHANGES

This DEP is a revision of the DEP of the same number dated February 2013. The following are the main, non-editorial changes.

Section/Clause	Change
1.1	Updated title of DEP 34.19.20.11-Gen. to "Passive fire protection of onshore facilities".
7	Updated title of DEP 34.19.20.11-Gen. to "Passive fire protection of onshore facilities".
7	Added the "Design Engineering Manual (DEM1) to Reference section.

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://swwww.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.

2. FIRE SAFETY ASSESSMENT

2.1 GENERAL

The determination of the plant's fire safety shall be based on the likelihood and consequences of a number of selected fire and hydrocarbon leakage scenarios for the plants concerned. Based upon the risk assessment, fire prevention, fire protection and fire fighting measures can be instituted. This can both be a quantitative as well as a qualitative assessment based upon experienced based rule setting.

For buildings, a fire safety assessment shall include evaluation of combustible materials, ignition sources, fire-spread potential, detection, fire protection and means of escape. The Principal shall ensure that this is carried out.

The following items shall be addressed in a building fire safety assessment:

- a. Identification of all possible fire hazards (including combustible or flammable materials and ignition sources)
- b. Identification of people and assets at risk from fire
- c. Methods of elimination, control or avoidance of fire hazards
- d. Consideration of whether existing fire safety measures are adequate or need improvement
- e. Documentation of fire safety assessment findings
- f. Preparation of Emergency Plan and Evacuation Plan
- g. Periodic reviews of assessments

Irrespective of the risk assessment technique utilised, the extent of fire protection is related to operating manpower levels, personnel safety requirements, environmental concerns, potential for business interruption and facility reputation, and shall be agreed with the Principal.

For situations not included in this DEP, NFPA codes or equivalent international standards shall be consulted. The relationship of NFPA codes or equivalent international standards and the situations covered in this DEP are discussed in (1.2).

For new projects and, where applicable, for extensions to existing plants, a **master plan of fire safety systems** shall be prepared. This plan covers the entire installation and shows 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 fire fighting equipment and such like) using the graphical symbols and abbreviations given in (Appendix 1). Fire and Gas detection systems details are normally displayed in specific drawings.

The Principal could also instead of requiring a master plan of fire safety systems dictate the development of a **Fire Hazard Drawing**. See (Appendix 5) for further guidance for developing such a drawing.

For the phases of design, engineering, construction and commissioning of plants, it shall be clearly defined which party is responsible for fire safety and fire protection.

2.2 SEQUENTIAL STEPS TO BE TAKEN DURING A FIRE SAFETY ASSESSMENT

2.2.1 Determination of loss of containment and fire scenarios

In order to achieve in a cost-effective way an acceptable degree of fire safety of the plant, all aspects contributing to fire safety shall be assessed throughout the development of the project.

2.2.2.1 Loss of containment scenarios

The scenarios to be considered should be restricted to those equipment failures that are likely to occur and which involve the leakage of flammable products and flammable gases,

toxic products and gases, of which the frequency of occurrence and the severity of the consequences have been taken into consideration. Examples of scenarios that meet the above criteria are:

- a. 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.
- b. Leaks from failure of an instrument fitting, typically 10 or 15 mm (0.4 or 0.6 in) in diameter.
- c. Small leaks from flange joints. Representative hole sizes are 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 compressed asbestos fibre (CAF) gaskets.
- d. Full bore ruptures of process lines up to size DN 20 (NPS 3/4).
- e. Pump and compressor seal failures. These failures can be represented by assuming equivalent hole sizes of 9 mm (0.35 in) diameter.
- f. For storage areas, releases into bund areas (e.g., mixer leak, etc.)

2.2.2.2 Fire scenarios

The scenarios to be considered 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. Typical credible scenarios include:

- a. For storage areas, full surface fixed roof tank fire scenarios.
- b. Vent fires on fixed and internal floating roof tanks
- c. For floating roof storage tanks, fires on the roof (partial or full surface) and fires in the rim seal area
- d. For process areas, jet fires, pool fires and combined jet/pool fires
- 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

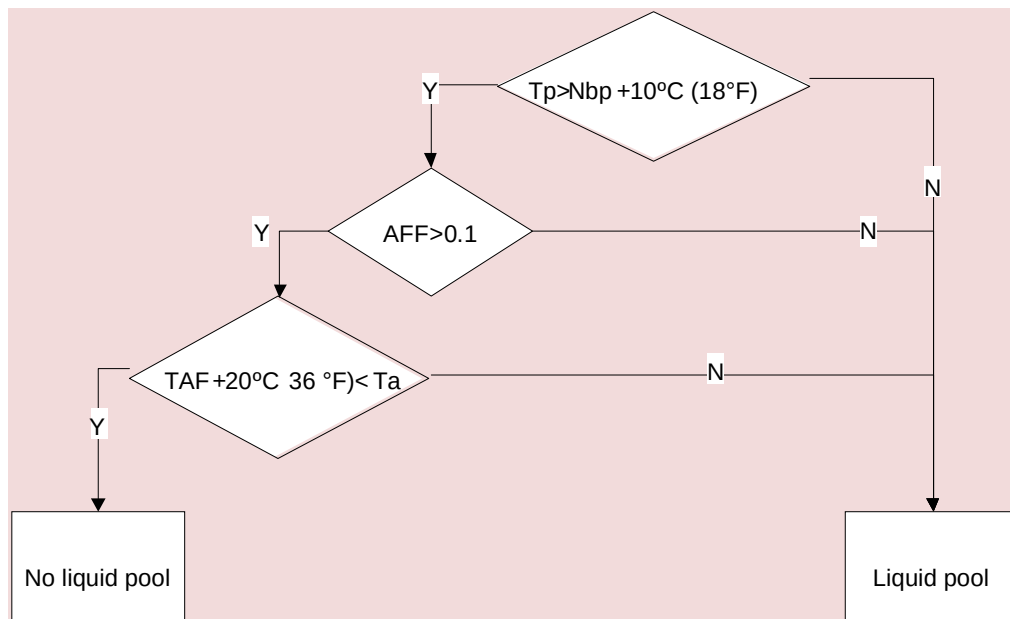
NOTE: For jet/pool fires, gas and liquid flow rates from holes shall be calculated using HCM.

NOTE: Boil over scenarios 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.

2.2.2.3 Pool fires

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. For the above categories the possibility of pool fires has therefore to be taken into account.

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. With the aid of the following decision tree it can be decided whether rainout occurs.



Where:

T_p	=	Temperature of process liquid, °C (°F)
N_{bp}	=	Normal boiling point, °C (°F)
AFF	=	Adiabatic flash fraction. The fraction on a mole base going to vapour when flashed from process conditions to 1 bara (14.5 psia)
TAF	=	Resulting temperature of the adiabatic flash, °C (°F)
T_a	=	Ambient temperature, °C (°F)

2.2.2.4 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/m² (80,000 Btu/h·ft²) to 450 kW/m² (140,000 Btu/h·ft²).

2.2.2.5 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.

2.2.2.6 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.

2.2.2.7 BLEVE

A BLEVE (Boiling Liquid Expanding Vapour Explosion) 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

2.2.2.8 Atmospheric storage tank fires

a) 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.

b) 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 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.

c) Floating Roof Tank Rim Seal Fire

A rim seal fire is one where 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.

d) Floating Roof Tank Full Surface Fire

A full surface fire is one where 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.

e) Floating Roof Tank Spill on Roof Fire

A spill-on-roof fire is one where 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 very difficult to prevent a spill on roof fire from escalating to a full surface fire because most fire fighting systems are designed for fires in the rim seal area

f) Bund Fire

A fire in the bund is any type of fire that occurs within the containment area outside the tank shell. These types 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

2.2.3 Assessment of the detection time

It shall be assessed how the fire or product leakage can be detected using fire/gas detectors, CCTV, process instrumentation, or 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.

Detection target setting as well as detector coverage factors of the detection system and the fire and gas detector positioning methodology shall be defined during the fire safety

assessment. The Principal shall approve the positioning methodology in an early design phase.

2.2.4 Determination of the fuel supply reduction measures

The available operational measures to isolate and/or reduce the fuel feeding the fire (manual valves, ROVs or EIVs, EDP and ESD systems, rapid dumping systems, etc.) shall be assessed. Ensure that the operational measures can be deployed during the emergency.

2.2.5 Quantification of the fire / leakage

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

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

2.2.6 Determination of required fire protection measures

The results obtained from the calculations thus performed 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.).

As a general rule, equipment may need cooling when exposed to heat radiation levels between 8 kW/m^2 ($2,500 \text{ Btu/h}\cdot\text{ft}^2$) and 32 kW/m^2 ($10,150 \text{ Btu/h}\cdot\text{ft}^2$). Such cooling could be provided by mobile means (e.g., by portable monitor). Above 32 kW/m^2 , cooling should be provided at an early stage, since unprotected steel will quickly exceed the critical metal temperature (just above 400°C [752°F]), which could result in the equipment losing its mechanical integrity and causing escalation of the fire emergency. (Normally fixed systems would be required.)

Typical 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 4).

2.3 FIRE PREVENTION MEASURES

Fire prevention measures are to a large extent an integral part of the design, engineering and construction of plants.

During the process and engineering design phases a large number of proven guidelines are applied which, together with good engineering practice, should result in processing facilities with a high degree of reliability and consequently a low probability of loss of containment.

Proper application of the appropriate DEPs for equipment, interconnecting piping and fittings should result in facilities design with a very low probability of uncontrolled loss of containment.

Additional measures to decrease the probability that explosion and fire incidents could occur comprise:

- Measures to prevent hydrocarbon leakage;
- Measures to minimise leakage quantities; and
- Measures to minimise the probability of ignition if a leakage should occur.

2.3.1 Measures to prevent hydrocarbon leakage

The piping arrangement shall be designed so that the probability of a leakage is minimised.

The number of flanged connections shall be minimised, particularly in sections with high pressures, sections containing hydrogen, light hydrocarbons or chemical products, and sections containing hot products at or above their auto-ignition temperature.

Small-bore process piping shall be minimized. Where used, designs shall be reviewed on a case-by-case basis for consequence of failure, using the criteria listed in (2.2.2.1). If such piping is required, it SHALL [PS] be designed properly and protected against mechanical failure as a result of vibration, collision, freezing or over-pressuring of blocked-in pipe sections.

Attention shall be paid to the fail-safe position of instrumentation and final control elements.

Conventional level gauges are relatively weak and therefore vulnerable. Gauge glasses should not be used in the following services. Magnetic level gauges are required in these applications.

- a. C4 and lighter products.
- b. Other hydrocarbon services that would potentially create a flammable heavier than air vapour cloud.
- c. Chemical services that can form a heavier than air vapour cloud capable of causing significant harm (e.g., ethylene oxide, ammonia, chlorine, etc.)
- d. Chemicals/materials that are above their auto-ignition temperature
- e. Hydrocarbon services with pressure higher than 70 bar (ga) [1000 psig].
- f. Hydrocarbon services at a temperature higher than 200 °C (400 °F).

The shaft sealing systems for rotating equipment SHALL [PS] be designed with the aim of reducing the probability of product leakage if seal components fail.

Redundant process and equipment monitoring alarms are highly effective in protection against malfunctioning process instrumentation and runaway of process conditions. Early detection of extreme temperatures, pressures, levels, etc. can prevent serious incidents.

Atmospheric tank level alarms – in particular, independent high-high level alarms with corrected action may be considered to be a risk reduction measure for tank overfill where an effective barrier is demonstrated.

2.3.2 Measures to minimise hydrocarbon leakage quantities

During the process and engineering design phases, a number of specific measures can be taken aimed at segregation of particular sections of the plant, rapid dumping of parts of the plant inventory and provision of rapid detection facilities to alert the operator as quickly as possible that loss of containment has taken place.

These measures are intended to reduce the quantities of fuel that can be consumed in case of fire. These fuel quantities determine the size and duration of a fire, on which basis the consequences of the credible fire incidents can be estimated, on the assumption that the probability of escalation is minimised by the fire protection measures.

To restrict or reduce the quantity of flammable product feeding the fire, isolating valves that are accessible and operable during a fire incident can be incorporated. If the manual isolation valve will not be accessible during a fire emergency, installation of a Remote Operable Emergency Isolation Valve (ROV or EIV) should be considered.

The positioning of ROVs or EIVs, taking into account isolatable inventories SHALL [PS] be determined during the process and engineering design phases.

Typically ROVs or Emergency Isolation Valves (EIVs) have been installed in the suction line of pumps when the upstream system contains:

- More than 4 m³ (140 ft³) of butane or more volatile product;

- More than 10 m³ (350 ft³) of hydrocarbon liquids handled above their auto-ignition temperature.

Critical isolating valves SHALL [PS] be specified fire safe if installed in locations where it is likely that the valve will be engulfed in flames during a fire emergency.

Conventional wafer type valves clamped between flanges with long bolts or tie rods are insufficiently fire safe and SHALL [PS] not be used in hydrocarbon service. Where such valves are installed in existing plants in locations where pool fires can occur, the external bolts shall be fireproofed or active fire protection facilities shall be installed.

For plants with a significant inventory of light hydrocarbons or toxic material an ESD system should be considered which can shut down a total plant or individual plant sections. The sections are selected on the basis of the location of the equipment, the layout of the plant section, and the quantity of hydrocarbons contained per section.

Pressure vessels can be provided with EDP facilities to enable controlled process pressure reduction, thus disposing of part of the inventory in a safe manner. Liquid dropout facilities can be applied if rapid disposal of the liquid inventory is required.

Instrumentation to detect loss of containment shall be considered if detection by personnel or by other means is likely to be too late to prevent escalation of the incident. (See 4.4.)

For detailed design requirements criteria to establish protection against overpressure and sectionalizing processing streams reference is made to DEP 80.45.10.11-Gen. and DEP 80.47.10.12-Gen.

2.3.3 Measures to minimise the probability of ignition of hydrocarbon leakage

In the design the layout SHALL [PS] be optimised to reduce to a tolerable level the probability of coincidence of a flammable vapour-air mixture and known electrical or other sources of ignition.

Electrical area classification will be dictated by local regulations/Codes (e.g., IEC in Europe or NEC in the US). Applicable standards such as IP and API-500 will be applied.

The overall area layout in combination with the surface drainage arrangement should minimise the probability of large pools of fuel collecting under, or in the vicinity of equipment containing flammable liquids or vapours. In case of loss of containment the spill will thus be confined to a small area. In case of ignition of the spill the probability of escalation will then be low.

The equipment layout should avoid installation of walls and roofs that might interfere with natural ventilation since confinement increases the level of damage if accumulated vapours ignite. Fire decks, i.e., impermeable concrete floors in plant structures, inhibit natural ventilation and shall therefore not be applied.

Noisy equipment or equipment requiring frequent opening up may have to be equipped with noise hoods and/or weather protection. If enclosures for such equipment are indispensable, special attention shall be paid to the ventilation of these enclosures. This can be achieved by providing adequate ventilation and minimizing the number of leak sources within the enclosure (flanges, for example, might preferably be located outside of the enclosures.)

A layout model such as the Shell Layout Methodology should be used to optimise the layout and to evaluate safety-related aspects of plant orientation and spacing.

Some types of insulation are susceptible to spontaneous ignition when soaked with certain process streams (e.g., waxy oils, and some heat transfer fluids). Processes that are susceptible to this require special insulation at expected leak points.

2.4 FIRE PROTECTION OBJECTIVES AND PRINCIPLES

2.4.1 General

Layout of and distances between fire-hazardous equipment shall be such that in the event of a fire the probability of escalation is reduced. However, since it is not always feasible to

achieve complete separation of individual pieces of equipment, within an operational complex, additional precautionary fire protection measures may be necessary.

Where fire protection is deemed necessary, passive fire protection and/or active fire protection measures shall be considered where feasible.

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. Detection may be done by personnel or by an instrument. The detection systems shall be capable of providing prompt detection, refer to DEP 32.30.20.11-Gen. Active fire protection systems in plants mainly comprise water spray systems, deluge systems and firewater monitors. Water mist may be used under specific circumstances in indoor plant. For control and extinguishment of flammable liquid pool fires, foam systems may be considered.

Where fire fighting via mobile response is required sufficient access shall be provided for manual fire-fighting operations. For areas requiring protection but where access is considered inadequate and cannot be improved, fixed exposure protection systems, which remain in operation until the fire brigade has arrived to determine the appropriate method of attack, SHALL [PS] be provided.

2.4.2 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.

Selection of fireproofing (PFP) shall take into account fire type (e.g., pool/jet), fire size, and likely duration. HCM will normally be required.

For the assessment of fireproofing criteria see (3).

2.4.3 Active fire protection

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. Systems may be automatically or manually activated. If manual, actuation points shall be outside any potential fire area. Their function is to protect against escalation of the fire emergency and avoid the need for manual intervention in the fire area.

2.5 FIRE FIGHTING PREPAREDNESS

2.5.1 General

The fire safety of a plant is the degree of invulnerability to fire and/or explosion incidents in terms of their probability of occurrence and associated potential damage. This degree is maximised by the integrated application of fire prevention, fire protection and fire-fighting measures.

If, despite the preventative measures, potential fire risks remain, fire protection measures need to be taken comprising measures to protect personnel, measures to protect the environment, measures to detect fires and releases at an early stage and measures to prevent escalation of a fire incident.

The plant organisation needs to be prepared to deploy a fire-fighting organisation to control and/or extinguish fires that occur despite the fire prevention and fire protection measures.

2.5.2 Organisation

Despite the degree of reliability of process equipment, process control and safeguarding systems and optimum application of fire prevention and fire protection measures, occasional fire incidents will continue to occur.

The probability of occurrence of these incidents constitutes the residual fire risk, i.e., the risk that remains after all normal prevention and protection measures have been taken.

Plants are provided with adequate first-aid fire-fighting equipment (hand-held extinguishers, small foam units, hose reels, steam lances and such) and well-trained plant personnel able to handle the small fire incidents with confidence.

It should further be able to mobilise large fire-fighting equipment (fire-trucks, foam transport vehicles, auxiliary vehicles) within a reasonable time after outbreak of a major fire and should have an organisation in place able to manage the large fire and explosion emergencies, possibly in collaboration with external fire brigades.

Care should be taken to ensure that First Intervention Team (FIT) and/or fire responders are not subjected to high levels of radiant heat during any emergency response and appropriate inherently fire-resisting Personal Protective Equipment (PPE) should be provided. As part of the preparation of Pre Incident Plans (see 2.5.3), the results of HCM should be used to assess the potential degree of exposure and to provide responders with information on appropriate safety distances. As a general rule, operators and/or FIT members should not be exposed to $>2.5 \text{ kW/m}^2$ ($>800 \text{ Btu/h}\cdot\text{ft}^2$) when dressed in "standard" inherently fire resisting PPE (e.g., coveralls). Fire responders wearing inherently fire resisting "bunker gear" should not be exposed to levels $>6.5 \text{ kW/m}^2$ ($2100 \text{ Btu/h}\cdot\text{ft}^2$). (However, local legislation may apply and these levels may be lower in some cases). Consequently, activation points for active fire protection systems should normally be outside these areas of potential exposure.

The outcome of the fire safety assessment or fire hazard analysis shall be used to determine the optimal structure of the fire fighting organisation and facilities. The following factors shall be taken into account;

- a) The size, location and complexity of the installation(s).
- b) Site Criticality.
- c) Fire-fighting Philosophy including Fire & Explosion Strategy.
- d) Available personnel (on-shift and call-out).
- e) The local fire regulations in force.
- f) The role, technical capabilities (manual and mobile equipment) and expected response time of municipal fire brigades.
- g) Possible legal requirements for an emergency centre, including medical services.
- h) Mutual aid arrangements in the region.

A prerequisite for such an organisation to act effectively is the existence of well-prepared pre-incident plans (2.5.3), based on well-defined scenarios. These scenarios, see (2.2.1), may best be generated by a study team consisting of operations, process, hardware and safety specialists.

The fire brigade shall be staffed by competent, experienced and trained personnel. The positions to be filled comprise the incident commander, drivers/operators of the fire fighting vehicles and a number of hose teams. The number of persons assigned to these hose teams depends on the overall manpower situation, the complexity of plants, the fire prevention and fire protection measures in place and the layout of the site. Personnel requirements shall be determined on a scenario specific basis according to the resources needed to successfully manage the incident.

Some of these personnel may be drawn from a permanent (full time) fire brigade. The remaining positions are in most cases taken by suitably trained and competent shift operators and maintenance personnel.

To assist in developing the organisation, and to ensure that responsibilities are clearly defined, job descriptions and responder competencies should be developed. Comprehensive competency profile examples and guidance on these aspects is given in Energy Institute IP19, 2nd Edition. As an alternative or in addition NFPA 1081 could be used. NFPA 1081 establishes minimum job performance requirements necessary to

perform the duties as a member of an organized industrial fire brigade providing services at a specific facility or site.

At the onset of a fire that is beyond the capabilities of the operating personnel responsible for the area, the shift supervisor assumes the duty of incident commander and co-ordinates the activities of a nominated First Intervention Team (FIT). This FIT consists of a number of personnel available on the site at any one time to operate the fire truck(s) and to manage the hose teams. The shift supervisor remains in charge of both the operational and fire-fighting activities until he is relieved from this duty by the Fire Chief who would typically be from a local fire brigade. Depending on the site-specific fire brigade, stand-by teams may be formed from other personnel not normally engaged in operational or maintenance activities.

In plants with very low personnel levels it may be impossible to form an effective FIT. If external fire-fighting support is not available at short notice, more extensive provision of ESD, fire protection and fire extinguishing systems may be needed.

2.5.3 Pre incident planning

The preparation of operational, technical and fire fighting details to allow credible fire and release incidents to be controlled in the most efficient and effective manner is called PRE-INCIDENT PLANNING. These Pre-Incident Plans that are part of the Site Emergency Plan cover:

- Planning and taking process operational actions to control the emergency
- Planning and taking operational fire fighting actions to control the emergency
- Co-ordinating the operational process and fire fighting actions

Pre-incident planning addresses the selection of likely and realistic scenarios, assesses how quickly personnel responsible to address the emergency becomes aware of the incident, determines which operational actions are required to reduce the fuel feeding the fire, quantifies the vapour cloud or fire, sets priorities for fire protection measures and quantifies the required fire fighting capacities in equipment and manpower to bring the incident under control.

It further addresses the consequences of release of toxic products and of the release of contaminated firewater.

The pre-incident plans form the basis for addressing the fires and releases. The plans need thus to be developed and written by operating personnel to achieve a good sense of ownership. Responsibility for these Plans and their necessary revisions is also in hands of the operating department(s).

2.5.4 Facilities

2.5.4.1 Communication

The speed and effectiveness of the various actions to be taken are also dependent 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.

2.5.4.2 Fire-fighting vehicles

The required number (n) and capacity of the fire-fighting vehicles is based on the largest determined fire scenario, which dictates the foam generating capacity and the number of personnel available for fire-fighting operations.

Where fire fighting using fire fighting vehicles is assessed to be a safety critical service in a plant, the number of (foam generating) vehicles SHALL [PS] be $n + 1$, since it cannot be excluded that one vehicle may fail to perform its duty during a crucial fire.

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 shall also be considered.

In certain operations provision of dedicated fires intervention vehicles to allow fast response to incidents by trained FIT members could be required. Mobilizing large fire fighting vehicles could in such situations be delayed to allow longer response times of manpower resources.

2.5.4.3 Mobile foam monitors

For backing up foam systems on atmospheric storage tanks, an adequate number of mobile or portable foam monitors shall be available with adequate capacity. Capacity shall be determined by consideration of application rates of water/foam etc. from NFPA/international standards/LASTFIRE.

2.5.4.4 Fire station

The provision of a fire station shall be considered to protect vehicles from degradation due to exposure to the weather, and to provide a maintenance workshop for fire-fighting equipment, storage space for fire-fighting agents, training space for fire-fighting instruction and office space for full-time fire brigade personnel. Consideration may need to be given to foam logistics, and bulk foam supplies may need to be located in the vicinity of the fire station.

Fire station(s) SHALL [PS] be in an area of low fire risk. Refer to DEP 80.47.10.33-Gen.

2.5.4.5 Fire training ground

Subject to permission by the local Authorities to light open fires, a training ground should be provided, or the use of appropriate external training facilities shall be arranged. If the size of the groups that can be mobilised for the training sessions is too small (less than 10 people) it may be more efficient and cost effective to send personnel to external fire training courses. Depending on FIT capabilities and requirements, the fire training ground shall include equipment simulating pressure fed fires, running liquid fires, pool fires, and, where appropriate, atmospheric storage tank fires such as rim-seal incidents.

First aid or incipient fire-fighting training shall be given to all personnel involved in handling flammable products and to personnel handling ignition sources. This training shall cover the use of portable and wheeled dry chemical extinguishers and small foam carts. For this type of training a facility as described in Standard Drawing S 88.030 should be provided.

Hose team training is required for the fire brigade personnel. The fires to be lit should be large enough to be realistic. For this type of training a facility as described in Standard Drawing S 88.031 should be provided.

3. ASSESSMENT OF FIREPROOFING

3.1 GENERAL

Fireproofing 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. If active fire protection systems also covering the area where this equipment is located are not expected to give timely and adequate protection, passive fire protection SHALL [PS] be provided.

In cases where flammable product can collect under or in the vicinity of supporting steel structures, passive fire protection SHALL [PS] be considered. Passive fire protection (fireproofing) is applied to all steel supporting structures whose sudden failure would lead to danger for personnel, escalation of the incident or unacceptable environmental pollution. It offers protection for a limited period and with a limited degree of exposure, i.e., until the full fire-fighting capabilities can be deployed.

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. 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.

Certain equipment which must continue to operate during a fire, such as remote-operated emergency shut-off and depressurising valves and actuators or critical electrical and instrument cables, may need fire protection to stay operable for a defined period of time.

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

3.1.1 Resistance against a fire

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.

A minimum of 30 minutes protection time against a hydrocarbon fire SHALL [PS] be provided, however longer protection times may be warranted or required depending on the equipment, function and available fire-fighting measures. Protection time shall be assessed taking into account fire size, duration, extent of flame impingement, etc, for which HCM may be needed.

It is assumed that after this period structures can be cooled by water or that plant operating staff will have been evacuated. In special cases where this is unlikely, increasing the fire resistance to a longer duration shall be considered. Where effective water-cooling is not feasible (e.g., due to the configuration of the structure), the required duration of the fire resistance depends on the estimated time for the fire to burn out or be extinguished.

Some fireproofing materials are susceptible to deterioration and/or break up in the event of application of jets of firewater (e.g., when used for cooling purposes).

The hydrocarbon fire test as defined in UL 1709 is applicable to all fireproofing systems provided on steel supports and structures within processing facilities. This fire is more severe than the cellulose type of fire that is usually referred to in building regulations. During the test a protected steel column is exposed to a particular heat flux that produces a temperature of 1093 °C (2000 °F). The test is terminated (failure point) when the average temperature of the steel substrate reaches 538 °C (1000 °F). Depending on local conditions, a fire test equivalent to UL 1709, such as BS 476, may be specified subject to the approval of the Principal.

Fireproofing for applications where jet fire scenarios are considered a design case may need Jet fire testing/approval and certification. The fire testing should as far as practicable reproduce the expected scenario conditions in terms of flow rate/flame size, etc.

3.2 DEFINING FIRE PROOFING ZONE

This DEP uses either the concept of a Fire Proofing Zone (FPZ) (see 3.2.1) for designs outside the USA or the concept of Potential Fire Source (see 3.2.2) typically for projects inside the USA to define where and to what extent fireproofing shall be applied. The Principal shall define which concept shall be used.

3.2.1 Fire proofing zone concept

An FPZ is defined as a zone where leakage of a flammable product can give rise to a pool fire of sufficient intensity and duration to cause failure of steel structures and equipment in the zone. An FPZ shall only be applied to a plant or system with an operating inventory of more than 5 tonnes (11,000 lbs) of flammable products. In this context, a "system" is the smallest volume of piping and equipment (including vessels) that can be "blocked in" in the event of a fire.

Liquid pools will collect on impermeable floor surfaces either at grade or on elevated tablespots or other closed surface decks. Such surfaces that can sustain a pool fire are further referred to as Hazard Level (HL). The concept of Hazard Level (HL) and PSLs are used to define the extent of the Fire Proofing Zones (FPZs) resulting from pool fires.

The extent of the FPZ is defined as a function of **liquid pool fires** as follows:

The FPZ is a volume with a cylindrical shape. The cylinder shall have a radius of 9 m (30 ft) from the PSL and a height of 8 m (26 ft) above HL (see Appendix 2).

3.2.2 Potential fire source concept

A potential fire source shall be defined as follows:

1. Location where a liquid release is reasonably possible (e.g., at pumps and equipment) and where fire can result with sufficient intensity or duration to cause damage to steel structures that supports main pipe racks and process equipment.
2. Potential fire source shall be determined from the fire hazard level of the process stream and the normal liquid hydrocarbon inventory in the equipment.

Fire Hazard Level of Process Stream	Minimum Vessel Inventory for Consideration as a Potential Fire Source	
	liters	gallons
Very Low	> 18,900	> 5000
Low	> 7,600	> 2000
Moderate	> 5,700	> 1500
High	> 3,800	> 1000
NOTE: For large process units it may be reasonable initially to assume that all hydrocarbon equipment is a potential fire source and then look for exceptions.		

The fire exposure envelope, this is the area where fireproofing shall be applied to structural steel, extends 8 m (26 ft) vertically and 9 m (30 ft) horizontally from the potential fire source.

3.3 FIREPROOFING OF EQUIPMENT AND STRUCTURES

3.3.1 Structures supporting equipment

Steel structures supporting vessels, columns or exchangers located within an FPZ or fire exposure envelope SHALL [PS] be fireproofed when one or more of the following criteria apply (see Appendix 3).

1. Sudden failure of the structure may cause danger to personnel.
2. The supported equipment contains a total of more than 2 tonnes (4,400 lb) of flammable product.