

PETRONAS TECHNICAL STANDARDS

DESIGN AND ENGINEERING PRACTICE

MANUAL

ASSESSMENT OF THE FIRE SAFETY OF ONSHORE INSTALLATIONS

PTS 80.47.10.30

JANUARY 2009



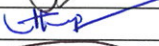
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This revision of PTS 80.47.10.30 – Assessment of the Fire Safety of Onshore Applications has been updated incorporating PETRONAS Lessons Learnt, Best Practice and new information issued by relevant industry code and standards. All updates in the document are highlighted in *italic* font.

The previous version of this PTS (Revision 1 January 2000) will be removed from PTS binder/ e-repository from herein onwards.

Document Approval

	Name	Designation	Date	Signature
Prepared/ Reviewed	Jamaliah Burok	Staff Engineer	23-Dec-08	
Approved	Bijay Kumar Nepak	Principal Engineer	Jan-09	
Verified	Samsudin Dato' Harun	Senior Manager, Engineering - GTS	27 Feb '09	
Verified	Pau Kiew Huai	General Manager, Engineering - GTS	4.3.09	
Endorsed	Pramod Kumar Karunakaran	Senior General Manager, GTS	5.3.09	

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PREFACE

PETRONAS Technical Standards (PTS) publications reflect the views, at the time of publication, of PETRONAS OPU/Divisions.

They are based on the experience acquired during the involvement with the design, construction, operation and maintenance of processing units and facilities. Where appropriate they are based on, or reference is made to, national and international standards and codes of practice.

The objective is to set the recommended standard for good technical practice to be applied by PETRONAS' OPU in oil and gas production facilities, refineries, gas processing plants, chemical plants, marketing facilities or any other such facility, and thereby to achieve maximum technical and economic benefit from standardisation.

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

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1. INTRODUCTION

1.1 SCOPE

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

This PTS 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 is a revision of the PTS of the same number dated *January 2000*. A summary of the main changes since the last edition is given in (1.5).

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

Fire, gas and smoke detection systems	PTS 32.30.20.11
Drainage and primary treatment systems	PTS 34.14.20.31
Fire proofing of steel structures	PTS 34.19.20.11
Active fire protection systems and equipment for onshore facilities	PTS 80.47.10.31
Use of fire fighting agents and movable fire fighting equipment for onshore applications	PTS 80.47.10.32
Fire-fighting vehicles and fire stations	PTS 80.47.10.33

1.2 DISTRIBUTION, INTENDED USE AND REGULATORY CONSIDERATIONS

Unless otherwise authorised by PETRONAS, the distribution of this PTS is confined to companies forming part of PETRONAS, and to Contractors nominated by them.

This PTS is intended for use in oil refineries, chemical plants, gas plants, supply/marketing installations and, where applicable, in onshore exploration and production facilities.

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

1.3 DEFINITIONS AND ABBREVIATIONS

1.3.1 General definitions

The **Contractor** is the party which 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 which manufactures or supplies equipment and services to perform the duties specified by the Contractor.

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

The word **shall** indicates a requirement.

The word **should** indicates a recommendation

1.3.2 Specific definitions and abbreviations

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.												
aqueous film forming foam	a synthetic foam consisting of fluorochemical and hydrocarbon surfactants combined with high boiling solvents.												
classification of fires	in accordance with NFPA, as follows: <table border="0"> <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.								
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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 border="0"> <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.</td></tr> <tr> <td>class II (1) products</td><td>Liquids which have flash points from 21 °C up to and including 55 °C, handled below flash point.</td></tr> <tr> <td>class II (2) products</td><td>Liquids which have flash points from 21 °C up to and including 55 °C, handled at or above flash point.</td></tr> <tr> <td>class III (1) products</td><td>Liquids which have flash points above 55 °C up to and including 100 °C, handled below flash point.</td></tr> <tr> <td>class III (2) products</td><td>Liquids which have flash points above 55 °C up to and including 100 °C, handled at or above flash point.</td></tr> </table>	class 0 products	Liquefied Petroleum Gases (LPG).	class I products	Liquids which have flash points below 21 °C.	class II (1) products	Liquids which have flash points from 21 °C up to and including 55 °C, handled below flash point.	class II (2) products	Liquids which have flash points from 21 °C up to and including 55 °C, handled at or above flash point.	class III (1) products	Liquids which have flash points above 55 °C up to and including 100 °C, handled below flash point.	class III (2) products	Liquids which have flash points above 55 °C up to and including 100 °C, handled at or above flash point.
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class III (2) products	Liquids which have flash points above 55 °C up to and including 100 °C, handled at or above flash point.												
class 1A products	a classification used by NFPA for liquids having flash points below 22.8 °C and having a boiling point below 37.8 °C.												
combustible product	The term combustible product is not used in this PTS. For this PTS, all liquid hydrocarbon products handled in plants shall be classed as flammable product. NOTE: This PTS does not use the term combustible product in order to avoid confusion caused by various codes which define combustible products differently. For example, according to NFPA 30, a combustible product has a flash point ≥ 37.8 °C, whereas other codes define it as a substance having a flash point > 61 °C.												
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.												
Escalation	an increase in risk due to increased likelihood and/or severity of consequences.												
fire area	a plant area where a sustained intense fire is considered credible. In												

	line with API RP 521, a 2500 square feet (232 m ²) surface on fire can be assumed to be the maximum size of fire to be encountered.
fire control	a reduction in fire intensity of approximately 90%.
fire-hazardous product service	- butane or lighter product; - hydrogen plus hydrocarbons when the partial pressure of hydrogen exceeds 0.7 MPa (7 bar abs), and - hydrocarbons at an operating temperature above the auto-ignition temperature.
fire-safe valves	metal-seated valves which provide critical tight shut-off during fire and which remain operable for a period of at least 15 minutes under these 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.
flammable product	For this PTS, all liquid hydrocarbon products handled in plants shall be classed as flammable product. See also combustible product and flammability. NOTE: This PTS uses the above definition in order to avoid confusion caused by various codes which 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.
fluoro-protein foam	a protein based foam with selected fluorinated surfactants which are loosely bonded to the protein to provide the foam with fuel resistance properties.
fixed foam system	permanent, complete installation including the foam station, distribution piping and foam application system.
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	the use of mathematical models to estimate the effect of explosions, fires and dispersion.
master plan of fire safety systems	a drawing covering the entire installation (location) on which all fire, smoke and gas detection systems, active fire protection systems and fire-fighting equipment (fixed, mobile and portable) are indicated.
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.
pre-incident planning	emergency planning in which technical and operational details are described to get plausible and realistic fire and release incidents under control 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).
semi-fixed foam system	permanent installation consisting of a foam application system connected to distribution piping which terminates at a safe distance. Mobile or portable foam producing equipment must 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.
(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.

The following abbreviations are used in this PTS. Other abbreviations used in this PTS are defined at the first place of use:

AFFF	Aqueous Film Forming Foam
BLEVE	Boiling Liquid Expanding Vapour Explosion
CAF	Compressed asbestos fibre
CCTV	Closed Circuit TeleVision
EDP	Emergency Depressuring
ESD	Emergency Shut-down
FAR	Field Auxiliary Room
FIT	First Intervention Team
FPZ	Fire Proofing Zone
FRED	Fire Release Exposure and Dispersion
HCM	Hazard Consequence Modelling
HL	Hazard Level
IPF	Instrumented Protective Function
ISGOTT	International Safety Guide for Oil Tankers and Terminals
PRV	Pressure Relief Valve
PSL	Potential Source of Leakage
ROV	Remotely Operated Valve
TSO	Tight Shut Off

VRV	Vacuum Relief Valve
UL	Underwriter's Laboratories

1.4 CROSS REFERENCES

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

1.5 SUMMARY OF CHANGES

This revision has been essentially only editorial, with no significant technical changes.

2. FIRE SAFETY

2.1 GENERAL

The fire safety of a plant is the degree to which the risk of fire and/or explosion incidents is managed to a level which is as low as reasonably practicable (ALARP) in terms of likelihood of occurrence and associated potential consequences. This risk is managed by the integrated application of controls and recovery measures to the fire hazards.

Fire hazards stem predominantly from ignition of accidentally leaked hydrocarbon products. All points in a plant or installation where such leakages are likely to occur can be identified as Potential Sources of Leakage (PSLs). Examples of PSLs include small bore connections to piping and equipment, including vents, valves, flanges, drains and instrument tappings; seals and swivels of rotary equipment; and expansion bellows.

Controls are designed to prevent incidents or events from occurring, such as the traditional fire prevention measures of process control and instrumented safeguards, plant lay-out, emergency shutdown or depressuring systems, and correct operation and maintenance. Recovery measures provide prompt minimisation of potential consequences; examples include fire protection measures such as hydrocarbon detection, spill containment, surface drainage, exposure protection systems, extinguishing systems and fire brigades.

The determination of the plant's fire safety shall be based on the quantified 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.

A number of structured techniques can be used to determine the degree of fire safety and the necessary risk management measures. The Fire Safety Assessment detailed within this PTS is one such tool. Other successful methods include FIREPRAN (FIRE Protection Analyses) and Fire Control and Recovery detailed in EP 95-0350 and EP 95-0351, respectively. All techniques shall utilise the April 1999 Risk Assessment Matrix "Yellow Guide" developed by the Shell Group HSE Advisors Panel and shall thus include determination of the criticality of the facility in terms of people, environment, assets and reputation.

Irrespective of the risk assessment technique utilised, the extent of fire protection is related to the operating manpower levels and shall be agreed with the Principal.

For situations not included in this PTS, the NFPA codes or equivalent shall be consulted.

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 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.

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.

The assessment of the fire safety shall be done by one or more fire safety engineers experienced in the integrated application of fire-prevention, fire protection (both passive and active systems) and fire-fighting measures.

2.2 SEQUENTIAL STEPS TO BE TAKEN DURING A FIRE SAFETY ASSESSMENT

2.2.1 Determination of 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.

During such an assessment all aspects of loss of containment, including the frequency of occurrence and the severity of the consequences of such an incident, the possibility of ignition leading to explosion and/or fire and the potential for escalation shall be considered. In this "hazard identification" stage an analysis is made of all potentially hazardous fuel inventories and/or PSLs present in the various defined areas. Account is taken of the type and physical conditions (temperature, pressure) of the fuel. On the basis of credible leak sizes the flows and duration can be calculated.

Amended per
Circular 69/03

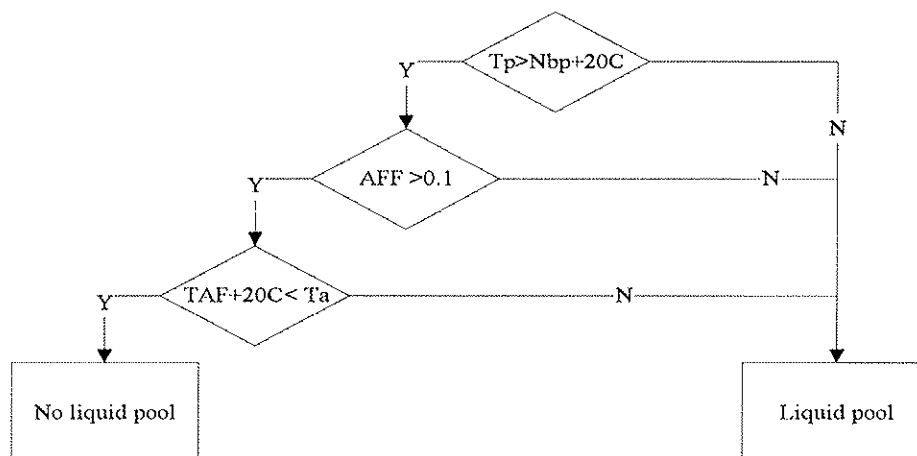
These elements determine the various consequences in terms of event types, i.e. pool fires, jet fires, flash fires, auto-ignition fires, vapour cloud explosions (deflagrations or detonations) and BLEVEs. The effects of these incidents in terms of heat radiation and explosion potential should be established by using appropriate state-of-the-art HCM models, (such as the "FRED: model)

Depending on the type of hydrocarbon product and on the process and ambient conditions, a leakage may spread as a liquid pool or be dispersed as either an aerosol liquid cloud or a vapour cloud. In case of ignition a pool fire or a jet fire will result and will be sustained by the leak source until the stream feeding the leak can be stopped.

2.2.1.1 Pool fires

Liquid pools can be formed by all hydrocarbon products containing pentane and heavier components but also by butanes/butenes at sub-zero ambient temperature. Additionally, propane and lighter refrigerated/cryogenic liquefied gases 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 rain-out occurs.



Where:

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

2.2.1.2 Jet fires

Vapour leakage will by nature disperse as a jet. Pressurised liquefied gases which will not form liquid pools upon accidental leakage will disperse as a vaporising liquid aerosol jet. Ignition of an liquid or a vapour jet results in a jet fire which 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.

2.2.2 Determination of a number of typical flammable product leakage scenarios

The scenarios to be considered should be confined to those equipment failures which involve the leakage of flammable product, of which the frequency of occurrence and the severity of the consequences have been taken into consideration and which may have a low probability of early detection.

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 diameter should be assumed.
- b) Leaks from failure of an instrument fitting, typically 10 or 15 mm in diameter.
- c) Small leaks from flange joints. Representative hole sizes are 1 mm diameter for ring type joints, 2.5 mm diameter for spiral wound gaskets and 7 mm diameter for compressed asbestos fibre (CAF) gaskets.
- d) Full bore ruptures of process lines up to size DN 20.
- e) Pump seal failures. These failures can be represented by assuming equivalent hole sizes of 9 mm diameter.

f) For storage areas, full surface fixed roof tank fire scenarios are considered.

NOTE: The gas and liquid flow rates from the holes shall be calculated using HCM.

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.

2.2.4 Determination of the fuel supply reduction measures

It shall be assessed the available operational measures to isolate and/or reduce the fuel feeding the fire (manual valves, ROVs, EDP and ESD systems, rapid dumping systems, etc.). 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, auto-ignition fires, vapour cloud explosions (deflagrations or detonations) and BLEVEs are calculated using HCM.

The effects of such fire scenarios in terms of 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 firemen, passive fire protection, etc.).

Generally, it may be assumed that steel equipment will not require protection when exposed to a heat radiation level of 12.5 kW/m^2 or less. At that radiation level the unprotected metal's temperature stabilises at about 300°C , which will not endanger its integrity.

However, at a heat radiation level of 37.5 kW/m^2 unprotected steel equipment will quickly exceed the critical metal temperature (just above 400°C), which could result in the equipment losing its mechanical integrity and causing escalation of the fire emergency.

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.

For the various processes Process Guides are available dealing with the process safety aspects. Sound judgement of experienced process engineers is of utmost importance in designing safe and operable processing facilities.

Proper application of the appropriate PTSs 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.

The need for small bore process piping shall be critically examined and shall not be used unless strictly required. If such piping is required, it shall 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. Level gauges shall not be used unless essential for the safe operation of the facilities. In particular, if level gauges are installed on high-pressure equipment or on equipment containing hydrogen, light hydrocarbons or chemical products and containing hot products at or above their auto-ignition temperature, the possibility should be considered of installing blow-out preventers (excess flow valves) on the isolating valves between the processing equipment and the level gauge. It shall be noted that blow-out preventers are more likely to remain effective in clean product service. If level gauges are essential in this service, the installing of high integrity level indicators of the magnetic type should be considered.

The shaft sealing systems for rotating equipment shall 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.

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 which 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 an ROV should be considered.

Typically ROVs have been installed in the suction line of pumps when the upstream system contains:

- more than 4 m³ of butane or more volatile product;
- more than 10 m³ of hydrocarbon liquids handled above their auto-ignition temperature.

Critical isolating valves shall 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 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.

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 lay-out 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 drop-out facilities can be applied if rapid disposal of the liquid inventory is required.

Instrumented detection should be considered if detection by personnel or by other means is likely to be too late to prevent escalation of the incident.

2.3.3 Measures to minimise the probability of ignition of hydrocarbon leakage

In the design the lay-out shall 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. For the plant equipment spacing requirements, PETRONAS generally apply the IP model codes and the IEC electrical safety codes as a minimum.

The overall area lay-out in combination with the surface drainage arrangement should minimise the probability of creating large pools of fuel 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 and safe area. In case of ignition of the spill the probability of escalation will then be low.

The equipment lay-out should enhance natural ventilation thus avoiding accumulation of an explosive mixture which on ignition could result in a devastating semi-confined vapour cloud explosion. 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.

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.

If flanges in insulated pipelines in hydrocarbon service have to be opened more frequently than during major shutdowns only, the cladding of the insulation shall be installed so that spillage of hydrocarbon into the insulation material is prevented.

2.4 FIRE PROTECTION OBJECTIVES AND PRINCIPLES

2.4.1 General

Lay-out of and distances between fire-hazardous equipment shall be such that in the event of a fire the probability of escalation is reduced to tolerable levels. 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.

The basic objective of fire protection is to limit or prevent the escalation of a fire, to avoid risk to life and to minimise material damage. The requirements of this PTS are based on the premise that in a plant complex only one major fire will occur at any one time.

Where fire protection is deemed necessary, passive fire protection measures shall be provided 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. Plants with low manpower levels shall consequently have to rely more on instrumented detection systems.

Active fire protection systems in plants mainly comprise water spray systems and fire water monitors.

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 be provided.

2.4.2 Passive fire protection

Passive fire protection performs its function without relying on activation. The prime function of passive fire protection is to retard the rate of temperature increase of a given substrate.

The principal value of fireproofing is realised during the early stages of a fire when efforts are primarily directed at shutting down units, isolating fuel flow to the fire, actuating fixed suppression equipment, and setting up fire water streams. If equipment is not fireproofed, equipment supports carrying heavy loads may collapse during this critical period and escalation take place. It may become impossible to operate emergency isolation valves, vent vessels, or actuate manually operated water spray systems.

If an intense fire persists for a prolonged period, fireproofing may have no significant effect on the final extent of property damage.

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, firewater 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.

2.5 FIRE BRIGADE AND FACILITIES

2.5.1 General

Despite the degree of reliability of process equipment and of process control and safeguarding systems, and even with optimum application of fire prevention and fire protection measures, the residual fire risk, i.e. the risk that remains after all normal prevention and protection measures have been taken, must still be managed.

Plants should be provided with adequate first-aid or incipient fire-fighting equipment (hand-held extinguishers, small foam units, hose reels, steam lances) and well-trained plant personnel able to handle small fire incidents with confidence. They should further be able to mobilise additional fire-fighting equipment (fire-trucks, foam transport vehicles, auxiliary vehicles) within a reasonable time after outbreak of a large fire and should have a fire brigade in place able to manage the emergencies, possibly in collaboration with external fire brigades.

2.5.2 Organisation

The optimal structure of the fire brigade should be decided with account being taken of the following site-specific factors:

- The size, location and complexity of the installation(s).
- Site Criticality.
- Fire-fighting Philosophy including Fire & Explosion Strategy.
- The available own manpower (on-shift and call-out).
- The local fire regulations in force.
- The role, technical capabilities (manual and mobile equipment) and expected response time of municipal fire brigades.
- Possible legal requirements for an emergency centre, including medical services.
- 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 has to 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 lay-out of the site.

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

At the onset of a fire which 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 men available on the site at any one time to operate the fire truck(s) and to man 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. 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 manning levels it may be impossible to form an effective FIT. If external fire-fighting support is not available at short notice either, the low manpower situation shall be compensated by the more extensive provision of ESD and extensive fire

protection and fire extinguishing systems.

2.5.3 Pre-incident planning

Pre-incident planning, which forms part of the site emergency plans, addresses the selection of likely and realistic scenarios, assesses how quickly the personnel responsible for addressing an emergency can become aware of an 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 (equipment and manpower) to bring the incident under control in the most efficient and effective way. It further addresses the consequences of toxic product leakage and of contaminated fire water.

Pre-incident planning is a very effective and efficient tool for improving the emergency preparedness of an organisation. The plans shall be completed prior to start-up of new installations. The plans shall be developed and written by operating personnel to achieve a good sense of ownership.

Guidance for pre-incident planning is given in OP 99-30011.

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.

As fire-fighting is a vital service in a plant, the number of foam generating vehicles shall 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 vehicle for transport of protective clothing, additional hoses, additional portable monitors and tools shall also be considered.

2.5.4.3 Mobile foam monitors

For backing up the sub-surface and semi-sub-surface foam injection systems on fixed roof storage tanks, an adequate number of portable or wheeled foam monitors shall be available with adequate capacity.

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. If there is a foam storage tank it shall be located in the vicinity of the fire station. See also (5.2.2).

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 which 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.

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 shall 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. The degree of required fire resistance is dictated by operability requirements. 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 be provided.

Fireproofing should not be considered as a replacement for active fire fighting or lead to relaxation of normal design requirements (spacing and layout considerations) and precautions in operation and maintenance.

The main (or even sole) objective of fireproofing of steel structures is to prevent the escalation of fires to an unacceptable level by providing a temporary protection until full fire-fighting capabilities can be deployed.

In cases where liquid flammable product can collect under or in the vicinity of supporting steel structures, passive fire protection shall 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.

Judicious application of fireproofing will delay an eventual collapse of steel structures and allow it to occur gradually and with visible signs. This allows time for isolation of the affected equipment and for operating and fire-fighting personnel to evacuate safely.

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 windbracing 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 be provided, however longer protection times may be required depending the equipment and its function and available fire-fighting measures.

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.

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 which 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. The test is terminated (failure point) when the average temperature of the steel substrate reaches 538 °C. 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.

3.2 FIRE PROOFING ZONE

This PTS uses the concept of a Fire Proofing Zone (FPZ) to define 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 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 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 table tops or other closed surface decks. Such surfaces which 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 from the PSL and a height of 8 m above HL (see Appendix 5).

In general it is not cost effective to apply fireproofing on **supporting steel structures** to protect against **jet fires**.

3.3 FIREPROOFING OF EQUIPMENT AND STRUCTURES

3.3.1 Structures supporting equipment

Steel structures supporting vessels, columns or exchangers located within an FPZ shall be fireproofed when one or more of the following criteria apply (see Appendix 6).

1. Sudden failure of the structure may cause danger to personnel.
2. The supported equipment contains a total of more than 2 tonnes of flammable product.
3. The supported equipment has a total mass (including contents) of more than 10 tonnes.
4. The supported equipment contains toxic material.
5. Failure of the steel structure and supported equipment may lead to consequences beyond the property limit, including environmental damage.

3.3.2 Column/vessel skirts

Column and vessel skirts located within a FPZ shall be fireproofed on the outside if one or more of the following criteria apply:

1. The column/vessel contains a total of more than 2 tonnes of flammable product.
2. The total mass of the column/vessel (including contents) is more than 10 tonnes.
3. The column/vessel contains toxic material.
4. Failure of the column/vessel may lead to consequences beyond the site perimeter including environmental damage.

Note: The above applies in the normal situation where there are no flanged pipe connections within the circumference of the skirt. However, should this be the case then fireproofing shall also be applied inside the skirt.

3.3.3 Saddle supports

Saddle supports for vessels and exchangers (even if located within a FPZ) shall not be fireproofed. For the supporting structure of vessels and exchangers, see (3.3.1).

3.3.4 Pipe rack and pipe supports

Steel structures supporting overhead pipe racks and individual pipe supports, located within an FPZ, shall be fireproofed if one or more of the following criteria apply:

1. The pipe is a flare line or an emergency depressurising vent line.
2. The pipe contains a toxic material.

3. The pipe is connected to equipment which would be severely damaged by additional nozzle loading in the event of loss of pipe support.
4. The pipe runs beneath an air cooler whose steel support structure is fireproofed (including horizontal members).
5. The pipe carries fire-fighting water and/or other utilities which would reduce the fire-fighting capability in the event of loss of support.
6. The pipe is an instrument air line or hydraulic control line whose loss would interfere with the ability to shut down the plant.

3.3.5 Furnace support structures

Irrespective of the location relative to the FPZ, stanchions shall be fireproofed from grade level to full height of stanchion. All structural members incorporated to reduce the effective buckling length of these stanchions shall be fireproofed.

3.3.6 Supports of pressurised spheres and bullets

Irrespective of the location relative to the FPZ, supporting legs of spheres shall be fireproofed from grade level up to 0.20 m below the intersection of the leg with the sphere.

All stanchions and beams supporting bullets and structural members incorporated to reduce the effective buckling length shall be fireproofed.

For skirts, see (3.3.2).

3.3.7 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, etc. The piles shall be filled with concrete from a level at least 2.0 m below low water level up to the underside of the deck. Steel reinforcement to withstand normal operating loads shall be considered. Drip trays draining to a sump shall be positioned where potential leakage of flammable fluids may occur.

Where fireproofing could be impractical (e.g. platforms located close to sea level), alternative fire protection measures, such as water spray systems, may be considered.

3.3.8 Valves and valve actuators

In all cases where valves can be engulfed in fire or exposed to high radiation fluxes as a result of a fire, the fire-safe requirements of the valve shall be determined. 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.

Two categories of valves can be identified;

- a fire tested design is one which has successfully passed prototype fire testing;
- a fire-safe design which by nature of its features/properties is capable of passing a fire test.

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

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

Soft seated valves shall be of a fire-tested design and metal seated valves shall be of a fire safe design.

Valve operating mechanisms shall be of a fire-safe design.

Fire testing and certification shall be in accordance with the requirements as specified in PTS 31.38.01.11 and the referenced MESC specifications.

All safety related valves, including safety related ROVs in pump suction and ESD and EDP valves, plus their actuators plus the actuating system, shall remain operable for at least 15 minutes. This can be achieved by locating the valves plus components outside the fire hazardous zone. If they have to be located in the fire area, continued operability can for instance be achieved by means of fire proofing the actuator assembly, by applying fire resistant cables, by applying a proprietary fireproofing system on cables or by putting the whole assembly in a fire resistant enclosure.

Conventional wafer type valves clamped between flanges with long bolts or tie rods are insufficiently fire safe and shall not be used in hydrocarbon service.

3.3.9 Cabling

Critical instrument and power supply cabling serving safeguarding systems shall be installed in such a way that they are protected against direct heat radiation and flame impingement. If this is not possible special fire-resistant cables shall be used in accordance with IEC-60331-21, i.e. able to withstand temperatures of at least 750 °C for a period of 90 minutes.

3.3.10 Process vessels, storage vessels and piping

In exceptional cases where activation of active systems is expected to be too slow or inadequate to avoid escalation, vessels and piping should be equipped with passive fire protection. 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 passive fire protection. The required fire resistance shall be determined by taking into consideration the expected response time of the fire brigade.

The material to be used for this application shall 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.

The Principal shall be contacted for advice if passive fire protection is considered the most appropriate protection for the hazard concerned (for guidance on types and installation of proprietary fireproofing systems see PTS 34.19.20.11).

Combined cold insulation / fire proofing is applied on cryogenic equipment. It consists of a layer of urethane foam, a layer of cellular glass and steel jacketing and provides immediate protection for a limited period of time.

4. ACTIVE FIRE PROTECTION SYSTEMS AND FACILITIES

4.1 FIRE WATER SUPPLY SYSTEM

4.1.1 General

Water (either as such or as a foam solution) is the most commonly used agent for cooling equipment and controlling and/or extinguishing the fire. It also provides protection for fire-fighters and other personnel in the event of fire. Water shall therefore be readily available at all the appropriate locations, at the correct pressure and in the required quantity. Fire water shall be considered a vital utility.

Fire water should not be used for any other purpose. If under non-fire conditions the water mains system has to be used for service water, the take-off connection shall be of a size smaller than the nominal size of the hydrant valve and be provided with a restriction device or pressure reducing valve, to ensure that the required water flow can be supplied without causing the main fire-water pumps to start automatically as a result of pressure loss in the mains. These flow limiting devices also serve to protect the hose handler against a sudden pressure increase. In addition precautions shall be taken to prevent back-flow of product into the fire main system.

4.1.2 Fire water flow rates

The radiation levels to which the various pieces of equipment may be exposed, as calculated during the fire safety assessment process (see (2.2.1)), form the basis for determining the quantities of fire-water required for exposure protection.

These quantities (Q , l/minute) are related to the radiation flux levels (W , kW/m^2) as follows:

1) for process areas, etc. which are not too windy, including 25% losses, use:

- for $W \leq 25 \text{ kW/m}^2$: $Q = 2 \text{ l/min/m}^2$ exposed area
- for $W > 25 \text{ kW/m}^2$: $Q = 1.2 + (0.033 * W) \text{ l/min/m}^2$ exposed area

2) for areas which are very windy, including 50% losses, use:

- for $W \leq 15 \text{ kW/m}^2$: $Q = 2 \text{ l/min/m}^2$ exposed area
- for $W > 15 \text{ kW/m}^2$: $Q = 1.4 + (0.04 * W) \text{ l/min/m}^2$ exposed area

The above formulae are used to calculate water requirements for three-dimensional spaces such as:

- the general process areas;
- atmospheric product storage tanks;
- pressure storage tanks (LPG, etc.);
- steel-walled and roofed refrigerated storage tanks (LNG, etc.).

For two-dimensional areas such as:

- oil movements pumping stations, manifolds, in-line blenders, etc.;
- jetty manifolds;
- product loading / unloading facilities,

general water application rates ranging from 6 to 12.2 l/min/m^2 of ground surface, depending on the products handled, may be applied.

Typical water application rates for general use that in general will provide adequate protection are given in (4.3.1).

Select on the plot plan a few fire areas with a high density of equipment and where a pool fire could occur. Determine the 12.5 kW/m^2 radiation contour. Calculate the water quantity

required to provide adequate exposure protection to the equipment located within the radiation contour.

Note that a full surface tank bund fire should normally not be considered for the water quantity calculation, since experience indicates that such bund fires are not likely to occur with well maintained and operated storage tanks.

In addition to the water requirements for exposure protection, water may be required to generate foam to extinguish a fire. Particularly for atmospheric storage tanks, exposure protection may be required for adjacent tanks while foam has to be generated to extinguish the tank fire itself.

Storage tanks equipped with a fixed subsurface foam extinguishing system, for instance, require 4.1 l/min/m^2 foam solution. The foam solution contains 97% water plus a 3% foam concentrate.

If portable/mobile foam equipment and/or fixed foam monitors are used, the generated application rate is influenced by losses during throw and updraft of the foam above the burning surface and these losses can be up to 60%. The typical application rate for these methods is 6.2 l/min/m^2 .

NFPA 11, NFPA 11A and, if applicable, foam Manufacturers' guidelines shall be followed for the specific foam application rates and duration of other types of extinguishing systems.

The largest of the above quantities thus found, usually the amount required to protect adjacent storage tanks against radiation from a full fixed roof tank fire and to extinguish the tank on fire, is taken as the design basis for the capacity of the fire-water pumps. This capacity is the basis of design of the mains system, which however shall never be less than $720 \text{ m}^3/\text{h}$, unless specifically agreed otherwise by the Principal.

4.1.3 Fire-water supply quantity and quality

Based on the fire scenarios both the required flow rate and duration of supply can be determined. Where possible, fire water should be supplied from open water, in which case the availability of the supply is unlimited.

To meet the fire-water requirements of a plant, fresh water with a low biological activity is preferred. Where the required quantity and quality are not available at acceptable cost, water storage facilities shall be provided.

The capacity of the storage facilities shall be sufficient for the expected duration of the fire. In climates where freezing occurs, provisions shall be made to prevent stored water from freezing, e.g. by circulation or by heating. Alternatively, the storage capacity can be increased to compensate for the ice layer.

The storage capacity can be determined with account being taken of periodic maintenance requirements of the fire-water storage facilities and the available reliable replenishment rates during fire-water consumption at maximum flow rate.

Resources that may be considered for replenishment are plant cooling water, open water or well water, subject to economic evaluation. If during an emergency a normally fresh water filled system has to be replenished with more corrosive water, the system can still be considered a fresh water system, assuming that prompt flushing takes place after emergency use to replace the corrosive water in the system.

In cases where the fire scenarios are not clear or where a longer duration fire cannot be excluded, a minimum of 6 hours uninterrupted water supply at maximum required rate shall be provided.

The installing of fire-water import facilities shall be considered. For instance, where reliable fire boats with sufficient pumping capacity are available they can be used to pump water into the fire-water distribution system (normally via a so-called "tugboat connection" at one or more jetties). The fire main system may also be connected to an independent and reliable fire main system of a neighbouring facility to serve as a replenishment source

4.1.4 Fire-water pumping arrangement

Fire water is considered a vital utility for a plant. Fire-water should be provided by at least two identical pumps, each of which is able to supply the largest required flow rate to the fire-water ring mains system. An alternative with a higher reliability is the installation of three identical pumps, each able to supply 60% of the largest required flow rate.

The fire-water pumps shall be of the submerged vertical type if they draw from open water, and of the horizontal type if they draw from a storage tank.

The fire-water pumps shall be installed at a location which is considered to be safe in the event of fire anywhere in the plant, where it is unlikely to be engulfed in an explosive vapour cloud originating in the plant, and where it is unlikely to be damaged by collision with vehicles and/or ships.

4.1.5 Selection of fire-water pump drivers

Pumps may be driven by electric motors, steam turbines, gas turbines or internal combustion engines, subject to availability and reliability criteria and according to application, location, fuel availability and economics.

The selection of the pump drivers shall be governed by the requirement of maximum reliability of the overall system. This includes the reliability of the associated utility systems (power, steam and fuel supply) and the instrumentation system.

In plants, both those relying on imported electric power as well as those generating their own electric power, the standard arrangement is that diesel engine driven pumps are able to provide the fire-water at the required flow rate. In a two pump arrangement, one is preferably electric motor driven and the other is diesel engine driven. Depending the reliability and separation of the fuel supply system both pumps may however be diesel driven. In a three pump arrangement, one pump is electric motor driven while the two other pumps are diesel engine driven.

Rather than providing the infrastructure for permanently installed back-up fire-water pumps, the provision of a number of standard diesel driven portable, submersible pumps should be considered. When needed they shall be mobilised within half an hour. A suitable water source, e.g. cooling water basin, shall be available. The pumps can deliver the water via hydrant connections into the firewater main or dedicated connections may be installed for this purpose on the firewater main. They are normally stored in a warehouse and shall be tested regularly. Providing these back-up fire-water pumps via a reliable mutual aid resource may also be considered

4.1.6 Fire water distribution system

4.1.6.1 Fire-water ring mains system - General

Fire-water shall always be able to be provided at the required flow rate in all plant sections under all circumstances. Non-availability of a section of the fire-water main shall not affect fire-water availability anywhere in the plant. The ring main shall be provided with block valves so that sections can be isolated for maintenance.

For the safety of personnel involved in manual fire fighting operations, facilities shall be provided enabling full control of the firewater pressure in all plant sections under all circumstances.

Fire-water ring mains of the required capacity shall thus be laid to surround all processing units, storage facilities for flammable liquids, loading facilities for road vehicles and rail cars, bottle filling plants, warehouses, workshops, utilities, laboratories and offices. Large areas shall be sub-divided into smaller sections, each enclosed by fire-water mains equipped with hydrants and block valves.

A single fire-water pipeline is acceptable for the non-critical fire-fighting training ground.

A full bore flushing connection is only required if the fire-water quality could be such that silt might settle in the piping, if marine growth is likely or if corrosion (rust flakes) or erosion

(cement particles) products can be formed.

The installation of a "ring" main on a jetty will not constitute a reliable fire-water supply because its availability could be endangered by piping corrosion or by major damage to the jetty caused by a ship. The corrosion problem can be solved by proper material selection. It is thus acceptable that fire-water may be supplied by a single pipeline. In some cases back-up can be provided via a separate pipeline supplying water spray systems from the foot of the jetty.

The fire-water pipelines to the jetty shall be provided with isolating valves at the foot of the jetty which can be closed in the event of serious damage to the jetty.

4.1.6.2 Fire-water ring mains/network design

The fire-water mains network pipe sizes shall be calculated using an approved state-of-the-art computer program. The calculations shall be based on the design rates at a pressure of 10 bar(ga) at the furthest take-off point under the most unfavourable water supply conditions.

4.1.6.3 Fire-water mains - Installation and material selection

To reduce the probability of losing the fire-water supply as a result of an explosion the fire-water ring main shall be laid underground within the 0.15 bar over-pressure contour in plant areas where explosions cannot be excluded. Over-pressures can be calculated using HCM. As a general and conservative guideline, the fire main should be laid underground within a radius of 100 m from process plant equipment and pressurised storage tanks.

In all low risk areas fire-water mains can be laid above ground.

In areas where the ambient temperature can drop below 0 °C for prolonged periods, the fire water mains shall be buried not less than 0.3 m below the frost line.

The selection of materials for the fire-water piping shall be based on the predominant water quality and on whether the piping is routed above or below ground.

4.1.6.4 Hydrants

Fire-water mains shall be provided with permanent hydrants, located in strategic positions around processing units/areas, loading/unloading facilities, LPG bottle filling plants, storage facilities for flammable liquids and LPG/LNG, and on jetty heads/berths.

When selecting the type of hydrant coupling, consideration shall be given to the coupling type in use by other fire brigades in the area. Alternatively, appropriate adapters shall be provided enabling interchange of equipment.

4.1.6.5 Dry Risers

The installing of dry risers shall be considered to provide a means to quickly supply water or foam to portable fire-fighting equipment at elevated levels of multi-storey structures.

4.2 FIRE WATER DISPOSAL FACILITIES

In general plant design, fire-water is normally discharged via the plant drainage system. In order to avoid flooding of plant areas, which would entail the danger of a fire spreading, it should be ensured that the drainage capacity of a plant section always exceeds the maximum fire-water demand to control the fire scenario in the plant section concerned.

The floors in the various plant sections should be profiled so that the maximum travel distances of burning liquid pools are limited and that burning spills will flow away from equipment, thus reducing the probability of escalation.

In on-plot drainage networks two main segregated systems are generally provided: an accidentally oil-contaminated (AOC) system and an oil drip/drain collection network. Fire-water is disposed of via this AOC system.

The AOC drainage network in new plants comprises a sump-free paved area with surface water run-offs being collected in perimeter drain channels and routed via flooded underground headers to end-of-pipe treatment. In existing plants, such liquid is generally drained via underground flooded pipelines.

The AOC systems will generally discharge to a holding basin or oil trap. Contaminated fire-water shall not be discharged directly to public water. Buffering facilities are provided to retain fire-water to allow inspection and analysis so that any further treatment requirements can be determined. The capacity of the buffering facility is determined by the fire scenarios. The buffering facilities are, where practical, an integral part of the controlled discharge facility for rain water effluents.

4.3 EXPOSURE PROTECTION SYSTEMS

These systems use water to suppress a fire by converting water to steam inside the flame, thus reducing the oxygen supply to the fire. The water consumes part of the heat generated by the fire, thus reducing the quantity of heat available to overheat and damage adjacent equipment.

The temperature for failure of structural steel is generally taken as 538 °C. For pressurised vessels 250 to 300 °C is taken as maximum, and for cabling a maximum temperature between 100 and 150 °C is taken.

By maintaining a water film on the exposed equipment its surface temperature is kept at or below 100 °C, thus avoiding escalation of the fire as a result of further damage to equipment. The preferred way of applying water onto equipment surface is by spraying it onto the section concerned. Applying the water at higher elevations and relying on rundown of the water easily leads to damage to the water film because of the uneven surface of the equipment or disturbance of the film by wind or updraught.

Exposure protection can be provided by water spray systems, deluge systems or fire-water monitors. Exposure protection shall preferably be provided by means of fire-water monitors. Fire water monitors are less vulnerable, considerably less costly, and more flexible in use.

4.3.1 Water application rates

Where the fire scenarios indicate that exposure protection is required, see (4.1.2) for guidance on the required water application rates.

The following typical application rates will in general provide adequate protection:

4.3.1.1 Pumps

For conventional pumps handling LNG, LPG and products near their auto ignition temperature, the pump and a border of 1.2 m around the pump shall be wetted. Directly over the pump, a rate of 40 l/min/m² of ground surface shall be applied, while around the pump water shall be applied at a rate of 20 l/min/m² of ground surface.

For pumps and equipment in congested areas (where a chimney effect may occur) or when installed under air-cooled heat exchangers, water shall be applied at 20 l/min/m² of ground surface.

4.3.1.2 Compressors

For compressors, a rate of 40 l/min/m² of ground surface shall be applied.

For water based exposure protection systems installed above lube oil/seal oil tanks, a rate of 8.5 l/min/m² equipment surface shall be applied.

4.3.1.3 Static equipment

For vessels, columns and heat exchangers holding a liquid volume of 4 m³ or more of butane or lighter products, the application rate shall be 8.5 l/min/m² equipment surface. Wetting shall be provided up to a height of 9 m above the potential source of the fire.

4.3.1.4 Storage tanks

For the roof of cone roof tanks spaced in accordance with the IP Code Part 3, a rate of 1.7 l/min/m² of surface area shall be applied.

For tanks spaced in accordance with the IP Code, a rate of 17 l/min/m of tank circumference shall be applied to the part of the tank circumference that is potentially exposed to an adjacent fire.

For pressure storage of butane and hydrocarbons, a rate of 8.5 l/min/m² of applicable equipment surface shall be applied.

4.3.1.5 Jetties

For jetty structures, support legs, manifolds and gangways, a rate of 20 l/min/m² equipment surface shall be applied.

4.3.2 Water spray systems

Water spray systems are engineered systems applying water at a pre-determined application rate onto the equipment and the surrounding area to be protected. The advantage is their correct water dosage. Disadvantages are high installation and maintenance costs. In congested areas, in most cases these systems are the only way to provide adequate protection.

In most cases, a few minutes delay to evaluate the situation after receipt of a fire alarm can be tolerated before activating the water spray system. This approach minimises the number of nuisance activations of spray systems.

A maximum of four pieces of equipment may normally be sprayed by one system. If two adjacent systems are likely to operate simultaneously, the total water flow shall not exceed 50% of the fire-water capacity supplied to the area using the normal pumps.

4.3.3 Automatic water spray ("deluge") systems

Automatic water spray systems are systems where the supply valve is activated automatically by a detection system installed in the same area. These systems are applied when delay in activating the water spray system is unacceptable in view of the immediate danger of escalation. The disadvantage is that nuisance activation of the system may occur. In cases where nuisance activation of the system is undesirable a double detection system shall be considered as classified in PTS 32.80.10.10

Automatic water spray systems are also called "water deluge systems".

4.3.4 Water Drenching systems

Water drenching systems are engineered systems applying water for exposure protection at a pre-determined application rate onto storage tanks. They can be installed as an alternative to stationary fire water monitors or a water spray system. A water drenching system shall be installed in combination with water deflectors for proper water flow transition from the roof to wall surfaces. The water drenching system is connected via a piping system to a reliable water source. The systems are activated manually.

The drenching systems are of a very basic design, easy to install, easy to maintain and easy to test. Disadvantage of these systems is that due to plate irregularities channelling of water on roofs may occur and thus may result in inadequate cooling.

In cases where the tank cannot be wetted completely by the water drenching systems the system shall be combined with stationary fire water monitors or a dedicated water spray system for these areas. Depending on the scenario and accessibility for movable equipment, additional coverage may be provided by intervention of fire-fighting personnel positioning and adjusting movable equipment.

4.3.5 Fire water monitors

Fixed manually adjustable and operated water monitors with adjustable nozzles should be installed at strategic points around and inside areas where fire hazards have been identified. Accessibility and prevailing wind directions shall be taken into account to arrive at the optimum positions.

Fire water monitors have relatively low installation and maintenance costs and provide very effective and flexible means to provide exposure protection.

The standard monitor has a water capacity of 120 m³/h at a working pressure of 10 bar(ga). However, monitors with a different capacity may be necessary for particular applications.

In congested plant sections where fixed ground level mounted water monitors may be less

effective because of obstructions, elevated fixed adjustable water monitors operated manually from grade level may be used.

If exposure protection is provided by means of fire-water monitors only, back-up protection by another monitor fed from another branch of the fire-water main shall be available. Monitors shall be located in a safe location with regard to the area they should cover.

Where exposure protection is provided by monitors, detection systems may still be required to alert operating personnel to the abnormal situation.

Wherever feasible fire water monitors shall be combined with permanent fire water hydrants.

Portable or wheeled monitors carried by fire brigade vehicles provide additional flexibility.

4.3.6 Water mist ("water fog") systems

Water mist systems apply water at a pre-determined application rate onto the equipment and the surrounding area. Essentially they were developed as alternatives to halon extinguishing systems, but also it has been found that they are efficient and effective means of killing fires. These systems are applied in situations where water damage to the equipment during testing and inadvertent actuation is to be avoided. Water mist systems achieve their extinguishing power by the high momentum discharge of small water droplets. These systems discharge water, either under pressure or gas/air assisted, through small orifice nozzles. This produces a proportion of small droplets (typically 150-400 μm) which can extinguish fires very rapidly by immediate vaporisation of the droplets. These systems use only small quantities of water and therefore minimise water damage. Once activated the water mist totally floods the protected space. Disadvantages are high installation and maintenance costs and the required quality of the water.

In view of the limited travel distance of the small droplets, a water mist system should not be applied in spaces larger than about 300 m³. For such an enclosure, Wall mounted water mist nozzles have adequate reach to flood the entire space, including shielded areas. Where heavily shielded areas are possible, e.g. in turbine enclosures, the addition of AFFF foam agent should be considered.

A typical application is protection of lube oil and seal oil tanks in congested areas. The dosing of water prevents water from entering the tank via the vent.

In most cases, a few minutes delay can be tolerated to evaluate the situation after receipt of a fire alarm before activating the water fog system. This approach minimises the number of nuisance activations of the systems.

For further information and guidance reference is made to E&P Forum Report No. 6.49/235.

4.3.7 Water curtains

Water curtains are not designed to provide protection to equipment or areas. They separate sections from each other or protect escape routes, thus preventing to some extent escalation from one section to the other, but do not prevent escalation in the section where the fire takes place.

4.3.8 Sprinkler systems (excluding deluge systems)

A wet-pipe sprinkler system is a permanently filled and pressurised water distribution piping system fitted with normally closed sprinkler nozzles. A frangible glass bulb keeps the nozzle closed by means of a plug. When exposed to a certain heat input the bulb fractures and the plug is pushed out by the water pressure. "Dry-pipe", "pre-action" and a combination of systems are also available.

Such systems only spray water via the activated nozzle. In a typical hydrocarbon plant the protection they provide is insufficient as both the area they cover and the water application rate are far too small to have the desired protection effect.

Such sprinkler systems are widely applied in buildings to extinguish class A fires.

Dry piped sprinkler systems can be used in computer installations where there is a need to prevent escalation from the computing facilities to other parts of the premises.

Design requirements shall be in accordance with NFPA 13.

4.5 DETECTION, ALARM, AUTOMATIC CONTROL AND MONITORING SYSTEMS

4.5.1 General

Prompt detection at the onset of a fire or hydrocarbon leakage anywhere in the plant and an immediate warning to operational and fire-fighting personnel are crucial factors in the basic concept of fire protection.

Detection of a fire in its earliest stage of development is essential if remedial actions are to be effective. Fire detection signals can be initiated either by personnel or by an instrument.

Instrumented detection is essential if delayed detection of a fire could lead to a fire too large for the extinguishing capabilities available, if leakage of material to the atmosphere results in a large flammable gas cloud, if the material is above its auto-ignition temperature and if leakage of a toxic substances would immediately endanger personnel.

Typical examples are instrumented detectors in the seal areas of floating roof tanks, in gas turbine enclosures, in air intakes of control rooms, in unmanned computer rooms and in fire-hazardous material stores.

4.5.2 Means of Detection

4.5.2.1 Detection by persons

Personnel detecting loss of containment, smoke or fire shall have efficient means to alert other personnel or call for assistance to deal with the incident.

Means to alert others are a personal radio link with the control centre, manual call points and direct telephone links. It may be decided not to install manual call points in the plant if other means of communication between the field and control centre are available and in widespread use.

Fire alarm call points in buildings shall be provided if required by NFPA 101, unless local regulations are more stringent.

4.5.2.2 Instrumented detection

PTS 32.30.20.11 shall be used for general information, detector type, design and installation.

E&P forum Report No. 6.75/284 "Incipient Fire Detection" provides additional guidance for ultra-sensitive smoke detection (or high sensitivity detector) systems.

For an overview of typical applications of fire, smoke and flammable gas detection see (Appendix 2). The associated cause and alarm/action matrix is shown in (Appendix 3).

4.5.3 Alarm presentation and location

A dedicated emergency annunciation panel shall be provided in manned installations to give an overview of all emergency related information, such as the status of the fire-water supply, gas, smoke and fire alarms, wind speed and direction, activated fire alarm call points, etc.

The display shall be installed in a continuously manned building in the plant. Slave displays may be installed at other locations where the occurrence of a fire needs to be known, e.g. the general control centre, the fire station and the plant entrance gate house.

4.5.4 Closed circuit television monitoring systems (CCTV)

Closed circuit television systems may be installed to provide additional supervision to compensate for low operating manpower levels. CCTV can assist Operations in surveying potentially fire-hazardous areas and enable them to take appropriate action when fire, smoke or gas is detected.

In particular areas which are less frequently patrolled by personnel, where the situation

cannot be observed from a distance because of obstructions or where there is an interface with frequently changing non-Company personnel, CCTV should be considered.

Cameras can be installed in a fixed position focused on high risk areas or may permanently scan large areas.

Typical locations may be pump floors in process and oil movements areas, road/rail car loading areas, jetties and inside plant buildings that contain process equipment.

Monitors shall be installed in the nominated control room close to the gas/fire/smoke detection presentation panel. Upon receiving a gas or fire alarm the cameras can be directed at the area concerned to complement or confirm the information provided by the detection system.

4.5.5 Systems to alert personnel

Toxic and explosive gas mixtures may pose an immediate danger to personnel. Personnel shall be alerted to this danger in and around the area concerned by audible and visual means.

In process buildings, sirens and beacons shall be installed which may signal automatically on leakage of flammable and toxic gases, or on the outbreak of a fire.

Evacuation alarm bells in office buildings shall be provided when required by NFPA 101.

The Principal may decide not to install site-wide fire sirens if alternative means of communication are available and to prevent nuisance to the public.

5. FIRE-FIGHTING AGENTS, SYSTEMS AND EQUIPMENT

In this section, only general guidance is given on fire-fighting agents and portable and movable fire-fighting equipment for the purposes of the Fire Safety assessment. PTS 80.47.10.32 "Use of fire fighting agents and movable fire fighting equipment for onshore applications" shall be used for detailed design and engineering and further guidance.

5.1 WATER

Water is the most appropriate extinguishing agent for Class A fires. It has limited use on Class B fires.

However, if properly applied to a fire of flammable product with a flash point above 40 °C, it is able to cool the surface of the product to below its flash point, thereby extinguishing the fire.

5.2 FIRE-FIGHTING FOAMS

5.2.1 Selecting the type of foam concentrate

The type of foam concentrate shall be selected according to the type of flammable liquids stored within the plant complex and the expertise of the fire brigade. The aim shall be to use as few types of foam as possible to avoid confusion under generally stressful fire emergency situations and to have some uniformity with outside fire brigades.

Effects of the foam concentrate on the environment and effluent treating system shall be taken into account when selecting a foam concentrate.

The recommended foam concentrate for use throughout a plant storing normal hydrocarbon products is 3% fluoroprotein foam. If the plant also produces or stores MTBE (methyl tertiary butyl ether), an adapted 3% fluoroprotein foam should be used.

For plants processing and storing polar solvents and/or alcohols, Universal foams shall be used. These foams are also suitable for extinguishing conventional hydrocarbon fires.

The specialised use of high and medium expansion foam compound and AFFF is addressed in (5.3).

5.2.2 Determining the quantity and storage of foam concentrate

The quantity of foam concentrate shall be selected so that it can extinguish the largest credible fire that could occur in the particular plant, using the most effective equipment available. See PTS 80.47.10.32 section 2.3.12. for further guidance.

As the calculation is based on the largest fire scenario, the foam quantity is also adequate for extinguishing all other fires in the plant complex.

The storage of the foam concentrate can be mobile, i.e. in the tanks of the various fire-fighting vehicles, in which case the non-availability of one vehicle shall be taken into consideration. If the mobile stock is insufficient, a fixed foam storage tank is required. If the plant complexes cover large areas, the provision may be considered more than one fixed foam compound storage facility, installed strategically in the vicinity of the main hydrocarbon storage tank and/or the jetty where large quantities of foam will be required in the event of a fire.

5.3 FOAM SYSTEMS

Foam systems are required when foam application by means of hand lines or foam monitors is not feasible (e.g. the size of the fire may be too large, the distances may be too far, or the time required to line up the manual systems may be too long).

5.3.1 Low expansion foam systems

Low expansion foam can be used to extinguish hydrocarbons on fire ranging from crude oil to flammable liquids with a flash point up to 60 °C. These systems are typically provided for storage tank protection and for remote and inaccessible areas like jetty manifolds.

Depending on the product in the storage tanks and the size of the tanks, either subsurface or semi-subsurface foam injection systems are applied.

Depending on the accessibility of the fire area and the affordable time delay before foam has to be applied, foam can be provided via a fire-fighting vehicle or via a dedicated foam station.

Generally for hydrocarbons the minimum required foam application rate of fixed foam systems is 4.1 l/min/m² burning surface.

For hydrocarbons with a flash point below 23 °C and a boiling point below 38 °C the minimum foam application rate shall generally be 6.0 l/min/m² burning surface.

5.3.2 Medium expansion foam systems

Medium expansion foam systems can be used to extinguish fires where some degree of in-depth coverage is necessary - for example, for total flooding of small enclosed or partially enclosed volumes. Medium-expansion foam can provide quick and effective coverage of flammable liquid spills or some toxic liquid spills where rapid vapour suppression is essential. It is effective both indoors and outdoors.

5.3.3 High expansion foam systems

High expansion foam is particularly suited for indoor fires in enclosed spaces such as warehouses. Its use outdoors can be limited because of the effects of wind and lack of confinement.

High expansion foam can be used on refrigerated LPG and LNG fires. The thick foam blanket acts as a radiation shield reducing the vaporisation of the fuel, thus reducing the quantity of fuel feeding the fire and consequently the fire intensity. The objective of this type of system is to control the burning rate, not to extinguish the fire. These systems are typically provided for potential LPG/LNG spill areas such as pump floors and manifold areas.

Foam concentrate for LNG shall be approved by the Principal. Selection of this concentrate shall allow for the fact that the maximum travel distance of expanded foam is 20 m, shall ensure that the foam blanket has a thickness of 1.5 to 2 m and an expansion ratio ranging from 200 (for windy locations, as specified by the Principal) to 500 (for normal locations), and shall take account of the fact that this system will be operated remotely and intermittently.

The average foam application rate shall be 3.2 l/min/m² ground surface. Because of the system's intermittent operation the foam generating capacity shall be between 4.8 and 6.4 l/min/m² burning surface.

5.3.4 Special foam systems

Special AFFF foam systems, generating non-aspirated foam are applied in situations where the immediate objective is to save human lives. Non-aspirated AFFF very quickly knocks down spill fires. The minimum application rate is 6.5 l/min/m² equipment surface.

5.4 DRY CHEMICAL POWDER SYSTEMS

A number of dry chemicals can inhibit the oxidation process within the flame but they are only effective if applied in the diffusion zone of the fire.

Dry powder systems shall be inspected and maintained by certified specialists but experience indicates that these systems are nonetheless vulnerable to malfunction or

nuisance activation. Slight malfunctioning of such a system may result in partial extinguishment followed by immediate re-ignition, which in itself can be hazardous. Such systems should therefore not be used.

5.5 GASEOUS EXTINGUISHING SYSTEMS

The fire safety assessment shall determine the type of extinguishing agent, the spaces that will be protected by each system, and the method of activating the system (see Appendix 4 for example). Only extinguishing agents which do not have a negative impact on the environment and those who are not electrically conductive shall be applied in the systems.

In determining the type of extinguishing agents a strong preference should be given to those which are non-toxic to humans at the design concentration.

The storage space required for such agents varies widely depending on the type of agent and should be taken into account during the selection process of the agent.

5.5.1 Carbon dioxide systems

Carbon dioxide extinguishes a fire by lowering the oxygen concentration to a level where the fire can no longer be sustained. Such an environment is fatal to humans.

Carbon dioxide systems are designed for total flooding of enclosures such as those of gas turbines. The systems are automatically activated by fire or gas detection and have extensive safeguards built in to ensure the safety of personnel present in the enclosure.

5.5.2 Clean agent systems

Clean agent systems are designed for total flooding of enclosures such as those of gas turbines.

Clean agents such as halocarbon agents (brand names: FM-200, FE-13, CEA-410, CEA-614, FE-25, TRIODIDE, etc.) and inert gas agents (brand names: ARGOTEC, ARGONITE, INERGEN) have been introduced in response to international restrictions on the production and use of fire-fighting halons. Of these, the inert gases are generally acceptable, provided adequate design precautions are taken to prevent personnel asphyxiation and overpressurising of enclosures. In general, none of the halocarbon alternatives are suitable, nor is it necessary for them to be applied in PETRONAS facilities, due to their enhanced global warming potential, their toxicity or the resultant products of decomposition when exposed to a fire. If halocarbons are proposed to be used by PETRONAS company, they should first seek clarifications on the level of risk that can be posed.

5.5.3 Inert gas systems

The purpose of inert gas systems is to prevent the creation of flammable conditions inside equipment normally containing flammable product, such as the vapour space of storage tanks. However, it should be realised that on release of the vapour space gases to atmosphere a flammable mixture will be formed, as the space still contains hydrocarbon gases.

5.5.3.1 Nitrogen extinguishing system

A nitrogen system can be used to extinguish a minor PRV fire (as result of a leaking valve) on refrigerated LNG and LPG storage tanks. The release rate of the nitrogen should at least be twenty times the vapour release rate.

5.5.4 Steam systems

Steam can be used to smother fires, to dilute gas/air mixtures in enclosed areas, to control flange fires in plants in hydrogen service and on equipment handling flammable products at or above their auto-ignition temperature.

Examples of fixed steam systems for these purposes are smothering steam systems on furnaces and boilers and steam ring systems on inaccessible flanges of plants in hydrogen

service.

5.6 PORTABLE AND MOVABLE FIRE-FIGHTING EQUIPMENT

5.6.1 General

The vast majority of fires in plants start small (i.e. incipient or first-aid fire) and are extinguished by the person detecting the fire using a portable or wheeled dry chemical or foam extinguisher. Provided all personnel dealing with hydrocarbons and ignition sources in a plant are skilled in handling extinguishers, the number of small fires escalating into large fires can be kept low.

5.6.2 Distribution

PTS 80.47.10.32 shall be used for guidance for distribution requirements.

6. FIRE SAFETY REQUIREMENTS FOR SPECIFIC AREAS AND EQUIPMENT

6.1 GENERAL

The optimum inherently safe state in a plant is achieved when there is a proper balance between all factors contributing to safety. Reliability and correct functioning of safety enhancing hardware systems shall be ensured by means of good safety management. The focus shall be on built-in safety rather than add-on safety.

As an example, preference shall be given to mounded pressurised storage rather than above-ground pressurised storage. Even if an above-ground storage facility is provided with add-on fire and gas detection and exposure protection systems, it will still have a lower overall degree of inherent safety than mounded storage.

This section describes the standard equipment arrangements, the corresponding fire hazard, the probability of occurrence of a fire and the standard fire protection measures.

The standard arrangement assumes a well-designed, maintained and operated plant, continuous manning of the plant (i.e. in case of an emergency, an operator can be on the scene within 5 minutes and effective fire-fighting operations are started within 10 minutes), regular inspection rounds by operators, good equipment lay-out, proper application of area classification guidelines, adequate process control and safeguarding facilities, etc. The description of the standard arrangement includes the fire protection measures.

Based on the standard arrangement, the fire scenario being considered and the estimated probability of occurrence, the adequacy of the fire protection facilities shall be assessed.

Subsequently, measures and factors which change the overall fire safety situation and possibly affect the extent of fire protection measures are discussed.

- NOTES:
- 1) If equipment supervision is inadequate (low operating manpower, remote location of the equipment, absence of sophisticated process and equipment performance monitoring and CCTV), increasing the extent of detection facilities should be considered.
 - 2) If the operation of equipment is completely unattended, the provision of automatic shutdown systems responding to equipment malfunction should be considered. This could include a fire extinguishing system.
 - 3) If responses to fire emergencies are slow (low manpower and an expected slow start of fire-fighting operations) more remote operated or automatic exposure protection systems shall be considered.

6.2 FIRE SAFETY FACILITIES FOR ROTATING EQUIPMENT

6.2.1 Pumps

6.2.1.1 Standard arrangement

The overall objective in designing pump line-ups and lay-outs is to ensure that, in the event of pump failure, the resulting spill/fire and consequential damage will be minimised.

The majority of pumps are spared, are equipped with efficient shaft sealing systems, can be safely isolated on the suction side either by a manual valve or by an ROV, are not located in congested areas prone to escalation, are not installed underneath pipe racks and air coolers, and are accessible for fire-fighting operations.

6.2.1.2 Pumps in fire-hazardous product service

Pumps in fire-hazardous product service are spared, are equipped with a sophisticated double shaft sealing system, can be safely isolated on the suction side either by a manual valve or by an ROV, have a manual discharge valve and a non-return valve in the discharge, are equipped with simple lubricating systems, have no remote equipment performance monitoring facilities, are accessible for manual fire-fighting operations and are equipped with fire detection and exposure protection systems.

The fire hazard for such a pump is an ignited, relatively small leakage via a damaged seal.

The probability of occurrence of such a fire is very small as seals of a double arrangement are equipped with an instrumented alarm which operates if the seal fails.

A seal fire shall be addressed by closing the pump suction valve and by extinguishing the fire with dry chemical or steam.

The fire detection system is installed to detect a fire in the seal area.

For pumps handling butane and lighter products, point gas detectors are installed near the pump seals.

The exposure protection system provides protection to the pump in case of a fire on adjacent equipment and provides protection to adjacent equipment if the pump is on fire. The exposure protection system should be provided by means of fire water monitors.

6.2.1.3 Pumps in other product service

Pumps in other product service are usually spared, are equipped with efficient single shaft sealing systems, have a manual suction and discharge valve and a non-return valve in the discharge, are equipped with simple lubricating systems, have no remote equipment performance monitoring facilities, are accessible for manual fire-fighting operations and are not equipped with fire protection systems.

The fire hazard for such a pump is an ignited, relatively small leakage via a damaged seal.

The probability of occurrence of such a fire is small as the product is not easily ignitable.

A seal fire can be extinguished by using dry chemical or steam.

6.2.1.4 Sophisticated expensive pumps

Sophisticated expensive pumps, such as hydrocracker feed pumps, are not spared for economic reasons, are equipped with a sophisticated double shaft sealing system, have a remotely operable suction valve, a manual discharge valve and a non-return valve in the discharge, are equipped with sophisticated lubricating systems, have remote equipment monitoring facilities, are accessible for manual fire-fighting operations and are equipped with exposure protection systems (normally a water spray system).

The fire hazard for such a pump is an ignited, relatively small, leakage via a damaged seal. If not extinguished in time, such a fire could escalate into the lubricating system.

The probability of occurrence of such a fire is very small as seals of a double arrangement are equipped with an instrumented alarm which operates if the seal fails.

A seal fire shall be addressed by closing the pump suction valve and by extinguishing the fire with dry chemical or steam.

The standard fire detection is installed to detect a fire in the seal area.

The exposure protection system provides protection to the pump in case of an external fire and provides protection to adjacent equipment if the pump is on fire.

6.2.1.5 Deviations / options

If loss of a non-spared pump would have serious consequences for the continued operation of the plant, the provision of maximum protection should be considered, for instance by installing an automatic water spray system with the objective of reducing the probability of losing the pump for mechanical or fire reasons.

Shaft seal systems remain the most vulnerable component of pumps. Given proper care during design, maintenance and operation, seal systems are reliable. If the failure rate is too high, resulting in too frequent a loss of containment via the defective seal, the provision of fire or gas detection may be considered (whichever is the more appropriate considering the process conditions) in the seal area or alternatively of higher quality seals.

If the product supply to a pump cannot be isolated under fire emergency conditions, the provision of either an ROV or an additional manual valve accessible under pump fire conditions shall be considered.

If access for manual fire-fighting operations or the effective use of fire water monitors is limited a water spray system shall be considered. If the situation is very congested and in cases where pumps are located underneath pipe racks or air coolers, which could quickly lead to escalation, an automatic water spray system shall be considered.

For groups of pumps with sophisticated shaft seal systems and consequently a very low probability of seal fires, the provision of one fire detection system covering a number of pumps in the area shall be considered.

For pumps in butane and lighter product service with sophisticated shaft seal systems and consequently a very low probability of leakage of product via the seal, a point gas detection system should not be installed. Instead, the provision of an area gas monitoring system for groups of pumps should be considered.

6.2.2 Compressors

6.2.2.1 Standard arrangement

The overall objective in designing compressor line-ups and lay-outs is to ensure that, in case of a compressor failure, the resulting leakage/fire and consequential damage will be small.

6.2.2.2 Reciprocating compressors

The majority of reciprocating compressors are spared, are equipped with a conventional seal system on the shaft, have a dedicated lubricating system for the entire unit, are equipped with equipment monitoring equipment, can be isolated by manual valves in suction and discharge, are located in the open air where escalation is unlikely and are accessible for fire-fighting operations. The gas supply to the typical compressor fire is already reduced considerably by just tripping the compressor. Exposure protection by means of fire-water monitors is provided.

The fire hazard for such a reciprocating compressor is an ignited, relatively small leakage at the top of the seal vent pipe at a safe location. Such leakage could originate from a leaking packing box seal. Escalation of such a fire to other parts of the compressor arrangement is unlikely.

A seal fire can be addressed by tripping the compressor and by extinguishing the fire with dry chemical or steam.

The objective of the fire-water monitor is to provide cooling to the equipment while the compressor is running down and the fuel supply to the fire is being shut off.

6.2.2.3 Centrifugal compressors

The majority of centrifugal compressors are normally not spared, are equipped with high quality shaft sealing systems, have a dedicated lubricating system with back-up for the entire unit, are equipped with equipment monitoring facilities, are equipped with a non-return valve in the discharge, can be isolated by an ROV in the suction and a manual valve in the discharge, are equipped with a remotely operable depressuring facility, are located in a naturally ventilated compressor house where escalation is unlikely and are equipped with water spray, gas and fire detection systems.

The gas supply to the fire can be isolated by tripping the compressor, by closing the suction ROV and by manual depressuring. For compressors in toxic and hydrogen service, a discharge ROV and EDP shall be provided. Large lubricating and seal oil tanks are located close to the compressor and contain the major quantity of flammable products in the area. The hazard of seal oil tanks, i.e. ignition of gas contaminated seal oil, is reduced by permanent inerting of the vapour space. The hazard of the luboil tank, i.e. ignition of luboil mist by static electricity, is also reduced by permanent inerting of the vapour space. A fire in the vicinity may escalate to the tanks.

Although the residual fire hazard for a well-operated compressor installation is low, the consequences of losing the installation are serious. A fire detection system covering tanks and pumps shall be installed. Fire protection shall therefore be provided focusing on containing a seal oil tank fire, thus avoiding escalation to the luboil unit and the compressor itself. This can be achieved by a manually-activated water mist (fog) system on the seal oil tank and pumps and an exposure protection system for the compressor.

For additional supervision, CCTV inside the compressor house shall be considered.

6.2.2.4 Rotary compressors

Rotary compressors are most often used in intermittent service and are thus not spared. The more sophisticated machines are equipped with high quality shaft sealing systems, have a dedicated lubricating system for the entire unit, are equipped with equipment monitoring facilities, can be isolated by manual valves in suction and discharge, are located in the open air where escalation is unlikely and are accessible for fire-fighting operations. The gas supply to the typical compressor fire is already reduced considerably by just tripping the compressor. Exposure protection by means of fire-water monitors and gas and fire detection for the seal areas is provided.

The fire hazard for such a positive displacement compressor with a relatively large number of shaft seals is an ignited, relatively small leakage via a damaged seal. If not extinguished in time, such a fire could escalate into a lubricating system fire.

The probability of occurrence of such a fire is very small as compressors in hydrocarbon service are equipped with seals, including a back-up seal, and an instrumented alarm which operates when the primary seal fails.

A seal fire shall be addressed by tripping the compressor and by extinguishing the fire with dry chemical or steam. The objective of the fire-water monitor is to provide cooling to the equipment while the compressor is running down and the fuel supply to the fire is being shut off.

6.2.2.5 Deviations / options

If loss of a non-spared compressor would have serious consequences for the continued operation of the plant, the provision of maximum protection may be considered in order to reduce the probability of losing the compressor for mechanical or fire reasons.

Shaft seal systems remain the most vulnerable component of compressors. Given proper care during design, maintenance and operation, seal systems are reliable. If the future rate is too high, resulting in too frequent a loss of containment via the defective seal, the provision of fire or gas protection may be considered (whichever is the more appropriate considering the process conditions) in the seal area or alternatively of better seals.

If the product supply to a compressor cannot be isolated under fire emergency conditions, the provision of either an ROV or an additional manual valve in the suction, accessible under fire conditions, shall be considered.

If compressors are installed in enclosures and access for manual fire-fighting operation is limited a water spray system shall be considered. If the situation is very congested, which could quickly lead to escalation, a water mist system or an automatic water spray system and fire and gas detection shall be considered.

If centrifugal compressors are located in the open air or where access for manual fire-fighting operation is good, exposure protection by means of water monitors shall be considered rather than a more expensive water spray system.

For compressors with sophisticated shaft seal systems and a consequently very low probability of seal fires, one fire detection system covering all seals shall be considered.

For compressors with sophisticated shaft seal systems and a consequently very low probability of product leakage via the seal, a point gas detection system should not be installed. For compressors in enclosures, an area gas detection system alone shall be considered.

6.2.3 Gas turbines

6.2.3.1 Standard arrangement

The majority of **gas turbines** are not spared for economic reasons, have a dedicated lubricating system with back-up for the entire unit, are equipped with equipment performance monitoring equipment, are equipped with an emergency shutdown system, are located in a tight, mechanically ventilated, noise-abating enclosure and are not accessible for fire-fighting operations.

The fuel supply to the installation is stopped when the turbine is tripped. The fuel supply station is often located inside the turbine enclosure. Large lubricating oil tanks form part of the foundation of the turbine installation. In case of a fire the luboil supply may need to be kept in operation to prevent irreparable damage to the turbine. The luboil system contains the major quantity of flammable product in the installation. The main fire hazard is a luboil leak resulting in a pool fire or a luboil jet projecting onto the uninsulated hot turbine surface.

Although the residual fire hazard for a well-operated gas turbine installation is low, the consequences of losing the installation are serious. Fire protection shall therefore be provided focusing on detection of fire and gas inside the enclosure, plus a gaseous or water mist extinguishing system. Depending the assessment, the location of the gas turbine and area classification, flammable gas detectors shall be installed in the outlet of the ventilation air system and should be installed in the inlet of the ventilation air systems and in the combustion air intake to the gas turbine.

6.2.3.2 Deviations / options

If the gas turbine is located in the open air and access for manual fire-fighting operation is good, exposure protection should be provided by water monitors alone. Fire and gas detection is then not required.

The fire risk rating improves if the fuel supply station is located outside the turbine enclosure.

If the gas turbine can also run on a liquid fuel, the possibility of a pool fire of this fuel shall be considered.

6.2.4 Steam turbines

6.2.4.1 Standard arrangement

The majority of **steam turbines** are not spared for economic reasons, have a dedicated lubricating system with back-up for the entire unit, are equipped with equipment performance monitoring equipment, are equipped with an emergency shutdown system, are located in a naturally ventilated "compressor house" and are not accessible for fire-fighting operations.

Large lubricating oil skids form part of the turbine installation. In case of a fire the luboil supply has to be kept in operation to prevent irreparable damage to the turbine. The luboil system contains the major quantity of flammable product in the installation. The main fire hazard is a luboil leak resulting in a pool fire, a luboil jet projecting onto an uninsulated part of the hot turbine surface or auto-ignition of luboil-soaked insulation.

Although the fire hazard for a well-operated steam turbine installation is very low, the consequences of losing the installation are serious. Fire protection shall therefore be provided focusing on detection of fire and exposure protection of the luboil skid.

6.2.4.2 Deviations / options

If the steam turbine is located in the open air and access for manual fire-fighting operation is good, exposure protection should be provided by water monitors alone. Fire detection is only required when the likelihood of early detection of a fire by personnel is low.

6.2.5 Turbo expanders

Turbo expanders are generally not spared for economic reasons, and share a luboil system and an emergency shutdown system with the other power recovery elements (compressor, steam turbine) in the installation. They are equipped with performance monitoring facilities, are equipped with an emergency shutdown system, are located in a tight, mechanically ventilated enclosure and are not accessible for fire fighting operations. The main fire hazard is a luboil leak resulting in a pool fire or a luboil jet projecting onto the uninsulated hot expander casing.

Fire protection should be provided focusing on detection of fire inside the enclosure plus a gaseous extinguishing system. Because of the possible presence of carbon monoxide gas inside the enclosure, appropriate gas detection should be considered to protect personnel entering the enclosure.

Although the residual fire hazard for a well-operated installation is low, the financial consequences of losing it are serious.

6.3 FIRE SAFETY FACILITIES FOR FIRED EQUIPMENT

6.3.1 Furnaces

6.3.1.1 Standard arrangement

Area classification and sound safety distance criteria determine the location of furnaces and their air intake. Advanced burner safeguarding prevents leakage of unburnt fuel into the combustion chamber. Optimum selection of the material of furnace piping reduces the probability of tube bursts.

The main fire hazard to be considered for a furnace is a tube burst.

Furnaces shall be provided with a system of smothering steam lines to control fires inside the furnace. Separate smothering steam lines, operable at a safe distance from the hazard, are to be installed in each radiant section of heaters, in individual header boxes and in the air duct downstream of the damper or air preheater.

To protect fired equipment against the effect of an external pool fire, the steel supporting structures shall be fireproofed, see (3.3.5). The fire will be extinguished by manual fire-fighting action.

6.3.1.2 Deviations / options

If only gaseous fuels are burnt in the furnace and gaseous hydrocarbons are heated in the furnace tubes, omission of the fire proofing of the supporting structure may be considered. In gas-only fired furnaces, the smothering steam to the air ducting can be omitted.

6.3.2 Steam boilers

6.3.2.1 Standard arrangement

Area classification and sound safety distance criteria determine the location of boilers and their air intakes. Advanced burner safeguarding prevents leakage of unburnt fuel into the combustion chamber.

Boilers shall be provided with a system of smothering steam lines to control the fires inside the air duct downstream of the damper or air preheater.

To protect fired equipment against the effect of an external pool fire, the steel supporting structures shall be fireproofed, see (3.3.5). The fire will be extinguished by manual fire-fighting action.

6.3.2.2 Deviations / options

If only gaseous fuels are burnt in the boiler, omission of the fire proofing of the supporting structure and the smothering steam to the air ducting should be considered.

6.4 FIRE SAFETY FACILITIES FOR STATIC EQUIPMENT

6.4.1 Columns and vessels

6.4.1.1 Standard arrangement

Columns and vessels are designed according to well-proven codes. Piping is subjected to stress calculations and is generally connected to this type of equipment by means of flanges. Level instrumentation often obviates the need for level glasses. The vessels are protected against overpressure. Emergency depressuring facilities are provided if the vessels normally hold a liquid volume of more than 4 m³ of butane and lighter products. Vessels in vacuum service are equipped with steam supply lines to break the vacuum.

The fire hazard to be considered for vessels is an external pool fire which may weaken the supporting structure of the vessel as well as the vessel itself. The pool fire could damage a level glass, resulting in escalation.

Supporting structures for vessels and columns shall be fire proofed, see (3.3.1). Exposure protection systems shall be provided for all non-fire proofed sections of columns and vessels normally holding a liquid volume of more than 4 m³ of butane and lighter products. The area to be wetted typically extends to 9 m above the hazard level, subject to HCM.

6.4.1.2 Deviations / options

Escalation as a result of damage to level glasses can be reduced by installing blow-out preventers in the glasses or by using magnetic type level gauges instead.

If the formation of a pool fire near or under the vessel is unlikely due to the slope of the plant floor, general exposure protection by means of fire-water monitors should be considered.

In congested areas where water monitors may be less effective in providing adequate exposure protection, water spray systems shall be installed.

6.4.2 Heat exchangers

Heat exchangers are designed according to well-proven codes. Piping is subjected to stress calculations and is connected to this type of equipment by means of flanges. Individual exchangers are only protected against thermal over-pressure.

6.4.2.1 Standard arrangement for steel heat exchangers

This type of heat exchanger is located on grade or in a process structure and usually operates at elevated temperatures.

The fire hazard to be considered for this type of equipment is an external pool fire which may weaken the supporting structure and the exchanger itself. The pool fire could affect the tightness of the many flanged connections thus causing escalation.

The supporting structure shall be fire proofed, see (3.3.1).

Exposure protection shall be provided for all heat exchangers holding a liquid volume of more than 4 m³ of butane and lighter products.

Flanges around heat exchangers containing hydrogen-rich products above auto-ignition temperature such as those found in hydro-processing units are further protected by permanently installed steam rings which are manually activated if a flange leak develops.

6.4.2.1.1 Deviations / options

If the formation of a pool fire near or under the heat exchanger is unlikely due to the grading of the plant floor, general exposure protection by means of fire-water monitors alone should be considered.

If congested areas where water monitors may be less effective in providing adequate exposure protection, water spray systems shall be installed.

6.4.2.2 Standard arrangement for aluminium heat exchangers

This type of heat exchanger is located on grade or in a process structure and operates at ambient and cryogenic temperatures.

The fire hazards to be considered for this type of equipment are pool fires and jet fires. Both types of fires may very quickly damage the exchanger itself. The pool fire may also weaken the supporting structure and could affect the tightness of the many flanged connections, thus causing escalation.

The supporting structure shall be fire proofed, see (3.3.1).

Because of their vulnerability to flame contact, exposure protection shall be provided for all heat exchangers irrespective of the volume they hold. Passive fire protection shall be applied to the sections of the heat exchanger which are affected by the pool fire and to the sections which can be affected by a jet fire. Active fire protection measures shall be provided for the other sections of the exchanger.

6.4.2.2.1 Deviations / options

Due to the service this type of equipment is used for, cryogenic-type insulation is normally provided. As insulation may also have fire protection properties, the actual fire protection measures may be relaxed to some extent.

If the formation of a pool fire near or under the heat exchanger is unlikely due to the grading of the plant floor, active fire protection alone should be considered.

In congested areas where water monitors may be less effective in providing adequate exposure protection, water spray systems shall be installed.

6.4.2.3 Standard arrangement for air-cooled heat exchangers

This type of heat exchanger is located at higher elevations beyond the reach of pool fire flames. It operates at moderate to high temperatures.

The fire hazard to be considered for this type of equipment is an external pool fire which may weaken the supporting structure of the exchanger itself.

The supporting structure shall be fire proofed, see (3.3.1).

Flanges around heat exchangers containing hydrogen-rich product above auto-ignition temperature such as those found in hydro-processing units are further protected by permanently installed steam rings which are manually activated if a flange leak develops.

6.4.2.3.1 Deviations / options

If the formation of a pool fire near or under the supporting structure of the heat exchanger is unlikely due to the grading of the plant floor, general exposure protection by means of fire-water monitors should be considered.

6.4.3 Slug catcher areas

6.4.3.1 Standard arrangement

NGLs may collect at the lower end of slugcatchers. Slugcatchers are equipped with remotely operable inlet and outlet valves and a low-rate manual depressuring valve. The liquid collection header is equipped with level glasses. A level control valve maintains a level in the header.

The fire hazard to be considered is an ignited liquid leakage from a flange connection. Escalation can take place if level glasses are damaged.

Fire protection measures may include burying parts of the slugcatcher and building

protective walls.

General exposure protection measures in the form of fire-water monitors able to cover the entire (not buried) slugcatcher shall be provided.

6.4.3.2 Deviations / options

Escalation as a result of damage to level glasses can be reduced by installing blow-out preventers in the glasses or magnetic type level gauges.

If the low end of the slug catcher is installed in a pit below grade, gas detection shall be installed inside the pit to provide early warning of loss of containment.

6.5 FIRE SAFETY FACILITIES FOR PRESSURISED STORAGE VESSELS AND STORAGE TANKS

6.5.1 Pressurised storage vessels

6.5.1.1 General

Pressurised storage vessels (spheres, bullets) normally holding a liquid volume of more than 4 m³ butane or lighter products shall be protected against radiation from a fire on the storage vessel itself or from a fire in the close vicinity of the vessel, thus minimising the probability of a BLEVE.

Quantitative Risk Assessment studies have shown that a mounded storage vessel constitutes a considerably lower risk of being involved in a BLEVE than an above ground storage vessel equipped with a conventional exposure protection system. Mounded storage is therefore the preferred option in terms of fire safety.

6.5.1.2 Above ground storage vessels - standard arrangement

Above ground pressurised storage vessels (spheres, bullets) normally holding a liquid volume of more than 4 m³ butane or lighter products are not equipped with emergency depressuring facilities, have no flanged connections below the liquid level in the vessel, are equipped with a remotely operable isolating valve in the bottom outlet line, have redundant level instruments and redundant level alarms. They are equipped with an overfill relief valve venting to safe location and a fire relief valve venting via a tailpipe to atmosphere. The vessels are located on a well compacted and smooth sloping floor with a liquid collection trench to minimise the probability of a pool fire underneath the vessel. The area lay-out enhances natural ventilation. Fire and gas detection and manually activated water-based exposure protection systems (i.e., water spray system, fixed water monitors, water drenching system in combination with water spray system or fixed water monitors) are provided.

The fire hazards to be considered are ignition at the outlet of a tailpipe of a passing relief valve and ignition of a leak from a flange connection on top of the vessel. The probability of both incidents is considered low. A fire originating from adjacent areas may be possible, depending on the situation. Normal safety distances minimise the effect of such a fire on the vessel.

Fire and gas detection focuses on leaks and fires around the flange connections and tailpipes on top of the vessel. In the event of a tailpipe or flange fire the water-based exposure protection system shall be activated to protect the vessel from overheating. Manual fire-fighting actions are required to extinguish the fire.

6.5.1.3 Deviations / options

In tropical areas the likelihood of a pool of LPG forming and of pool fires underneath the vessel, caused by a leak of the vessel concerned, is insignificant. Omission of the sloping floor and the liquid collecting trench should therefore be considered.

For stand-alone pressurised storage vessels in tropical climates, omission of the bottom half of the water spray system may be considered.

For storage vessels with potential leak sources on the bottom side of the vessel, the provision of gas detection near the source and of water spray nozzles at the potential leak source, which are able to quickly dilute leaking product to below the lower flammable limit, shall be considered.

Exposure protection by means of water monitors shall be considered rather than a more expensive water spray system. The monitors shall cover all areas to be protected at the same time. Water to the monitors shall be supplied via an easily operable common valve. Alternatively a water drenching system combined with water monitors can be provided for exposure protection.

If the relief valve outlets are piped to a remote safe location and an ignited leakage has no noticeable effect on the vessel itself, omission of the top half of the water spray shall be considered. In view of potential leaks from the flange connections on top of the vessel, the provision of gas detection near the potential leak source and of water spray nozzles aimed at the flange connection, which are able to dilute leaking product to below the lower flammable limit, shall be considered.

If local regulations do not accept exposure protection by means of water, then passive fire protection shall be applied.

Omission of the gas and fire detection facilities from the standard arrangement may be considered. The level of safety without these instruments can be considered adequate.

6.5.1.4 Mounded storage vessels - standard arrangement

Mounded pressurised storage vessels, normally containing a liquid volume of more than 4 m³ butane or lighter products, are not equipped with emergency depressuring valves, have no flanged connections below the liquid level in the vessel and are equipped with a submerged pump mounted in a well. They have redundant level instruments and level alarms. They are equipped with an overfill relief valve venting to safe location and a fire relief valve venting via a tailpipe to atmosphere. They are entirely covered with soil except for the part of the dome and pump-well which protrude through the mound and except for appurtenances. The mound is protected against erosion. Fire and gas detection is provided. A manually activated water based exposure protection system shall be provided to protect the exposed parts from overheating.

The fire hazards to be considered are ignition at the outlet of a tailpipe of a passing relief valve and ignition of a leak of a flange connection on top of the vessel. The probability of both incidents is considered low. A fire originating in adjacent areas may be possible, but is not expected to have an effect on the storage vessel.

Fire and gas detection focuses on leaks and fires around the flange connections and tailpipes on top of the vessel. In the event of a tailpipe or flange fire the mound protects the vessel from overheating. The water-based exposure protection system shall be activated to protect the exposed parts from overheating. Manual fire-fighting actions are required to extinguish the fire.

6.5.1.5 Deviations / options

Omitting the gas and fire detection facilities from the standard arrangement may be considered. The level of safety without these instruments can be considered adequate.

6.5.2 Fixed roof storage tanks

6.5.2.1 Standard arrangement

Fixed roof tanks are normally used to store Class II (1), Class III (1), Class III (2) and Unclassified products. IP intertank spacing criteria or equivalent are applied. Tanks storing Class III (2) and lighter products are located in a bund with adequate capacity. Separate High-High level alarms are installed to prevent overfill. The vapour space is not inerted and vents to the atmosphere via a P-V valve.

For tanks over 15 m in diameter and height storing Class II (1) or Class III (2) products, foam extinguishing systems are installed. Fires on smaller tanks shall be extinguished using the available mobile equipment.

For tanks up to 40 m in diameter storing Class III (1) and Unclassified products no fixed foam extinguishing systems are installed. For these products, the risk of ignition is low, due to the low product volatility. Should the tank catch fire it shall be extinguished using the available mobile equipment.

Fixed roof tanks over 40 m in diameter storing Class III (1) and Unclassified product are equipped with fixed foam extinguishing systems as there is no hard evidence that full surface fires in tanks with such a diameter or larger can be successfully extinguished with

mobile equipment.

Tanks containing non-water miscible products shall be equipped with a subsurface foam injection system. Subsurface foam injection systems are not suitable for products having a viscosity above 100 mm² (cSt), an operating temperature above 95 °C and Class 1A products (NFPA classification).

Tanks containing polar and/or water-miscible flammable products shall be provided with a semi-subsurface foam injection system.

A prolonged tank fire may escalate to neighbouring tanks. Depending on the outcome of HCM calculations, exposure protection against heat radiation from fires in adjacent areas may have to be provided (e.g. water monitors, water drenching system, water spray system).

The fire hazard for a fixed roof tank is an internal explosion, resulting in damage to the roof and escalating into a full surface fire.

6.5.2.2 Deviations / options

The overall safety of a fixed roof tank can be increased considerably by inerting the vapour space or by vapour balancing with other tanks, thus avoiding the drawing in of air via the P-V valve when the tank is emptied.

In the availability of fire-fighting manpower is limited, if the fire brigade is slow to respond or has limited capabilities or if fire-fighting is hampered by poor access, the provision of foam systems even for tanks smaller than those stated in (6.5.2.1) shall be considered.

Conversely, if the availability of fire-fighting manpower is excellent, if the fire brigade is quick to respond or has excellent capabilities or if access for fire-fighting is good, relying on mobile equipment to extinguish the fire shall be considered instead of installing fixed foam extinguishing systems.

6.5.3 Fixed roof tanks equipped with an internal floating cover

6.5.3.1 Standard arrangement

Conventional fixed roof tanks in flammable product service can be equipped with an internal floating cover to reduce excessive vapour emissions.

As the seal of the floating cover is not 100 per cent efficient, some hydrocarbons will still enter the space above the floater. Depending on the flash point of the stored product and the prevailing temperature, a vapour/air mixture can be formed in the space.

A variety of types of floating covers can be applied. The non-ferrous types with the exception of GRE floating covers (6.5.3.2) have little resistance to fire. The steel versions stay intact for a longer period under fire exposure.

The fire hazard for this type of tank is an explosion in the space above the floater, resulting in damage to the floater and further escalation into a fire of the non-covered surface of the tank contents. Because of the uncertain failure mode of the floating cover, this type of tank in general has to be equipped with topside foam application (to extinguish a fire if the floating cover stays virtually intact and afloat) **and** a subsurface foam injection system (to extinguish a fire if the floating cover partly sinks or disintegrates).

Fire-fighting operations on this type of tank compared to conventional fixed roof tanks can be more complicated.

6.5.3.2 Deviations / options

For tanks with steel floaters equipped with separate sealed floatation compartments the probability of sinking of the roof is very low, assuming the mechanical inspection schedules are adhered to. The fire scenario for this type of tank is a rim-seal fire. In this case, omitting the subsurface foam injection system and providing a semi-fixed rim-seal foam system shall be considered.

Glass Reinforced Epoxy (GRE) type floaters are considered unsinkable provided they are fire retardant, are electrically conducting, have at least two 100% capacity bleeder vent valves, have high integrity fire resistant seals, and have some sort of overflow to limit the load on top of the floater. The fire scenario for this type of tank is a rim-seal fire. In this case, omitting the subsurface foam injection system and providing a semi-fixed rim-seal foam system shall be considered.

To keep the mixture out of the flammable range, the vapour space can be made free-venting above the floater. The objective is to permanently dilute the mixture to below the lower flammable limit (LFL). The potential for an explosion in the space above the cover is low.

By closing the space and venting it via P-V valves, emissions are reduced further. Depending on the flash point of the stored product and the prevailing temperature, the vapour/air mixture in the space above the floating cover may frequently pass through the flammable range. The potential for an explosion in the space above the floater is high.

By closing the space and venting it via vapour balancing/recovery systems the vapour in the space is in general always above the upper flammable limit (UFL). With this configuration precautions shall be taken to prevent migration of a fire in one part of the balancing system to another part. The potential for an explosion in the space above the cover is low.

6.5.4 Floating roof tanks

6.5.4.1 Standard arrangement

Floating roof tanks are normally used to store Class I and Class II (2) products. Intertank spacing according to the IP Code or equivalent is applied. Tanks storing these products are located in a bund with adequate capacity. Separate High-High level alarms are installed to prevent overfill. Fire retardant rim seals are used. The floating roof is either of the single deck, pontoon type design or of the double deck design. Stainless steel shunt contacts are fitted for earthing the floating roof across the rim space.

Because of the low risk of failure of floating roof tanks, only a fire in the rim seal area shall be considered. Tanks are thus only equipped with a heat detection system in the rim seal area, a foam dam on the roof and foam pourers around the circumference of the tank. Foam solution to the foam pourers is supplied by fire trucks.

A prolonged fire in an adjacent area may escalate to the floating roof tank. Depending on the outcome of HCM calculations, exposure protection (e.g., water monitors, water drenching system, water spray system) against heat radiation from fires in adjacent areas may have to be provided.

The fire hazard for a floating roof tank is a rim seal fire.

6.5.4.2 Deviations / options

For tanks in waxy service the tank wall may become coated with a layer of wax, depending on the pour point of the stored product and the prevailing ambient temperature. A seal fire could then escalate into a brief but intense wall fire. Provided prompt fire-fighting action is taken, escalation is unlikely. The best protection against this type of incident is to prevent the formation of a wax layer by externally insulating the tank wall.

Secondary seals reduce vapour emissions and improve the fire risk rating of the tank even further.

For tanks not equipped with fire retardant seals, a seal fire could quickly escalate to the entire seal area. Prompt fire-fighting action is required.

If the availability of fire-fighting manpower is excellent and if the fire brigade is quick to respond and has good capability, the provision of one foam power alone near the access stairs platform at wind girder level, equipped with two hose connections, shall be considered. Seal fires beyond the reach of the foam pourer shall be extinguished by manual

foam application.

If no fire trucks are available or if the foam generating capacity of the truck is inadequate or if fire-fighting manpower is not quickly available, a foam station shall be provided.

Tanks equipped solely with a one-shot extinguishing system (e.g. a modular foam extinguishing system or a BCF-type extinguishing system) are not considered adequately protected. The standard foam pourer system remains required for these tanks to achieve an acceptable level of protection.

6.5.5 Combi Tanks (Geodesic Dome Roof Tanks)

6.5.5.1 Standard arrangement

Combi tanks are normally used to store Class I and Class II (2) products. Intertank spacing according to the IP Code or equivalent is applied. Tanks storing these products are located in a bund with adequate capacity. Separate High-High level alarms are installed to prevent overfill. Free venting light-weight aluminium geodesic dome roofs are installed.

Glass Reinforced Epoxy (GRE) type floaters are used. The GRE floaters shall be fire retardant and electrically conducting and shall have high integrity stainless steel fire resistant seals. To limit the load on top of the floater they shall have some sort of overflow.

Despite the natural venting of the space between the floater and the dome it cannot be excluded that for brief periods a flammable mixture is formed in that space while a tank initially standing on its legs is filled. Ignition of a flammable mixture is expected to (partly) damage the dome to relieve the over-pressure of the explosion. It is not expected that this explosion will result in ignition of the floater or its seal and in structural damage to the floater which may cause further escalation.

To establish the minimum fire protection requirements the expected frequency of landing of the floating cover shall be taken into account during the fire safety assessment.

In the remote eventuality of a seal fire, it shall be possible to extinguish that fire (see (6.5.4.1) and (6.5.4.2) for guidance on fire protection systems).

6.5.5.2 Deviations / options

For non-standard combi tank designs, a full fire safety assessment shall be conducted. Depending on the materials used for the dome and floater section, (6.5.3), (6.5.4), or (6.5.5) shall be used for guidance.

Consider omitting the fire detection system if the tank is standard design. The level of safety without this system can be considered adequate.

6.5.6 Atmospheric refrigerated liquefied gas storage tanks

6.5.6.1 Standard arrangement

Such refrigerated storage tanks are of the full containment type with top entry of all connections and a concrete roof. A number of relief valves vent via a tailpipe to the atmosphere. In the pump discharge manifold there are a number of valve glands and flanged connections. There is a grated floor underneath the manifold. The tank is protected against over- and under-pressure. Fire detection and water based exposure protection systems are provided. There are a number of point gas detectors in the manifold area.

For virtually all circumstances and tank types the following vulnerable components require exposure protection by water based systems:

- level and pressure instruments;
- nozzles of piping of 4" diameter and larger on the tank roof;
- bodies of PRVs, VRVs and RCRVs;
- piping and valves on the pumping platform.

The fire hazard for such a tank is the ignited discharge of the tail pipe of a failed open relief valve. The radiation will in time result in damage to adjacent relief valves. Tail pipes may be provided with inert gas connections, operable from a safe distance, to extinguish the fire.

In addition to the use of water based exposure protection systems, water can be used to control and/or extinguish certain liquefied gas fires if considered to be the best or required option (e.g. if a small fire would block escape routes, to stop flame impingement, or to isolate a PRV during a fire in case radiation restricts access).

The use and combination of water based fire protection and fire-fighting systems by means of fixed fire-water monitors is the preferred option in terms of flexibility, "unlimited" supply, straightforward maintenance and cost effectiveness.

For example, fixed fire-water monitors can be used to control or extinguish a single PRV fire or to protect people against radiation. Fixed fire-water monitors can provide additional cooling if required. Installing a fire-water manifold on the tank with at least two outlets to feed fire-hoses increases the flexibility of the fire protection/fighting facilities.

6.5.6.2 Deviations / options

For tanks with steel roofs and no concrete protection, a full surface fire shall be considered. Depending on the inter-tank spacing and HCM results, exposure protection against heat radiation from fires on adjacent tanks may have to be provided.

LNG and NGL storage tank fires are unlikely due to the inherent safety of the tank design. If they do occur they may not be extinguishable due to the intensity of the fire and consequently a complete burn-out of the tank has to be accepted. Attempting to extinguish such a fire will result in a cloud of flammable vapour which is considered a greater hazard than the tank fire itself.

6.6 FIRE SAFETY FACILITIES FOR MISCELLANEOUS EQUIPMENT

6.6.1 Pipe racks and pipe tracks

Precautions shall only be taken at those locations in pipe racks and pipe tracks where equipment is installed which could possibly leak or cause fires. In such cases the installing of spill walls which direct the spill away to a safe area shall be considered. For refrigerated gases, directing the spill to a containment area equipped with a high expansion foam system should be considered.

Pipe racks shall be fireproofed if a sustained pool fire is considered possible. The objective is to maintain the mechanical integrity of the pipe rack so that it continues to provide proper support for the pipelines.

6.6.2 Off-site pump stations

Off-site pump stations in storage areas are normally unmanned. A wide variety of products are transferred with these pumps. Quantities and pressure can be quite high. In the majority of cases the pumps are spared. Pumps are in general of conventional design. Experience shows that pumps frequently subjected to starting and stopping are less reliable and more often experience seal and bearing damage. Drain sumps shall be provided with high level alarms.

In addition to the fire and gas detection recommendations of (6.2.1) the installing of CCTV shall be considered.

In view of the low probability of escalation of a fire to adjacent equipment and the good accessibility, fire-water monitors shall be provided in the area. Two separate monitors, each fed from a different branch (i.e. separated by a block valve) of the fire-water mains, should each be able to cover the pumps.

6.6.3 Effluent treatment areas

In this area some equipment contains appreciable quantities of heavy hydrocarbons. The area is normally manned.

Installation of strategically located fire-water monitors able to cover the equipment concerned shall be considered.

A wheeled foam cart and portable dry chemical extinguishers shall be provided.

6.6.4 LPG bottling facilities

LPG bottling facilities shall be laid out so that adequate ventilation is obtained. They shall be equipped with gas detection facilities. The installation shall be shut down automatically on confirmed detection of gas or on loss of the ventilation system.

To prevent damage, all delicate equipment shall be water sprayed. The water spray system shall be activated by gas detection, by fire detection and manually.

Portable dry chemical fire extinguishers shall be provided in and around the area.

All fire and smoke detection systems shall be connected to the central fire alarm system.

6.7 FIRE SAFETY FACILITIES FOR LOADING AREAS

6.7.1 Rail car loading facilities

6.7.1.1 Standard arrangement

Loading facilities for rail-cars transporting flammable liquid hydrocarbons are equipped with top loading via arms, no vapour return, an interlocking system preventing loading/unloading while the cars are moving, an interlocking system preventing loading/unloading operations when the earthing cable is not connected and an Emergency Shutdown System. It is a manned-only operation and the tankers are filled by volume or weight. The facility is equipped with an automatic or remote operable water spray system covering the tanker concerned plus half of each adjacent tanker.

The fire hazard for such a facility is ignition of spilled product as a result of overfilling and ignition of a vapour cloud.

In view of the variety of rail tankers and products and the frequency of coupling and uncoupling operations the probability of occurrence of a spill/fire is quite high.

Depending on the product the fire can be extinguished with water, dry chemical or foam.

6.7.1.2 Deviations / options

The possibility of fire caused by leakage of vapour from the rail-car vent is small if systems are equipped with vapour return facilities.

The possibility of fire caused by overfill is small if systems are equipped with bottom loading.

For systems using loading hoses the increased probability of product spillage due to hose failure or mishandling shall be taken into consideration. A spill containment area and foam system shall be considered.

6.7.2 Road car loading facilities

6.7.2.1 Standard arrangement

Loading facilities for road cars transporting flammable liquid hydrocarbons are equipped with bottom loading via arms with dry-break couplings, vapour return, an interlocking system preventing loading/unloading while the cars are moving, an interlocking system preventing loading/unloading operations when the earthing cable is not connected and an Emergency Shutdown System. It is a manned-only operation and the tankers are filled by volume or weight. The facility is protected by an automatic or remote operable non-aspirated AFFF foam spray system covering the floor under the vehicle, the tanker itself plus the adjacent tanker on either side. When all personnel are safe, the foam supply is switched off and the spray system can continue to operate as a water spray system.

The fire hazard for such a facility is ignition of spilled product (e.g. as a result of overfilling).

In view of the variety of road tankers and products, the presence of ignition sources in the form of vehicles and the frequency of coupling and uncoupling operations, the probability of occurrence of a spill/fire is quite high. For this type of area the probability of failure of the product transfer equipment is relatively high. The foam system is provided to reduce the probability of injury to personnel.

Depending on the product the fire can be extinguished with water, dry chemical or foam.

6.7.2.2 Deviations / options

For systems not equipped with a vapour return, the extent of the emitted vapour cloud shall be taken into consideration when determining the lay-out of the overall situation and control of potential ignition sources.

For systems not equipped with bottom loading, the likelihood of overfill increases and the overall fire risk rating becomes worse.

For systems using loading hoses, the increased probability of product spillage due to hose failure or mishandling shall be taken into consideration. A spill containment area and foam system shall be considered.

In facilities where only non-company personnel are possibly present during operation the AFFF foam spray systems shall be activated automatically.

The purpose of the automatic AFFF foam spray system is to knock down flames quickly enabling personnel to escape to a safe area. Actual fire-fighting requires more resources. If no fire trucks are available, or if the foam generating capacity of the truck is inadequate or if the fire brigade is not promptly available, a foam station shall be installed providing extended foam supply to the spray system and feeding low expansion foam to strategically located foam monitors.

In loading facilities where only LPG or lighter hydrocarbons are handled, a fire and gas detection and a water based exposure protection system shall be provided.

6.7.3 Jetty terminals

6.7.3.1 General

For the majority of plants, jetties are the main import and export facility for their feedstock and products. Fire incidents at jetties may have a serious impact on the operations of the plant, in particular if the jetty is frequently used and if there are no alternative import and export facilities.

Incidents can originate at the jetty itself, at the ship-shore interface or on board a ship moored to the jetty.

Strict adherence to procedures for all marine and transfer operations is imperative to ensure ongoing safety of the jetty facilities.

If the jetty is part of a plant, the plant water ring mains system shall be of sufficient capacity to cope with the water demand of the jetty.

If the jetty is located in an area where a fire-water ring mains system is not available, the jetty shall be equipped with its own fire-water system in accordance with (Section 3).

Because access for fire-fighting vehicles to the jetty head is not considered safe and since it may be difficult for fire-fighters to escape quickly in the event of escalation, jetties are often equipped with fixed fire protection and fire-fighting systems.

Adequate fire protection shall be provided for the jetty and all its equipment against a major fire which may occur on the jetty, or against a fire in the manifold of a ship berthed at the jetty.

The protection facilities shall also be designed to protect the directly exposed areas of a ship at berth against a fire on the jetty.

Ships are normally equipped with protection facilities to cope with a major on-board fire. The jetty fire protection facilities therefore need only provide assistance to the ship at berth when requested by the master of the ship or his representative.

Assistance should include:

- the ability to provide the ship's fire-water system with water through an International Shore Fire Connection according to ISGOTT;
- the ability to cool the ship's manifold;
- the ability to provide exposure protection for the ship's crew, e.g. when disconnecting hoses or loading arms under fire emergency conditions;

- the ability to provide exposure protection to the gangway and to the ship's crew when using the gangway to escape from the ship.

6.7.3.2 Standard arrangement for jetty facilities

Jetty structures are generally of a design which provides a high degree of passive protection against fire. During transfer operations the jetty is manned and the jetty operator is in direct contact with the ship's personnel. Product is transferred via loading arms equipped with extension alarms. The shore isolation valves are of the fire safe design and are located as close as possible to the loading arms. All hydrocarbon lines are provided with isolation valves that are safely accessible under jetty head fire conditions and are positioned so that they are unlikely to be in collision with a ship that may have broken away. The drain sump on the jetty contains minor quantities of hydrocarbons.

6.7.3.3 Standard arrangement for fire on the jetty

For a fire on a jetty a number of water monitors are installed, fed via a normally dry supply line. They are directed and adjusted so that the entire manifold area and other process equipment can be wetted by opening the single valve to the dry header. A water spray system is installed to wet the static part of the loading arms.

The fire hazard on a jetty is ignition of leakage of hydrocarbon from a pipe component or a fire in the drain sump.

The probability of occurrence of a jetty fire is very low.

6.7.3.4 Standard jetty arrangement for a fire on the ship

For a fire on a ship a number of water monitors fed via a normally dry supply line are located, directed and adjusted so that the entire manifold area can be wetted by opening the single valve to the dry header. A water spray system is installed to wet the static part of the loading arms. In case assistance is required by the ship, one or more of the monitors can be directed to the area to be protected, e.g. the ship's manifold and gangway, leaving sufficient protection for the jetty facilities.

The fire hazard on a ship is ignition of leakage of hydrocarbon from a pipe component in the ship's manifold area.

The probability of occurrence of a ship fire is very low.

6.7.3.5 Deviations / options

For wooden jetties or jetties supported on non-fireproofed piles, active exposure protection shall be applied against a spill fire on the water, the objective being to maintain the integrity of the jetty structure.

If the jetty is unmanned, additional instrumented supervision, in the form of CCTV, as well as additional gas and fire detection shall be considered.

If transfer facilities are equipped with an ESD system, the flow feeding the fire can be isolated more easily and quickly resulting in a smaller fire. The ESD system shall be of a fire safe design and operable from a safe location on the jetty, from the ship and from the control centre.

If the open drain sump is located under hydrocarbon-containing equipment, a water spray system covering the pit shall be considered.

When loading hoses are used, the probability of loss of containment is increased. A hydrocarbon spill on the water, jetty deck or ship's deck is more likely. Fire proofing or exposure protection of the hose gantry shall be considered to maintain its mechanical integrity under fire conditions underneath.

In cases where loss of the jetty would have a dramatic impact on the import and export capacity of the plant increasing the extent of the fire safety measures shall be considered.

6.7.3.6 Jetty fire protection facilities

6.7.3.6.1 Standard arrangement

A single fire-water pipeline is installed along the jetty approach up to the jetty head. This pipeline is equipped with two-way hydrants spaced along the approach and with four-way hydrants on the jetty head. One of the four-way hydrants, located near the gangway, is provided with the required International shore fire connection according to ISGOTT.

Two four-way water hydrants shall be provided at the parking space near the approach to the jetty. They shall be connected to the fire-water main system in order to supply the fire-fighting vehicles if these have to back up the jetty systems.

A subheader of the fire-water line supplies water to the fixed, manually-operated and adjustable water monitors, fitted with jet/fog nozzles, installed on the jetty head. The inlet valve to each water monitor shall be in the normally open position. Water to this header is supplied via a block valve remotely operable from the jetty control room, from the jetty approach on shore and from the nominated control room. Appropriate measures shall be taken to assure operation under all conditions, particularly in climates where freezing can occur.

An automatic water spray system on the static part of the loading arms is supplied from the fire-water line and is equipped with a strainer and a remotely operated isolating valve. Systems with a small number of spray heads may be combined into a single system to reduce the number of water spray valves.

The required water rate for the overall jetty systems depends on a large number of variables but is mainly determined by the expected size and duration of a fire, including the amount of water required to avert the potential damage caused by that fire. The maximum water requirements shall be based on the maximum number of systems which may be required to operate simultaneously.

If a sustained fire is possible at the jetty, the fire may have to be extinguished by foam.

Deck-mounted foam monitors, pre-directed to cover the entire jetty manifold area and able to apply foam gently, shall then be considered. Depending on the accessibility under manifold fire conditions the monitors may have to be fed via a dry solution line.

The foam solution shall be provided by fire fighting vehicles and should be able to reach all foam monitors within 2 minutes after the vehicles start pumping foam solution into the header. Measures shall be taken to avoid hydraulic shock when the dry line is being filled.

A parking space for two fire-fighting vehicles and one foam compound carrier shall be provided on the shore at the approach to the jetty, near to the dry foam solution line manifold.

If there are no fire boats available in the port that are able to throw sufficient foam onto the ship's deck the provision of a foam monitor with a capacity of 240 m³/h of foam solution shall be considered.

The monitor shall be positioned at such an elevation that the ship's manifold area (at all water levels) facing the jetty head and the water between the jetty head and the ship can be covered with a foam blanket. Depending on the accessibility of the monitor under fire conditions at the ship's manifold, it may be necessary to make the monitor remotely operable, in which case it shall be electrically operated and remotely controlled from a safe location.

If a gantry tower is available, the foam monitor may be installed on this structure, otherwise a separate monitor tower should be provided if considered necessary.

Fire proofing or exposure protection of the gantry/monitor tower shall be considered to maintain its mechanical integrity under fire conditions underneath.

Portable and mobile dry chemical and foam extinguishing equipment shall be provided.

6.7.3.6.2 Deviations / options

If adequate coverage of the gangway or the ship's manifold area cannot be achieved with the fixed monitors normally directed at the jetty manifold, the provision of dedicated monitors shall be considered. These may have to be installed at an elevated position and shall be provided with an adjustable nozzle which, for this situation, should be normally in the spray mode and not in the jet mode. If they are not easily accessible, remote actuation and operation may have to be considered.

If water monitors can be positioned so that they will be able to wet all sides of the static part of the loading arms adequately, it may not be necessary to install the water spray system for the loading arms.

If the foam cannot be provided by fire trucks because of distance or slow response, a dedicated foam system shall be provided. A foam station located at a safe location feeding the monitors via the dry solution line shall then be considered. In this case a pipeline shall be installed for refilling the foam station storage tank from the foam carrier.

The foam station shall be so designed and located that the foam solution will reach all foam monitors within 2 minutes after the station has been activated. For further details of the foam station and the dry solution pipeline, see PTS 80.47.10.31

6.8 FIRE SAFETY FACILITIES FOR BUILDINGS

6.8.1 General

Buildings shall be designed in accordance with PTS 34.17.00.32 which provides requirements and recommendations for passive fire protection (fireproofing of internal and external walls).

The main objective of fire protection facilities in buildings is to protect the life and safety of the occupants. In general, local fire regulations include specific requirements.

The consequent loss of business, the cost of replacement of equipment in the building and the cost of repair of fire damage shall also be considered when specifying fire protection systems.

Fire water shall be available close to and inside the building. In view of the relatively small quantities and low pressure requirement of fire-water for typical building fires, the potable water supply may be adequate. Both inside and outside the building fire-water hydrant connections shall be provided.

At strategic locations in hallways, corridors and other large spaces in buildings fire extinguishers or hose reels shall be provided. Clear instructions or pictograms shall be provided indicating which type of extinguishing agents is recommended for a particular purpose.

If required, fire call points of the 'break glass type' shall be provided. The call points shall be connected to the central fire alarm system and shall activate an evacuation alarm. The evacuation alarm shall be an audible signal and shall operate throughout the entire building.

The guidelines given in NFPA 101 shall be applied, unless local regulations are more stringent.

6.8.2 Plant buildings

6.8.2.1 Control rooms/control centres

Control rooms are normally manned continuously. Fires which may develop in the manned spaces will thus be discovered at an early stage.

Unnoticed fires in the unmanned parts of a control centre may damage equipment and/or instruments to such an extent that the operation and production of a plant may have to be interrupted for a considerable period of time for the necessary repairs to be carried out.

To safeguard plant operation it is therefore crucial that a rapid fire and smoke detection system is provided, allowing prompt intervention by personnel.

The installing of an ultra-sensitive smoke detection system shall be considered in all normally unmanned critical areas such as the auxiliary rooms, computer and computer software rooms and all enclosed cabinets where hot spots could develop.

Heat detectors shall be considered for the battery room, laboratory areas and storage rooms.

Gas detectors shall be considered in or near the air inlet ducts to provide an early warning of ingress of flammable gas. On detection of gas the air intake shall be closed and the air handling system shall switch over to internal circulation.

For applications where spurious trips are not acceptable, automatic detection systems classified according to PTS 32.80.10.10 shall be applied.

The power supply arrangement to process control equipment shall be designed so that, in the event of a fire or smoke formation, the individual control cabinets of the relevant systems can be electrically isolated.

If loss of the equipment in the space would have a severe impact on the continued operation of the plant installation a gaseous fire extinguishing system shall be considered.

All heat, smoke, and gas detection systems and automatically operated fire-fighting systems shall be connected to the central fire alarm system.

6.8.2.2 Field auxiliary rooms (FARs)

FARs are normally unmanned. Unnoticed fires in a FAR may damage equipment and/or instruments to such an extent that the operation and production of a plant may have to be interrupted for a considerable period of time for the necessary repairs to be carried out.

To safeguard plant operation it is therefore of utmost importance that a rapid fire and smoke detection system is provided, allowing prompt intervention by personnel. Installation of an ultra-sensitive smoke detection system in all critical spaces and installation of conventional smoke and fire detectors in the other spaces of the buildings shall be considered.

Where detection systems have a trip function and where spurious trips are not acceptable, automatic detection systems classified according to PTS 32.80.10.10 shall be applied.

The power supply arrangement to process control equipment shall be designed so that in the event of a fire or smoke formation, the control cabinets of the relevant systems can be electrically isolated.

If loss of the equipment in the space would have a severe impact on the continued operation of the plant, installation of a gaseous fire extinguishing system shall be considered.

All heat, smoke, and gas detection systems and automatically operated gaseous fire-fighting systems shall be connected to the central fire alarm system.

6.8.2.3 Laboratories

For spaces in laboratory buildings which are not manned continuously, installation of conventional fire and smoke detection facilities shall be considered.

In hazardous areas, near the entrances to the laboratory and to storage and engine rooms and at each workbench, fire extinguishers shall be installed.

In addition, hose reels with 25 mm diameter hoses connected to the potable water system shall be installed in the corridors, so that storage rooms, offices and laboratory areas will be well within reach of the water nozzles.

All fire and smoke detection systems shall be connected to the central fire alarm system.

6.8.2.4 Analyser houses & metering stations

Analyser houses and metering stations are normally unmanned. They may be located in or very close to hazardous plant areas and may contain equipment only suitable for non-hazardous areas. Samples are prepared in a well ventilated area adjacent to the enclosed area housing the analysers.

The ventilation air intake is located in a non-hazardous area. It provides a slight overpressure inside the enclosure. Enclosure exhaust intakes are located at floor and ceiling level thus sweeping heavier and lighter-than-air hydrocarbon vapours. The ventilation rate of the enclosure shall be adequate to prevent an explosive mixture inside the enclosure, assuming full bore failure of the worst sample line (in terms of size, pressure and fluid).

Gas detectors are installed in the air intake. On confirmed detection of gas all non-Zone 1 electrical equipment inside the enclosure and the ventilation system are switched off.

Gas detection is also installed inside the enclosure. On confirmed detection of gas all non-Zone 1 electrical equipment is switched off. The ventilation system continues to operate.

Conventional smoke detection inside the enclosure has an alarm function only.

Carbon dioxide extinguishers shall be provided near the entrances of the building.

All gas and smoke detection systems shall be connected to the central fire alarm system.

6.8.2.5 Switch houses / electrical sub-stations

These buildings are located in non-hazardous areas and (normally) contain conventional switchgear and cabling. Provided housekeeping is good, there are no combustible materials located in the buildings to cause a class A fire.

The likely fire scenario in this type of building is due to severe damage of switchgear as a result of a short circuit. If there is a resultant fire, it would be very small.

Malfunctioning of power supply will reveal itself via other indications.

A conventional smoke detection system which can provide information on overheating and fires inside the building shall be installed. The detection shall have an alarm function only.

Carbon dioxide extinguishers shall be provided near the entrances of the building. The smoke detection system shall be connected to the central fire alarm system.

Electronic equipment, such as Variable Speed Drive Systems, may be installed in the same space in the building. Unnoticed fires in the building may damage the equipment to such an extent that the operation and production of a plant has to be interrupted for a considerable period of time for the necessary repairs to be carried out.

To safeguard plant operation it is in that case of utmost importance that a rapid fire and smoke detection system is provided, allowing prompt intervention by personnel. An ultra-sensitive smoke detection system shall then be installed.

6.8.2.6 Transformers

Transformers are located in the open, in fenced-off non-hazardous areas. They contain small quantities of oil which may leak and catch fire. Under the transformer a collection basin is provided.

The likely fire scenario in this type of equipment is damage as result of an explosion.

Malfunctioning of a transformer will reveal itself via other indications.

Provide portable carbon dioxide or dry chemical extinguishers in the vicinity of the transformers.

6.8.2.7 Battery rooms

Battery rooms are unmanned spaces inside control room buildings and FARs. They contain large quantities of either sealed recombination lead acid, vented lead-acid or vented Ni-Cd batteries, which serve as back up power supply in case of failure of the normal power supply. A conventional smoke detector shall be installed to alert personnel of irregularities.

If conventional vented lead-acid batteries are used, hydrogen vapours will be formed during charging. Ni-Cd batteries produce oxygen vapours. In either case the battery room shall be equipped with an explosion proof exhaust fan.

The air shall be exhausted from the highest location of the space to ensure that the very light and highly explosive hydrogen vapours cannot accumulate. An alarm shall be provided in case the ventilation system fails.

Carbon dioxide extinguishers shall be provided near the entrances of the building.

The smoke detection system shall be connected to the central fire alarm system.

6.8.2.8 Fire stations

In normally unmanned fire stations the installing of conventional smoke detectors shall be considered in all spaces and fire detection in the garage for the fire-fighting vehicles.

All fire and smoke detection systems shall be connected to the central fire alarm system.

6.8.2.9 Fire water pump houses

In normally unmanned fire-water pump houses the installing of fire detection above the

diesel engines shall be considered. The diesel fuel tanks should be located in the open air, or at least they shall be located in a space separated from the engines.

Carbon dioxide or dry chemical extinguishers shall be provided near the entrances of the building. The fire detection system shall be connected to the central fire alarm system.

6.8.2.10 Packed product warehouses

A detailed assessment is required to determine the fire protection measures required for product warehouses. The type of building, type of product, value stored, likelihood of ignition, presence of ignition sources, type of packing materials, size of compartments in the building, fire resistance of separation walls, presence of (automatic) fire doors etc. shall all be taken into account. See PETRONAS Marketing / Chemicals publication titled "The PETRONAS Guide to the Warehousing of Chemicals" for further guidance.

6.8.2.11 Packed product storage yard

Packed products like LPG (in bottles) and lubricating oil (in drums) are in general stored in the open air. A detailed assessment, taking into consideration lay-out, type of product, quantities stored and type of transport vehicles used, is required to determine the fire protection measures required for this type of packed product storage.

Dry chemical powder extinguishers and fire water monitors able to keep the product containers cool provides in general adequate protection.

6.8.2.12 General warehouses

These warehouses are manned during office hours only and serve to store spare parts and other consumables.

Fire protection shall mainly consist of dry chemical powder fire extinguishers and hose reels with 25 mm hoses connected to the potable water supply.

Depending on the value and criticality of the stored products the provision of conventional smoke detectors shall be considered.

The smoke detection system shall be connected to the central fire alarm system.

6.8.2.13 Flammables store

Flammables for in-house use, like paint, fuels and lubricating oils, are stored in a normally unmanned well-ventilated enclosure. Electrical equipment in the enclosure complies with the area classification. The walls and roof have a fire resistance of two hours.

Fire detection should be installed inside the enclosure, connected to the central fire alarm system.

Depending on the size of the warehouse and the likelihood that a prolonged warehouse fire will escalate into a fire to adjacent buildings the installing of an extinguishing system shall be considered. If required, a high expansion foam system should be used.

Carbon dioxide or dry chemical extinguishers shall be provided near the entrances of the building.

The fire detection system shall be connected to the central fire alarm system.

6.8.2.14 Workshops

Workshops are located in non-hazardous areas and contain minor quantities of flammable products. Welding and other hot equipment is operated by craftsmen. Bottles with compressed welding gases are stored outside the buildings in fenced-off areas. Housekeeping requires constant attention by all involved.

The fires to be considered are those of rags in dustbins and of very small quantities of liquid hydrocarbons.

Fire protection shall mainly consist of dry chemical powder fire extinguishers and hose reels

with 25 mm hoses connected to the potable water supply. A fire detection system may need to be installed.

6.8.3 Office buildings

6.8.3.1 Administration office

Hallways and corridors, as well as rooms with a high potential fire risk such as canteens and printer rooms, shall be equipped with conventional smoke/fire detectors. These detectors shall also be considered in ventilation systems.

All fire and smoke detection systems shall be connected to the central fire alarm system.

The following fire protection and extinguishing equipment shall be considered:

- A sufficient number of hose reels shall be installed, each containing 25 mm diameter fire hose of maximum length 25 m connected to the potable water system, positioned so that each office is well within reach of the water nozzles.
- For multi-storey buildings dry risers for external fire-fighting assistance shall be installed at two opposite sides of the office building adjacent to the escape stairs. The ground level inlet to the dry riser and the outlets at each floor shall be equipped with valved hose couplings.
- Portable equipment shall be available in accordance with the requirements of PTS 80.47.10.32.
- See also NFPA 101 for requirements on fire detection systems, fire alarm call points, notification of occupants systems, means of egress, fire extinguishing systems, etc.

6.8.3.2 Training centre

For the normally unmanned training centre the installing of conventional smoke and fire detectors in all spaces shall be considered.

All fire and smoke detection systems shall be connected to the central fire alarm system.

These detectors should also be considered for installation in ventilation systems.

The following fire protection and extinguishing equipment shall be considered:

- A sufficient number of hose reels shall be installed, each containing 25 mm diameter fire hose of maximum length 25 m connected to the potable water system, positioned so that each office is well within reach of the water nozzles.
- For multi-storey buildings dry risers for external fire-fighting assistance shall be installed at two opposite sides of the building adjacent to the escape stairs. The ground level inlet to the dry riser and the outlets at each floor shall be equipped with valved hose couplings.
- Portable equipment, shall be available in accordance with the requirements of PTS 80.47.10.32.
- See also NFPA 101 for requirements on fire detection systems, fire alarm call points, notification of occupants means of egress, fire extinguishing systems, etc.

6.8.3.3 Computer rooms

Computer rooms are normally unmanned and have a high degree of fire resistance, which makes escalation of an external fire into the computer room unlikely.

Given proper housekeeping, the likelihood of a fire originating in the computer room is very low. If loss of the computer room would have a serious effect on the continued operation of the plant or would cause loss of critical data the installing of an ultra-sensitive smoke detection system and a gaseous extinguishing system shall be considered.

7. REFERENCES

In this PTS, reference is made to the following publications:

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

PETRONAS STANDARDS

Index to PTS publications and standard specifications	PTS 00.00.05.05
Index to standard drawings	PTS 00.00.06.06
Piping - general requirements	PTS 31.38.01.11
Symbols and identification system - Instrumentation	PTS 32.10.03.10
Fire, gas and smoke detection systems	PTS 32.30.20.11
Classification and implementation of instrumented protective functions	PTS 32.80.10.10
Drainage and primary treatment facilities	PTS 34.14.20.31
Minimum requirements for design and engineering of buildings	PTS 34.17.00.32
Fireproofing of steel structures	PTS 34.19.20.11
Active fire protection systems and equipment for onshore facilities	PTS 80.47.10.31
Use of fire fighting agents and movable fire fighting equipment for onshore applications	PTS 80.47.10.32
Fire-fighting vehicles and fire stations	PTS 80.47.10.33
The Shell guide to the warehousing of chemicals	
Physical effects modelling	PTS 60.164
Fire control and recovery	PTS 60.165

Amended per
Circular 69/03

Pre-incident planning guide	OP 99-30011
Guidelines on the use of water mist fire extinguishment systems in E&P industry applications	E&P Forum
	Report No. 6.49/235

STANDARD DRAWINGS

NOTE: The latest edition of Standard Drawings can be found in
PTS 00.00.06.06

Fire training ground for first aid training	S 88.030
Fire training ground for hose team training	S 88.031

AMERICAN STANDARDS

Guide for pressure-relieving and depressuring systems	API RP 521
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Issued by:
American Petroleum Institute
Publication and Distribution Section
2101 L Street N.W.
Washington, D.C. 2003J
USA.

Standard for low expansion foam	NFPA 11
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Medium and high expansion foam agents	NFPA 11A
Carbon dioxide extinguishing systems	NFPA 12
Installation of sprinkler systems	NFPA 13
Flammable and combustible liquids code	NFPA 30
Code for safety to life from fire in buildings and structures	NFPA 101
Standard system for the identification of the fire hazards of materials	NFPA 704

Issued by:
National Fire Protection Association (NFPA)
Batterymarch Park
Quincy, MA 02269
USA

BRITISH STANDARDS

Recommendations for graphic symbols and abbreviations for fire protection drawings	BS 1635
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Issued by:
British Standards Institution
389 Chiswick High Road
London W4 4AL
UK

Incipient fire detection	E&P Forum Report No. 6.75/284
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Issued by:
OGP (International Association of Oil and Gas Producers)
25/28 Old Burlington Street
London W1X 1LB
UK

Model code of safe practice in the petroleum industry; Part 3: Refining	IP Code Part 3
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Issued by:
The Institute of Petroleum
61, New Cavendish Street
London W1M 8AR
United Kingdom.

INTERNATIONAL STANDARDS

Tests for electric cables under fire conditions - Circuit integrity	IEC 60331-21
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Issued by:
International Electrotechnical Commission
3 Rue de Varembe
CH 1211 Geneva 20
Switzerland.

International safety guide for oil tankers and terminals	ISGOTT
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Issued by:
International Chamber of Shipping
Carthusian Court
12 Carthusian Street
London EC1M 6EB
United Kingdom

APPENDIX 1 GRAPHICAL SYMBOLS AND ABBREVIATIONS

The following typical graphical symbols and abbreviations should be utilised in fire protection schemes and drawings.

If the NFPA codes are specified for the design of the fire-fighting systems, the symbols and abbreviations of the NFPA codes may be applied if approved by the Principal. If the NFPA codes do not provide the appropriate symbols for the fire protection drawings of onshore installations, the symbols in this Appendix should be applied.

BS 1635 may be used if additional symbols and abbreviations are required.

1.1 FIXED FIRE PROTECTION EQUIPMENT/SYSTEMS

Fixed automatic water spray system



Fixed manually operated water spray system



Fixed automatic water fog system



Fixed manually operated water fog system



Fixed automatic low expansion foam system



Fixed manually operated low expansion foam system



Fixed automatic medium expansion foam system



Fixed manually operated medium expansion foam system



Fixed automatic high expansion foam system



Fixed manually operated high expansion foam system



Fixed automatic AFFF (aqueous film forming foam) system



Fixed manually operated AFFF system



Fixed automatic alcohol-resistant foam system



Fixed manually operated alcohol-resistant foam system



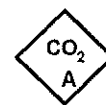
Fixed automatic Inergen system



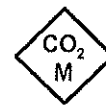
Fixed manually operated Inergen system



Fixed automatic carbon dioxide system



Fixed manually operated carbon dioxide system



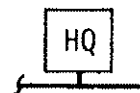
Fixed manually operated dry powder system



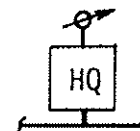
Hydrant post (pillar) double



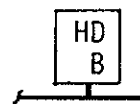
Hydrant post (pillar) quadruple



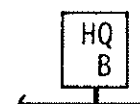
Hydrant post (pillar) quadruple with monitor



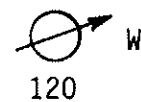
Hydrant post (pillar) double equipped with bottom drain valve



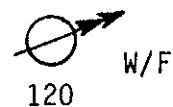
Hydrant post (pillar) quadruple equipped with bottom drain valve



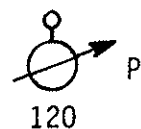
Fixed-installed monitor, manually adjustable and operated, for water (capacity in m³/h)



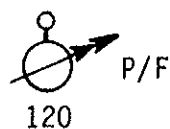
Fixed-installed monitor, manually adjustable and operated, for water and for foam (capacity in m^3/h water foam solution)



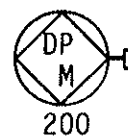
Fixed-installed monitor, remotely adjustable and operated, for powder (capacity in m^3/h)



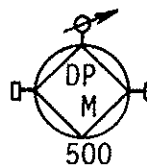
Fixed-installed monitor, remotely adjustable and operated, for powder and for foam (capacity in m^3/h water foam solution)



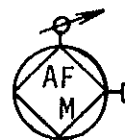
Fixed manually operated dry powder unit with one hose reel (capacity in kg)



Fixed manually operated dry powder unit with two hose reels and powder gun (capacity in kg)



Fixed manually operated AFFF unit with one hose reel and monitor (capacity in m^3)



Fixed installed high back pressure foam generator



Dry riser



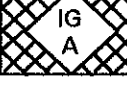
Steam ring



Hose box



Fire point	
On/off control valve for automatic spray systems spring opening	
Fixed manually operated sub-surface foam system	
Fixed manually operated semi-sub-surface foam system	
Area protected by fixed automatic water spray system	
Area protected by fixed manually operated water spray system	
Area protected by fixed automatic water fog system	
Area protected by fixed manually operated fog system	
Area protected by fixed automatic water curtain	
Area protected by fixed manually operated water curtain	
Area protected by fixed automatic low expansion foam system	
Area protected by fixed manually operated low expansion foam system	
Area protected by fixed automatic medium expansion foam system	
Area protected by fixed manually operated medium expansion foam system	

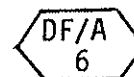
	
Area protected by fixed automatic high expansion foam system	
Area protected by fixed manually operated high expansion foam system	
Area protected by fixed automatic AFFF system	
Area protected by fixed manually operated AFFF system	
Area protected by fixed automatic alcohol-resistant foam system	
Area protected by fixed manually operated alcohol-resistant foam system	
Area protected by fixed automatic carbon dioxide system	
Area protected by fixed manually operated carbon dioxide system	
Area protected by fixed automatic Inergen system	
Area protected by fixed manually operated Inergen system	
Area protected by fixed automatic dry powder system	
Area protected by manually operated dry powder system	



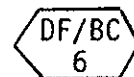
1.2 PORTABLE FIRE EXTINGUISHING EQUIPMENT

1.2.1 Portable extinguishers

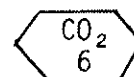
Powder,
where A indicates the type of dry powder, and the number is
the filling weight in kg, which may be 2, 6, 9, or 12 kg.



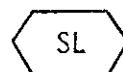
Powder,
where BC indicates the type of dry powder, and the number
is the filling weight in kg, which may be 2, 6, 9, or 12 kg.



Carbon dioxide

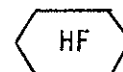


Steam lance



1.2.2 Portable foam generators

High expansion foam generator



Medium expansion foam generator



High back pressure foam generator



1.3 FIXED FIRE-DETECTION EQUIPMENT, AUTOMATIC

Area covered by flammable gas detector



Area covered by ultraviolet flame detector



Area covered by infra-red flame detector



1.4 FIRE-WARNING SYSTEM, MANUAL

Siren

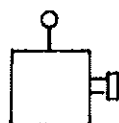


1.5 FIRE SUPERVISORY SYSTEM, AUTOMATIC

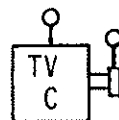
Fixed installation television camera



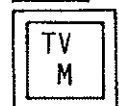
Fixed remotely operated television camera



Fixed remotely operated television camera with remotely operated zoom lens



Television monitor



1.6 SYMBOLS AND IDENTIFICATION SYSTEM - INSTRUMENTATION

See PTS 32.10.03.10

APPENDIX 2 TYPICAL APPLICATIONS FOR HEAT, FIRE, SMOKE AND FLAMMABLE GAS DETECTION

Areas of application	Detection type						
	Heat		Fire	Smoke		Flammable gas	
	Linear	Spot (1)	UV IR	Conventional	Ultra-sensitive	Line-of-sight	Point
Selected hydrocarbon pumps	X						X
Gas turbine/gas compressor in enclosures		X (2)	X UV/IR				X
Selected areas or equipment holding hydrocarbons	X						
LPG bottle filling			X IR			X	X
LNG containment area	X (3)					X	
Floating roof tank rim seal area	X (4)	X (4)					
LPG storage vessel	X						X
Refrigerated LPG/LNG tank	X					X	
Control room building		(X)		X			X
Analyser house		(X)		X			X
Plant laboratory		(X)		X			
Main laboratory		(X)		X			
Instrument auxiliary room, cabinets, floor cavity, cable routes					X		
Battery room		(X)		X			
Computer auxiliary room					X		
Switchhouse / Substation		(X)		X			
Workshop - general		(X)		X			
Workshop - process analysers		(X)		X			X
Warehouse - general		(X)		X			
Warehouse - packed products		(X)		X			
Packed product (incl. LPG) storage yard			X IR			X	
Administration buildings		(X)		X			
Canteen		(X)		X			
Kitchen		(X)	X IR	X			
Training centre		(X)		X			
Fire station			X IR	X			
Garage			X IR	X			

- NOTES:
- (X) indicates that spot smoke detectors should be of the integral heat detection type.
 - Rate of rise heat detector
 - Low temperature heat detector
 - Use either polyethylene tube or frangible quartzoid bulb detector

APPENDIX 3 TYPICAL CAUSE AND ALARM/ACTION MATRIX

CAUSE	Detected or signalled by	RESULTING ALARM OR ACTION											
		Audible alarm in CR	Visual and audible alarm on DCS	Visual alarm on mimic panel	Audible alarm in building	Visual alarm in building	Audible alarm in plant 1)	Visual alarm in plant 1)	Close fresh air intake 1)	Close fire tight dampers 1)	Start fire-water pump 1)	Open water spray valves 1)	Activate gaseous extinguishing system 1)
GENERAL	Manual call point (in building)	X	X	X	X	X							
	Manual call point (in open plant)	X	X	X			X	X		X			
HEAT	Space	X	X	X	X	X							
	Rate of rise	X	X	X	X	X							X
	Polyethylene tube	X	X	X						X	X		
	Frangible quartzoid bulb	X	X	X						X	X		
FIRE or FLAME	Infrared	X	X	X	X	X				X			X
	Ultraviolet	X	X	X	X	X				X			
	Building air intake high temperature	X	X	X	X				X				
SMOKE	Ionisation	X	X	X	X	X				X			
	Scattered light	X	X	X	X	X				X			
GAS	Ultra sensitive	X	X	X	X	X				X	X		X
	Toxic gas	X	X	X	X	X	X	X					
	Flammable gas high	X	X	X									
	Flammable gas high	X	X	X	X	X	X	X					X

NOTES: 1) Where revealed failure robust initiators are implemented, action shall only be performed when 2 out of 'n' initiators are in alarm.

2) This matrix is also used in PTS 32.30.20.11

APPENDIX 4 TYPICAL CONTROL AND ALARM ANNUNCIATING FUNCTION DIAGRAM OF A GASEOUS EXTINGUISHING SYSTEM.

Control function diagram

X = Applicable - = Not applicable

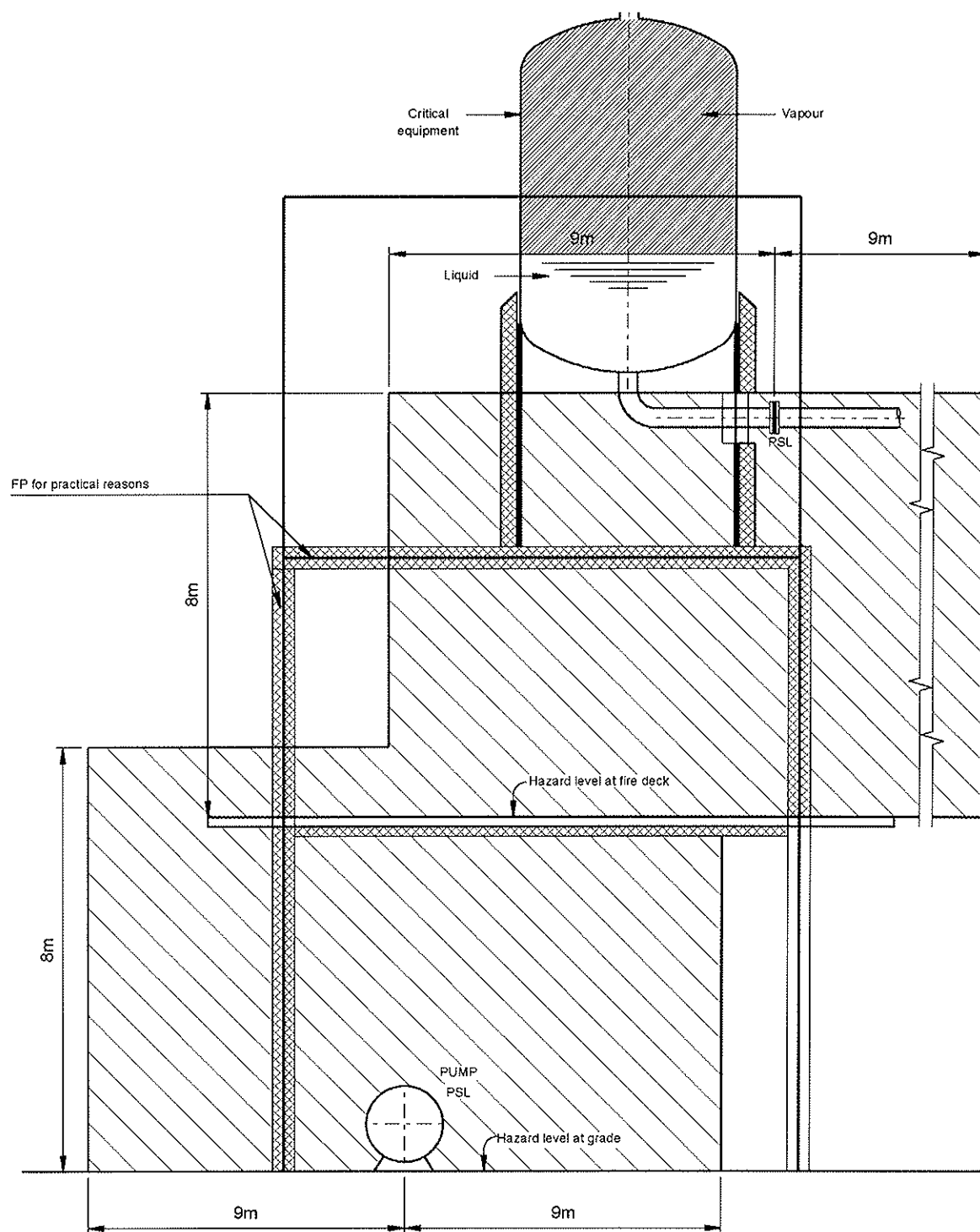
	Stop Ventilators	Close Dampers	Stop Turbine	Compartment Carbon Dioxide Release	Emergency Alarm (Fire)	Inhibit Restart of Turbine
1. <i>Automatic Actions</i>						
a. Gas in <u>common</u> ventilation air and combustion air intake - high (2 of 3 gas detectors)	X	X	X	-	-	X
b. Gas in auxiliary or turbine compartment - high (2 of 3 gas detectors)	-	-	X	-	-	X
c. Fire in compartments (2 or more UV detectors, 2 heat detectors)	X	X	X	X	X	X
2. <i>Manual Actions</i>						
a. Turbine trip						
- Fire and gas detection panel in main control room	-	-	X	-	-	-
- Local CO ₂ panel	-	-	X	-	-	-
b. Compartment Carbon Dioxide Release						
- Fire and gas detection console in main control room	X	X	X	X	X	X
- Local CO ₂ panel	X	X	X	X	X	X

Alarm annunciating function diagram

-- Not applicable C= Common pre-alarm P= Pre-alarm (dedicated) T= Trip alarm E= Emergency (/Fire) alarm

	Local CO ₂ Panel	Panel in Main Control Room	Panel in Field Auxiliary Room	Inside Compartment	Outside Compartment, above doors
a. Gas in common ventilation and combustion air intake:					
Individual gas detector					
- low/high 2 of 3 gas detectors	-	C	-	C	C
- high	T/E	T/E	T/E	E	E
b. Gas in auxiliary or turbine compartment:					
Individual gas detector					
- low/high 2 of 3 gas detectors	C	C	C	C	C
- high	T/E	T/E	T/E	E	E
c. Fire in compartments					
One IR or one heat detector	-	C	-	C	C
2 or more IR detectors or heat detectors	T/E*	T/E	T/E	E	E
d. Manual release of CO ₂	T/E*	T/E	T/E	E	E
e. Power failure on CO ₂ system (incl. Detection)	-	C	P	-	-
f. Low carbon dioxide weight	-	C	P	-	-
g. Pressure switch downstream of automatic release valves operated (CO ₂ discharge)	E	E	E	-	E

APPENDIX 5 FIRE PROOFING ZONES



Notes:

Fireproofing zone



Fireproofing



PSL = Potential source of leakage

**APPENDIX 6 DECISION FLOW CHART FOR FIREPROOFING OF STRUCTURES
SUPPORTING EQUIPMENT**

