



FIRE CONTROL AND RECOVERY

PTS 60.2303

Rev 1

JUNE 2006

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HSE Manual Amendment Record Sheet**PTS Number: 60.2303****PTS Title: Fire Control and Recovery**

Chapter No.	Section No.	Description	Issue No.	Date	Revision No.	Date	Approved by : (initial)
All	All	PTS 60.165 Fire Control and Recovery	1	Nov 04	0	0	IGA

Chapter No.	Section No.	Description	Issue No.	Date	Revision No.	Date	Approved by : (initial)
All	All	Renumbering from PTS 60.165 to PTS 60.2303	1	June 06	1	June 06	IGA

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1. **INTRODUCTION**

1.1 **OBJECTIVES**

This document has been prepared for those involved in the management and implementation of fire and explosion control and recovery measures during the operation of facilities.

The objectives of the document are to:

- provide an overview of fire and explosion theory
- describe measures for fire control and recovery in the operational phase of EP facilities
- explain these measures in the context of HSE Management Systems, and the Hazards and Effects Management Process (HEMP) and Fire and Explosion Strategy (FES)
- describe the important features and organisation of fire and explosion response groups, fire departments, equipment, competencies and training.

1.2 **BACKGROUND**

Most opportunities to remove or minimise hazards exist in the design and engineering phase of a development. Once in the operations phase, sound inspection and maintenance planning together with well thought out emergency response procedures, exercises, training and competent personnel, will ensure that the risks associated with the process, system or facility are reduced to a level As Low As Reasonably Practicable (ALARP).

Typically this can be achieved by:

- removing or reducing hazards
- reducing the probability of hazardous events occurring
- minimising the risk of escalation in the event of the release of a hazard
- providing adequate resources and planning to effectively counter fire and explosion hazardous events
- performance testing procedures and equipment and comparing them with those required.

1.3 **SCOPE**

This document provides guidance on the measures required to manage fire and explosion hazards and respond to hazardous events during the operations phase of a

facility or installation.

The operational aspects from the above documents are in this document, whereas the design aspects are in PTS 60.0107 Design.

Detailed technical engineering standards, design information and specifications have been transferred to the relevant PTS.

PTS 60.2302 describes FIREPRAN which is a team review process for the assessment of fire and explosion control and recovery measures in a plant or facility, comparing these with the physical effect modelling described in PTS 60.2211 and the guidelines in this document.

1.4 OVERVIEW

The document is organised as follows:

Chapter 1	Description
Chapter 2	Fire and explosion control and recovery in the context of HSE MS deals with the hazards and effects management process as it applies to fire- and explosion-related hazards. Fire and explosion strategies, performance standards and other tools and techniques are covered.
Chapter 3	Fire and explosion hazardous events describes the nature of fires and explosions to assist in understanding the relevance of mitigation and recovery measures.
Chapter 4	Control measures for fire and explosion related hazards deals with those operational measures that reduce the likelihood of release events of flammable hydrocarbon and other materials, as well as controlling ignition sources.
Chapter 5	Recovery from fires and explosions provides guidance on establishing fire and explosion scenarios and maintaining the performance of recovery measures.
Chapter 6	Pre-fire planning covers the essential ingredients of effective pre-fire plans.
Chapter 7	OPU in house fire and response groups covers the general role and competence requirements for groups in different operating environments.
Chapter 8	External fire and explosion response groups deals with other organisations that could provide assistance in an emergency.
Chapter 9	Communications deals with chains of command and methods of

communication.

- Chapter 10** **Salvage operations** deals with post-fire incident recovery.
- Chapter 11** **Fire departments and manning** deals with overall manning levels required for fire departments to operate cost-effectively.
- Chapter 12** **Fire vehicle and equipment selection** gives guidance on specifying fire vehicles and associated equipment.

2. **FIRE AND EXPLOSION CONTROL AND RECOVERY IN THE CONTEXT OF HSE MS**

2.1 **HSE MANAGEMENT SYSTEM AND HSE CASE**

The HSE Management System described in PTS 60.0101 aims to ensure that management of the business is continually working towards reducing risks to ALARP levels. It contains the Hazards and Effects Management Process. This is a general approach to the management of hazards and their potential effects which should form part of planning operational activities.

The HSE Case has become the means of demonstrating that hazards associated with a particular operation have been identified, assessed and suitable control measures applied from appraisal right through to abandonment. It should also demonstrate that hazardous events, resulting from loss of containment of a hazard, have been identified and that appropriate mitigation/ recovery preparedness measures are in place. The HSE Case should include sections on both operations and maintenance to document that these activities can be carried out whilst keeping risks in the ALARP region. The relevant risk reduction objectives are normally incorporated in a Fire and Explosion Strategy (FES). This does not have to be separately documented and the relevant information may be included as part of the HSE Case Information on management of hazards and hazardous events in a facility or installation.

2.2 **FIRE AND EXPLOSION STRATEGY (FES)**

2.2.1 **Development of FES**

A Fire and Explosion Strategy (FES) is defined in ISO/CD/13 702 'Control and Mitigation of Fire and Explosion in Offshore Installations' as the results of the process that uses information from the fire and explosion evaluation to determine the measures required to manage these hazardous events and the role of these measures.

An FES will be different for each facility or installation although the framework and some components may be similar.

The starting point for the development of an FES is the OPU HSE MS which sets the policy and strategic objectives of the business. It will also cover organisation, responsibilities, resources, standards, documentation and the management of hazards.

The management of hazards through the HEMP is fully described in PTS 60.0401 and includes the basic steps of identifying and assessing hazards and effects. **Controls** for each threat which may cause the release of a hazard are selected as required together with recovery measures which reduce the consequences should the hazard be released. This information is included in the HSE Case, Hazards and Effects Register.

The FES records the conclusion of the HEMP as it applies to fires and explosions and summarises the key aspects of the following:

- a) the physical effects of representative fire and explosion hazardous events
- b) the **risks** associated with fires and explosions
- c) how the facility has been designed to minimise the consequences of fires and explosions
- d) the measures to prevent fires and explosions arising
- e) the assumptions used in risk assessments regarding the measures provided to control and to recover from fires and explosions
- f) the role of recovery measures and the essential systems and performance criteria of these measures (performance criteria for systems on a complex facility may be described elsewhere and referenced in the FES).

2.2.2 Level of detail in FES

The level of detail in the FES will vary depending on the scale of the installation and the stage in the installation life cycle when the hazard management and risk assessment process is undertaken, For example:

complex facilities

For example, a large production platform incorporating complex facilities, drilling modules and large accommodation modules are likely to require detailed studies to address major hazards and fire and explosion hazardous events.

for simpler facilities

For example, for a wellhead platform or simple onshore plant with limited process facilities, it may be possible to rely on application of recognised codes and standards as a suitable base for hazard management which reflects industry experience for this type of facility.

for facilities which are a repeat of earlier designs

Evaluations undertaken for the original design may be deemed sufficient to determine the measures needed to manage hazards and fire and explosion hazardous events.

for facilities in the early design phases

Evaluations will necessarily be less detailed than those undertaken during later design phases. The FES will be progressively refined as a design for a new installation develops but the conclusions and information will always be recorded in the Hazards and Effects Register for the project.

The FES should be updated whenever there is a significant change to the facility which may affect the management of the fire and explosion hazardous event.

2.2.3 Determination of risk

The risks may be determined in either a quantitative or qualitative manner. For a complex manned offshore structure the assessment of risk will usually be rigorous and quantitative. In other environments risk will be assessed in a more subjective manner.

As with other risks, risk due to fire and explosion can be presented on a Risk Matrix (refer PTS 60.0401) by plotting the probability of events which could result in fire or explosion on one axis against the severity of the expected consequences in terms of people, assets, environment and reputation including cost on the other axis. The tolerability of risk can be displayed on the matrix and here factors such as the strategic criticality of uninterrupted operation of the facility can be reflected.

More often than not it is impractical to determine the total risk by examining the risk presented by every conceivable scenario which might result in a fire or explosion. However in identifying most of the threats and scenarios it will become apparent where the main risk contributors are.

2.2.4 Objectives and system performance criteria

To reduce the risks so that they are ALARP it must be established what, **if any**, measures are required to reduce the probability or consequences arising from a fire or explosion. The FES records how this is to be done and sets out the high level goals for control and recovery measures. Cascading from these are the goals and objectives for the various systems which will be required and the performance criteria for these systems and their sub systems. These performance criteria include reliability and availability requirements. An example of how such a cascade is defined for one particular system can be found in the PTS on Fire Water Systems for use on offshore facilities.

Many of the control measures used on a hydrocarbon plant, to reduce the probability of hazardous events involving fires and explosions are common with those used to prevent unplanned hydrocarbon releases. These include for example corrosion allowances/monitoring, limiting small bore connections, avoidance of screwed fittings, lifting procedures over live equipment and location of risers to avoid impact.

In developing the FES, there are a wide range of issues which should be considered to ensure that the measures selected are capable of performing their function when required to do so. These issues include:

- nature of fires and explosions which may occur
- the environment
- the nature of the fluids to be handled
- the anticipated ambient conditions
- the temperature and pressure of fluids handled
- the quantities of flammable materials to be processed and stored
- the amount, complexity and layout of equipment on the installation
- the location of the installation with respect to external assistance/support
- the production and manning philosophy`

- human factors.

2.2.5 Specification of systems and procedures

The FES should describe the essential systems that have been selected to meet the overall objectives and their role in the management of fires and explosions. These systems comprise both hardware and procedures. They include:

- installation layout
- emergency shut down systems
- control of ignition
- control of spills
- emergency power systems
- fire and gas detection
- active fire protection
- passive fire protection
- explosion mitigation and protection systems
- evacuation, escape and rescue
- inspection testing and maintenance.

In describing the functional requirements and performance criteria of these systems and their elements the following should be considered:

- the essential duties that the system is expected to perform and the parameters within which it must operate
- the integrity, reliability and availability of the system
- the survivability of the system under the emergency conditions which may be present when it is required to operate
- the dependency on other systems which may not be available in an emergency.

Consideration of the above will form the basis of the specification of each of the systems and their elements. To maintain the integrity of the FES throughout the life of the installation, the means to verify the performance criteria of the systems and their elements must be defined. This is equally true of operating procedures and systems such as PTW systems, emergency procedures and Manual of Permitted Operations (MOPO) which must be fully defined such that their effectiveness can be periodically confirmed. In this document the focus is on the operations requirements of the FES.

2.3 STRUCTURED REVIEW TECHNIQUES FOR HAZARD MANAGEMENT

A number of structured review techniques are used to check that fire control and recovery measures are adequate and appropriate. Many of these are first used in the design phase (D) but the integrity and performance of the measures finally adopted has to be maintained and confirmed in the operations phase (O). The most common techniques are listed below:

- FIREPRAN (Fire Prevention and Protection Analysis) (D, O)

- FEA (Fire and Explosion Analysis) (D, O)
- EPR (Explosion Protection Review) (D)
- PEMs (Physical Effects Models and Consequence Models) (D)
- ESSA (Emergency Systems Survivability Analysis) (D, O)
- SIA (Smoke Ingress Analysis) (D)
- TR/EERA (Temporary Refuge/Escapes Evacuation and Rescue Analysis) (D)
- HAZID (Hazard Identification) (D, O)
- HAZOP (Hazard and Operability Study) (D, O)
- PLM (Platform Layout Methodology) (D)

3. **FIRE AND EXPLOSION HAZARDOUS EVENTS**

3.1 **General**

During the design of a facility, fire and explosion control and recovery measures are considered and developed. This is done using fire and explosion scenario planning, physical effects and consequence modelling. The required response measures will be established on a performance basis and recorded in the FES for the facility.

In the operations phase it is important that these control and recovery measures are understood and that the hardware and procedures are maintained and performance-tested. In the operations phase it is important that additional hazards and effects which may be present are identified and managed.

3.2 **FIRES**

3.2.1 **General**

During production and maintenance there are many combinations of causes, that can result in a fire in plants.

Liquid hydrocarbon fires can take many forms depending upon the pressure at the release and the volatility and flash point of the material. A jet fire usually requires a highly volatile or vaporised liquid flammable under pressure. Heavier hydrocarbons can produce running fires and ultimately pool fires where the burning material comes to rest.

3.2.2 **Types of fires**

Plant operations have the potential to generate all the following classes of fire.

- Class A** Ordinary combustible materials, eg rubbers, wood, paper, tapes, diskettes, etc.
Flammable liquids such as hydrocarbons. These exhibit various fire characteristics according to their type and process conditions.
- Class B** Solvents, additives, glycols, alcohols, etc., are also included.
Electrical fires, eg overheating of cable insulation, fire in an
- Class C** energised electrical transformer or switch gear.
- Class D** Fires in combustible metals, eg magnesium, aluminium and titanium.

Flammable hydrocarbon (gas, condensate and oil) fires are by far the most hazardous types that may occur in EP facilities and fall into the following general categories:

Jet fires are turbulent diffusion flames resulting from the combustion of a fuel in a gaseous, vapour or spray form, continuously released under pressure with forward momentum.

Pool fires are turbulent diffusion fires burning above an upward-facing horizontal

pool of vaporising fuel under conditions where the fuel vapour or gas has zero or very low initial momentum.

Running fires are fires caused by ignited fuel flowing under gravity to the lowest point in the area where a pool fire often forms.

Cloud fires are transient fires resulting from the ignition of a cloud or vapour not subject to significant flame acceleration through the effects of confinement, turbulence or due to obstructions.

For hydrocarbon fire types an important consideration is the resulting heat flux levels.

These can be calculated based on the following parameters:

- fire characteristics, i.e. length, shape and orientation of the flame
- flame surface emissive power, i.e. emitted radiation from the flame
- geometry of flame and target, i.e. orientation of the flame surface relative to the target surface.

Calculations are usually carried out using Physical Effects and Consequence Models although these are not usually suitable for running fires. Further information is given in PTS 60.2211 Physical Effects Modelling.

3.2.3 **Thermal energy transfer**

Once a vapour-air mixture has ignited, part of the energy from the combustion process is evolved as heat which is distributed as conducted, convected and radiated components. These components which can cause further failures and fire spread are described below.

Conduction is the transfer of thermal energy along or through conductive materials, e.g. steel girders, deckplating, bulkheads.

Convection is the transfer of thermal energy from one location to another by air movement due to density variations, wind or draught.

Radiation is the transfer of thermal energy in the form of electromagnetic radiation. Its intensity is dependent upon the temperature of the sources emitting the radiation, e.g. flares.

3.2.4 **Escalation**

Once a fire or explosion/fire sequence of hazardous events has started, escalation caused by one or more of the above mechanisms is almost inevitable, unless measures are taken to prevent it. The progressive transfer of thermal energy to adjacent plant and equipment will result in further failures and expansion of the area where combustion is taking place. Two examples are boilover and boiling liquid expanding vapour explosions (BLEVE).

Boilover is an escalation phenomenon where all, or part of the contents of a crude oil storage tank are forced upwards and out of the tank, due to superheated crude caused by oil burning on the surface, coming into contact with the water layer at the bottom of the tank and flashing it to steam. The result is massive escalation of the fire as a large part of the contents of the tank are ejected.

BLEVE (boiling liquid expanded vapour explosions) is an escalation phenomenon that involves vessels containing vaporising liquids. If such a vessel fractures, whilst exposed to a fire, the loss of containment leads to the immediate release of an enormous vapour cloud as the previously compressed liquid flashes to vapour. This may ignite giving a fireball and blast that can have catastrophic consequences.

Both of these can be a serious danger to firefighters as well as threatening recovery systems. Consequence assessment and physical effects modelling should be used to develop an understanding of the term 'safe distance' and ensure fire response measures employ procedures that contain this information.

The primary role of mitigation and recovery fire protection systems is to prevent escalation moving to the next stage. This allows time for control measures such as blowdown and ESD to have their full effect.

Failure to fully assess the escalation potential of a fire/explosion scenario may result in inappropriate fire protection measures and inadequate response resources. Without external intervention a fire in this situation will escalate until burn out is reached. Re-instatement times are likely to be long and expensive. It is therefore necessary to consider the various possible escalation scenarios and the adequacy of the control and recovery measures to meet the objectives set in the FES.

3.2.5 Combustion products

Products of combustion can be divided into four categories; combustion gases, flames, heat and smoke. The effect of these products on human life and property should be carefully considered during the conceptual design.

Combustion gases comprise carbon monoxide, carbon dioxide, sulphur dioxide, ammonia, hydrogen cyanide, nitrogen oxides, halogen acids, isocyanates, acrolein and volatile hydrocarbons in high concentrations. Control measures and consequences are as follows:

- design specifications for flammable and combustible solids (eg cables, soft furnishings, wall panelling) should take the above effects into account and try to use fire retardant or inert materials
- superheated, oxygen-deficient combustion gases may react violently if fresh air is suddenly introduced (eg when entering the fire area)
- fatalities from inhalation of combustion gases and hot air are far more common

than are fire deaths from all other causes combined.

Flame luminosity varies with the efficiency with which the fuel is burning:

- low molecular weight alcohols in the pure state (eg methanol, ethanol and propanol) burn efficiently in air and generate a hot almost invisible (non-luminous) flame
- hydrocarbon fuels usually burn fairly inefficiently in air and generate highly visible, luminous flames and copious quantities of smoke (the one exception is a jet fire that entrains large quantities of air in the hydrocarbon vapour stream)
- flame height for a liquid hydrocarbon is typically 1-2 times the diameter of the pool in still air conditions.

Heat (thermal energy) is the combustion effect most responsible for the spread of a fire:

- for the purpose of fire prevention and protection, radiation, conduction and convection (direct transport of heat through the spread of fire gases) have to be considered
- heat transfer in crude oil storage tanks can result in superheated oil reaching the water layer at the bottom of the tank. This causes it to flash to vapour and much of the tank's contents are ejected violently, greatly escalating the size of the fire. This has to be taken into account when implementing mitigation and recovery measures against this type of fire.

Smoke is produced by burning hydrocarbons and solids in considerable quantities, (particularly under conditions of incomplete combustion). It is also produced in large quantities by burning electrical and electronic equipment;

- smoke consists of finely divided particulate matter and suspended liquid droplets (aerosols)
- smoke can contain toxic by-products of combustion
- smoke creates a serious hazard to personnel due to its physiological effects and reduction of visibility
- smoke control should be considered during engineering design, especially with regard to material selection, enclosed spaces, escape routes, and ventilation.

This information forms the basis of operations fire control and recovery measures dealt within this document.

3.3 EXPLOSIONS

3.3.1 General

Although explosions are combustion events, their potential for escalation is not simply related to their thermal energy output but to physical effects associated with expanding burning gases, generated by the explosion event. Flame speed is also critical and this depends on the density of obstacles in the path of the flame front. Further information on this point is given in PTS 60.2211 Physical Effects Modelling.

When a flammable vapour or gas mixes with air and the concentration exceeds its lower flammable limit (LFL) and is less than its upper flammable limit (UFL), an ignition source will ignite the mixture. Ignition will take the form of a flame front travelling through the mixture causing rapid expansion of the burning gas mixture. The flame front is accelerated by the presence of obstructions which cause the process to become turbulent and burn more efficiently.

If this event takes place in a confined space then the enclosure usually suffers a significant internal overpressure of short duration. Overpressures as low as 0.5 bar in an enclosure can cause moderate structural damage and more severe damage to unprotected equipment and systems. A further source of damage is the rapid turbulent flow of the burnt gas itself, which causes drag effects on equipment of significant surface area.

3.3.2 Types of explosions

Deflagration is a type of confined explosion in which an exothermic reaction propagates from the burning gases to the unreacted material by conduction, convection, and radiation. In this process the combustion zone progresses through the material at a rate that is less than the velocity of sound in the unreacted materials. Maximum pressures of approximately eight times the initial pressure result from deflagration of stoichiometric gas-air mixtures in enclosures. Unconfined vapour clouds can also develop high overpressures.

Detonation is a type of confined explosion involving an exothermic reaction characterised by the presence of a shock wave in the material, which establishes and maintains the reaction. A distinctive difference from a deflagration is that the reaction zone propagates at a rate greater than the velocity of sound in the unreacted material. The principal heating mechanism is one of shock compression. Detonations give rise to very high overpressures but rarely occur in EP operations.

ISO/CD/13 702 (Ref. 1) gives a useful description of fires and explosions in Annexes A1 and A2 which provide useful further reading on these subjects.

4. CONTROL MEASURES FOR FIRE AND EXPLOSION RELATED HAZARDS

4.1 CONTROL MEASURES FOR HYDROCARBON OPERATIONS

4.1.1 Hydrocarbons in EP operations

Hydrocarbons which are gases at normal ambient temperatures and atmospheric pressure are flammable and readily ignited in air. Those which are normally liquids will gradually vaporise when exposed to the atmosphere and under certain conditions the vapour air mixture over the liquid surface will become flammable. The tendency for a liquid to vaporise is known as its volatility. Volatility increases with temperature.

The pressure exerted in a closed container by the vaporisation of a liquid is referred to as the vapour pressure. The flash point is the temperature to which the liquid must be heated to produce sufficient vapour to form a vapour-air mixture that can be ignited by an ignition source.

The upper and lower flammability limits (UFL and LFL) correspond to the minimum and maximum proportions of vapour in air that will ignite. Products with a wide flammability range are potentially more vulnerable to ignition because the probability of ignition is higher.

4.1.2 Hydrocarbon ignition

Ignition is caused by the supply of sufficient heat or energy to initiate combustion. For a given flammable substance there are two temperatures at which the threshold heat supply will be sufficient to cause combustion, ie two ignition temperatures. These two temperatures are termed the spontaneous or auto-ignition temperature (AIT) and the flash point ignition temperature.

Materials such as lagging, rags, sawdust, etc when contaminated with oil may give rise to spontaneous ignition due to a self heating reaction which accelerates due to heat being retained within the material.

In facilities the possibility of product becoming ignited will depend on the existence of an ignitable vapour-air mixture in the presence of an ignition source. Ignitable atmospheres can exist in the following places:

- in the vapour space of fixed roof tanks (especially during pumping down operations)
- at the vents of storage tanks during filling operation
- at the vents during filling of tank trucks, tank cars, drums or other containers
- at the surfaces of sumps and oil/water separators
- at poorly fitting seals of floating roof tanks.

An abnormal situation, such as a leaking valve, fitting or pump, overflow of a storage tank, or any other unplanned release of liquid or gaseous hydrocarbons can also result in the formation of flammable vapour-air mixtures. The likelihood of ignition (assuming an ignition source is present) varies directly as the volatility of the product.

4.1.3 Hydrocarbon combustion process

The combustion of a flammable material (e.g. a hydrocarbon containing carbon and hydrogen) is a chemical oxidation reaction involving the formation of water, carbon dioxide, carbon monoxide (and other toxic gases) and generally resulting in the release of heat, smoke and flame.

For combustion to occur, a threshold heat supply/ignition source, oxygen (or oxidant) and fuel must all be present in the correct proportions. The basis of fire control measures is to prevent a fuel release event. Recovery measures seek to remove one of the other components, or to inhibit the combustion chemical reaction chain.

4.1.4 Reducing the likelihood of fires and explosions

Operations are responsible for safeguarding design technical integrity during the operations phase, over the life of the facility.

Fire and explosion prevention measures start in design and share the same goals as those aimed at preventing plant releases. There are two main methods for reducing the likelihood of a release event of flammable materials during operations as follows:

- maintaining the highest level of inherent safety with simplicity, fault tolerance and operator independence high on the list of design functional requirements
- managing hazards effectively during production and maintenance activities.

To achieve these objectives, which are usually set in the facility FES, operations control measures should have the following goals:

- minimise the likelihood of hazard release events (inventory control)
- minimise the risk of fires and explosions occurring (ignition source control).

These objectives can be met using the following measures:

- elimination or reduction of hazardous inventories
 - inherently safe designs (maintain their integrity)
 - substitution (use safer materials for construction and maintenance)
 - attenuation (operate at lower temperatures and pressures if practicable)
 - simplification (avoid complex operations and maintenance procedures)
 - intensification (group planned maintenance into shutdown periods).
- location of hazardous inventories -separation (avoid compromising the layout philosophy) -segregation (avoid the inadvertent interconnection of utility systems, drains and ventilation) -area classification (avoid compromising hazardous areas) -orientation (site potential ignition sources upwind of hydrocarbon plant).
- containment of hazardous materials

- reduce the number of potential leak sources (avoid introducing specification breaks) -maintain the design integrity (avoid uncontrolled modifications or repairs).
- control of ignition sources (for minor and major releases)
- area classification (avoid the introduction of uncontrolled ignition sources)
- ventilation (keep functional to ensure dilution of any hydrocarbon vapour)
- selection of electrical equipment (ensure electrical equipment is appropriate for the area in which it is installed or used)
- portable ignition sources (e.g. diesels and petrol engines)
- fixed ignition sources (e.g. turbines, furnaces)
- radio frequency ignition sources (e.g. high power radar transmissions).

4.1.5 Safe operating procedures

A fire or explosion cannot be initiated without a release or availability of flammable material coupled with an ignition source. Fire and explosion prevention measures in operations are mostly aimed at reducing as far as practicable the likelihood that sufficient concentrations of flammable or combustible materials reach an available ignition source.

This principle should be inherent in all procedures developed to cover during production operations, maintenance, repair and construction work. Plant operation procedures should also seek to maintain the integrity of those prevention measures incorporated in design. Procedural measures alone, which are subject to human factors uncertainties, should not be relied upon, in isolation, to effectively prevent hazardous events.

Typical procedures are as follows:

- permit to work
- gas free certification
- hazardous area requirements
- confined space work
- ignition source control (electrical equipment permitted on site and its location)
- access control (both personnel and vehicles).

This can sometimes be achieved to a point where recovery measures to reduce their consequences may no longer be justified. A final decision on this would be based on which risks are considered critical and the tolerability of potential consequences.

Each case has to be considered on its merits and once personnel and environmental risks have been dealt with, the criticality of the asset and consequences of lost production may well demand further protection measures, to minimise consequences which are not tolerable.

In summary the priorities are as follows:

- remove operational hazards as far as practicable from where personnel need to work, thereby reducing exposure
- reduce the likelihood/probability of ignited hazardous events occurring during operations and maintenance by efficient procedural controls of flammables and ignition sources.

4.1.6 Maintenance activities

Maintenance activities have an important role to play as preventive measures in their own right (planned maintenance before failure) as well as ensuring other preventive measures remain fully functional during operations. Activities include:

- identification of plant and equipment where failures could have significant consequences in the form of fire and/or explosions and implementation of a planned maintenance strategy as a preventive measure
- maintenance of plant equipment and instrumentation to a high standard so that incipient plant upsets are detected and the necessary automatic or manual shutdown measures implemented
- maintenance and regular testing of ESD and EDP valves and systems, as they may be employed if a process upset looks like developing into an unplanned release
- maintenance of electrical equipment, especially that designed for use in hazardous areas
- maintenance requirements linked to consequence assessment studies and the findings of previous incidents.

Operational procedures should be directed at:

- reduction of hazards in production and maintenance tasks using safe operating procedures
- introduction of generally safer working methods

- strict understanding and use of permit to work (PTW) procedures and access control where appropriate.

As far as reasonably practicable, under specified operating conditions, there should be no unaddressed foreseeable risk of failure that could result in a loss of technical integrity, release of hydrocarbons and a potential fire and/or explosion. PTS 60.0109 Production and Maintenance can be referred to for further details.

4.1.7 Operations reference plan

The maintenance requirements needed to combat fire and explosion control and recovery equipment failure form a module of an Operations Reference Plan. Within this plan is contained the activities matrix for maintaining fire control (eg inventory control and ignition sources) and recovery (eg detection, alarm, evacuation and protection systems) measures.

4.1.8 Reducing potential hydrocarbon leak sources

Preventing loss of containment is a major factor in maintaining plant technical integrity. This is addressed in the PTS 60.2202 Mechanical Integrity.

Some factors which may cause loss of containment are:

- exceeding the design envelope
- over pressure
- corrosion/erosion
- mechanical damage
- incorrect operation
- material failure
- design error
- construction defects.

Threats that can compromise plant integrity during the operating life of the facility are influenced by:

- the number of specification breaks
- process facility complexity
- the number of flanges and small bore connections, etc

- the number of local atmospheric vent points, etc
- failure to consider dynamic, in addition to, steady state loads
- failure to protect against dropped objects
- the need to consider maintenance and inspection requirements during the design phase
- the need to recognise the potential for human error if the design requires constant operator intervention
- the need to carry out adequate operator training.

Measures can be taken to minimise the size and duration of a release, in the event of a loss of containment. These measures should be addressed in fire and explosion prevention and protection reviews, HAZOPs and other structured review techniques. Structured review techniques are listed in PTS 60.2204 Process Hazards Analysis.

4.2 CONTROL MEASURES FOR OTHER FLAMMABLE MATERIALS

4.2.1 Combustible solids

Non-hydrocarbon combustible solid hazards are generally associated with cellulosic and polymeric materials used in the construction and operation of installations. These can often be present in facilities, especially living quarters, offices and stores. The following measures can reduce the likelihood of a significant fire:

- removal
- replacement with non-combustible materials
- quantity reduction
- sub-division
- surface area reduction
- redistribution and relocation.

The characteristics to be reviewed when assessing the fire performance of cellulosic or polymeric type materials include:

- ease of ignition
- rate of flame spread
- heat of combustion
- smoke and toxic gas production.

PTS and industry standards should be used to assist in reducing the use of flammable materials, particularly electrical cables. Electrical installations, living quarters, computer installations, etc can all have the likelihood of a significant fire and smoke generation reduced by careful choice of materials.

Replacement equipment and components for maintenance and repair work are often delivered in cellulosic or plastic packing materials. These materials should be controlled and not allowed to accumulate in any location.

4.2.2 Combustible liquids

These are present in facilities in a variety of forms. Primary sources are the hydrocarbons being processed but chemicals, lubricating oils, heating oils, diesel, gasoline, paint and other sources have to be considered.

Where releases of flammable/combustible liquids could occur, adequate drainage arrangements should be in place.

Storage and bunding of flammable hydrocarbon liquids should be in accordance with PTS 34.11.00.11 (Ref.2) and PTS 34.18.51.10. (Ref. 3) to minimise the likelihood of escape and ignition.

4.2.3 Flammable gases

These will be present in non process applications such as fuel and cutting gas, eg acetylene supplies. They can be generated from pressurised flammable liquids, eg LPG cylinders. They need to be stored in well ventilated cages with controlled personnel access.

4.3 IGNITION SOURCE CONTROL

4.3.1 Identification and assessment

Designing out ignition sources completely is not practicable, but many can be eliminated and often substituted with lower energy equipment that will do the same job. The use of certified equipment and electric heaters instead of fired heaters is one example.

Typical sources of ignition include, but are not limited to:

- open flames non intrinsically safe lighting
- hot surfaces
- radiant heat
- smoking
- cutting and welding (hot work)
- spontaneous ignition
- frictional heat or sparks
- static electricity/lightning
- electrical sparks/stray currents
- internal combustion engines
- furnaces and heating equipment
- compressors or other equipment temporarily on site.

Operations measure should ensure that equipment that has the potential to act as an

ignition source is not introduced into areas where hydrocarbon vapours could be present. Two different scenarios are likely to be encountered as follows:

- major releases
- minor releases.

A case by case assessment should be made for facilities to identify which non essential energy sources exist and in the event of a gas release these should be de-energised by remote isolation, eg electrical tripping as part of a partial or total emergency shutdown. One example of this would be the utility power points for hand tools.

Essential electrical systems required to operate in an emergency outside a temporary refuge or an emergency control point should be suitable for use in Zone 1 hazardous areas and have proven water resistance if exposed to water deluge systems. Pump driven foam systems, electrical actuators and emergency lighting should remain energised.

4.3.2 Area classification and environmental control

The aim of hazardous area classification is to avoid the ignition of those releases which inevitably occur from time to time in the operation of facilities handling flammable liquids and vapours.

Classification of hazardous areas affects the type of electrical equipment permitted and hence can reduce sources of ignition. At the design stage, measures usually aim at achieving the least hazardous classification. Operations activities should ensure that these measures are not compromised by introducing materials that could give off a flammable vapour. Consideration should also be given to hydrocarbon releases from non-routine operational activities and from major releases.

The PTS on hazardous area classification is based on IP Code part 15, the Institute of Petroleum Area Classification Code for Petroleum Installations, Model Code of safe Practice Part 15 (Ref. 4).

Build up of flammable vapours beyond their lower flammability limit can be prevented by efficient ventilation of an enclosure. This progressively dilutes any leaks or fugitive vapours present rendering, the flammable gas/air mixture incapable of combustion.

Similar measures can reduce the concentration of combustion products in a particular area. On offshore platforms open modules aid dispersion with natural ventilation wherever practicable.

Areas which are normally manned (eg living quarters) are usually pressurised to exclude smoke, toxic fumes and flammable gas. The inlet ducting for the HVAC systems to these areas are usually fitted with gas detectors to automatically alarm, shutdown pressurisation fans and close inlet and outlet dampers. HVAC shutdown upon fire detection will result in the overpressure being lost.

Maintenance and inspection schedules should ensure that detection and isolation

measures are operating according to the required performance standard. Checks should include automatic or remotely operated vents in the roof of a building, automatically closing fire/smoke doors and air conditioning dampers within buildings and modules.

4.3.3 Segregation

Segregation of ignition sources from flammables should be optimised during operations within the limits of the design. All options available to reduce the likelihood of ignition should be employed during operations and maintenance by the implementation of such means as permit to work systems and safe operating procedures. Each area of the plant should be designated with a clear management authority having jurisdiction over electrical and hot work activities.

4.3.4 Access control

Access to any area of a facility where hydrocarbon vapours could be present should be controlled by a central permit to work system.

Where vehicles regularly traverse plant facilities, their potential as ignition sources should be assessed. Petrol engines and catalytic converters provide sparks and hot surfaces with sufficient energy to ignite hydrocarbon vapours. Access control measures coupled with vehicle specification (e.g. diesel engines) reduce the likelihood of a vapour accumulation being ignited.

Access control for personnel should ensure that items capable of igniting flammable vapours are not permitted in production areas of plant facilities. These items include matches, lighters, radios, cameras, etc.

5. RECOVERY FROM FIRES AND EXPLOSIONS

5.1 GENERAL

There are a range of operational measures that prevent escalation and assist recovery from fires and explosions. Usually, early detection of an incident and an effective response, depends on early fire or gas detection followed up by executive action. These may include the automatic or manual actuation of evacuation alarms, initiation of shut down procedures and selective power isolation, actuation of fixed fire protection systems and mobilisation of emergency response pre-plans. The latter may involve in-house and/or other fire services.

5.2 OPERATIONS RECOVERY MEASURES

5.2.1 **Fire and gas detection**

Assuming an appropriate design philosophy has been developed, the reliability and availability of fire and gas detection systems (based on FES performance criteria which reflect their contribution to risk reduction) is largely dependent on servicing and maintenance. Control room (operations) emergency procedures should be integrated with site fire and explosion response pre-plans and have a clear response strategy when gas or fire is detected. These should include alarm and emergency shutdown protocols as well as ignition source isolation.

Fire and gas systems are maintenance critical safety systems and require:

- maintenance of gas detection systems to a high standard so they detect gas accumulations well before they reach a potentially hazardous level, and on detection initiate inventory isolation, blow down of residual pressures and isolate all non-essential ignition sources
- maintenance of fire and smoke detection systems (especially high sensitivity smoke detection) to a high standard so they detect actual or incipient fires rapidly and initiate alarms, executive actions and automatic fixed systems.

5.2.2 **Emergency shutdown/emergency depressurisation ESD/EDP**

The severity of consequences, in the case of an ignited release, can be reduced by controlling the amount of inventory available for combustion. This is achieved by and emergency depressurisation (EDP) of the plant involved in the fire as well as vessels or pipe work upon which flames or thermal energy may impinge. In most cases the vented gas is routed to a flare where it can burn in a controlled manner.

Emergency shutdown (ESD) systems limit the hydrocarbon inventory available to a release event. They can be both manual (local control point in plant) and automatic (fire and gas detection system). Circumstances, in which a control room initiated emergency shutdown may be required, should be evaluated and training, based on preplanned responses, given.

Shutdown and blowdown are primary means of preventing a minor incident from resulting in a major loss, by shutting off the flow of fuel to a fire and removing flammable material from the equipment in the vicinity of the fire. EDP should generally be provided for pressurised gaseous inventories with the gas going to flare. Where ESD or EDP valves are located such that they may be involved in fire or explosion events, they should be suitably protected, regularly inspected, tested and maintained.

Pressure vessels (and other pressurised equipment) are normally fitted with relief valves which open at a pre-set pressure to ensure that internal pressure does not exceed the maximum allowable working pressure. They may not prevent pressure vessel failure under fire conditions due to loss of vessel material strength with increasing temperature.

The venting constraints of relief valve design should also be taken into account when assessing the level of protection given to pressure vessels exposed to potential fire scenarios. For gas filled vessels, relief valves to atmosphere have little value from the point of view of fire protection. Pressure relief devices should be regularly maintained and tested at predetermined intervals (usually set by regulatory authority) to see they achieve their design parameters.

Emergency shutdown valves and blowdown valves, which normally fail shut and open respectively, need regular inspection and testing to ensure they function during an incident. Checks are needed to see that EDP valves failing open will not overload the flare system.

- maintenance and testing of passively fire protected well, facility and pipeline shutdown valves
- regular maintenance and testing of the isolation and shut-off for the fuel source.

Flare headers and other essential emergency equipment should be protected if they are vulnerable to early failure in a fire or explosion situation. An ESSA study may be needed here.

All operations activities are influenced by the designs they involve. Operations

feedback to engineering should encourage designs which do not generate complicated or highly conditional operational and maintenance procedures.

5.2.3 Power supplies and isolation

Power generation and distribution should be suitable for the loads expected during emergencies as well as for normal production. Power supplies essential for response to emergencies should be protected against fire and explosion events. These measures should include firewater supply, fire and gas detection and protection systems, instrumentation, alarms, controls, emergency lighting, ESD systems, essential HVAC and necessary communications, drilling emergency systems, an air compressor and diesel transfer pump where required.

Non-essential power, which may act as a source of ignition should be isolated on gas detection. It is important that during operations and maintenance activities portable or uncontrolled power sources are not introduced into areas where hydrocarbon vapours could be present. It is recognised that "essential" power sources still have the potential to be ignition sources.

Electrical equipment utility points should not be energised in areas where firefighters are required to enter with water based extinguishing means and isolation is required before firefighting operations commence.

5.2.4 Pump-out of product

Where hydrocarbon storage tanks are threatened by fire it may be prudent to pump the inventory to a safer location and reduce the fuel available to the fire. There are several points to be considered:

- removal of liquid hydrocarbon (eg crude oil) from a storage tank reduces its ability to act as a heat sink for thermal energy
- if the fire has been burning for some time, pump-out may cause a vortex bringing superheated surface hydrocarbon from the fire zone into contact with the water layer in the bottom of the tank creating a boilover condition.

5.3 EXPLOSION MITIGATION

5.3.1 Layout

Benefits of an effective layout philosophy is the protection of utilities such as fire pumps from hydrocarbon fires and reduction of potential explosion overpressures and damage scenarios. Effective layout philosophies can mitigate explosions by using the following measures:

- reducing congestion
- locating obstacles away from vents

- orientation of obstacles to provide a low drag profile to the explosion venting flow.

Venting can employ:

- open module designs
- grated floors
- weakly attached weather cladding
- explosion relief panels and hatches.

The measures should not be compromised during operations, construction and maintenance activities.

5.3.2 Structural resistance to fire and/or explosion loads

Fire/blast walls can provide protection from escalation by confining a fire or explosion to one particular area. Regular inspection of fire and explosion wall integrity is needed to ensure they function as designed when required. Where access through the barrier is required and unavoidable, the aperture should be filled with a door or hatch of at least the same performance as the rest of the barrier. These points of access should be self closing to prevent escalation of fire or transmission of explosion overpressures to other parts of the plant. Cable and pipe apertures should be sealed to a similar standard.

5.4 ESCAPE, EVACUATION AND REFUGE

5.4.1 Alarm systems and communications

For protection of personnel it is essential that manual and automatic alarm systems are simple and easy to understand. They should be fully functional and well maintained. The cause and effects diagram for the facility should be up to date and show clearly which incidents are likely to trigger which alarms, along with permissible overrides. Where some form of executive action is needed, alarms should be easy to interpret and be acted upon.

Effective communications are essential for safe operations and critical to control and recovery from a fire or explosion incident. Public address systems form an important part of the communications chain and should be regularly maintained and tested, as a key recovery measure.

Where alarm and PA systems may be exposed to fire and/or explosion events they should be suitably protected and the protection measures regularly inspected and maintained along with the system itself.

5.4.2 Escape and evacuation

As a general principle escape routes should be the same routes that personnel would use during normal access to an area. This approach helps to ensure that personnel are familiar with escape routes which should be identified with signs, marking, emergency escape lighting, and where necessary by way-finding lights if visibility could be a problem. Some escape routes may need heat shielding or protection from smoke to remain viable in certain emergencies.

Escape routes should never be compromised. Maintenance activities often require replacement components to be brought on site ready for installation in the plant. Operations should ensure that packing and spare parts are not allowed to block escape and evacuation routes during this process.

Where major work is anticipated and an escape route will be temporarily unavailable, alternative escape routes should be indicated and suitably marked.

The objectives for escape and evacuation routes in onshore and offshore facilities should not be compromised by production operations as follows:

- to enable all personnel to leave an area where they are directly affected by an incident, such that risks to them are maintained, as low as reasonably practicable
- to enable all personnel to get from a part of the installation they are likely to occupy to a Temporary Refuge (TR)
- to enable all personnel to transfer from a TR to an embarkation area, in order to successfully evacuate using the selected method, within the TR endurance time
- to ensure that all escape routes from areas likely to be occupied, including TR(s), are capable of handling the maximum flow of personnel required for subsequent successful evacuation
- to ensure that the escape routes available from all areas of the installation are readily identifiable by all personnel in any emergency.

Regular escape and evacuation drills should be conducted to ensure that all personnel are familiar with the location of escape routes and safe refuges. Exercises should be independently observed and any congestion which delays escape noted and arrangements made to correct the situation. The average time needed to clear areas which contain hazards to personnel should be used to determine the period during which recovery measures need to keep escape and evacuation routes viable.

Evacuation requirements will be different in onshore facilities from offshore installations. Onshore personnel may be able to walk clear of the facility using the escape routes. Offshore the primary means of evacuation will generally be the normal mode of transport to and from the installation. This is usually by helicopter but bridge links can sometimes be a primary route for evacuation. Similar to escape routes, evacuation routes may need to be protected from smoke, heat and structural damage.

In certain cases a secondary means of evacuation may be needed and offshore this is usually a form of Totally Enclosed Motor Propelled Survival Craft (TEMPSC). Maintenance of these craft should form part of the overall fire and explosion, recovery measures, maintenance programme.

5.4.3 Mustering

Normal muster areas should be provided for all personnel at facilities or installations. Muster areas should be located to facilitate subsequent evacuation and the normally used areas should be close to a TR. In some onshore facilities the muster area may serve as a refuge if suitably located.

Mustering allows people manning a facility to be accounted for and better control of evacuation from the area of a potential incident. Muster areas must be adequate in size and facilities, to accommodate the numbers personnel who will need to use them.

5.4.4 Temporary refuges (TR)

The concept of a TR is mainly relevant to offshore facilities but can be considered for onshore plant. It may not always be a sophisticated enclosure but could be an onsite muster area or a protected stairwell to which access is available for most potential fire and explosion scenarios. All facilities or installations should have one or more areas dedicated to this purpose. The siting of these areas should be determined using the fire and explosion scenario, physical effects and consequences modelling data as detailed in PTS 60.2211.

A TR affords protection to personnel who need to seek shelter for a period derived from potential fire scenario studies. Personnel may need to stay there whilst they review the options for controlling an incident and organise an evacuation. To meet its design objectives its air supply, fire and gas detection, smoke dampers and communication systems need to be regularly tested and maintained.

TRs are normally protected by location and use of passive fire protection cladding which should be maintained to a high standard. They may not necessarily be an enclosure as such and further information is given in ISO CD 13 702 (Ref. 1) section 14.3.3. and PTS 37.17.10.11 (Ref. 5).

5.4.5 Crowd control

Where an incident occurs in a facility close to a populated area, the danger of a crowd gathering, possibly where emergency services need access, needs to be addressed. Crowd control measures should aim to keep people at a safe distance from the incident and out of the path of essential services.

5.5 ACTIVE FIRE PROTECTION

5.5.1 General

Active fire protection is not always essential as part of the recovery measures from hydrocarbon and other fires. It should normally be considered when the risk reducing contributions of other threat control, escalation control and recovery measures have been fully explored. If these are considered inadequate in reducing risk to ALARP levels or potential consequences are still not considered tolerable then active fire protection may have an important role to play in achieving the objectives of the facility or installation FES.

5.5.2 Fire pumps and firewater

Firewater availability is critical for effective escalation control and recovery measures following fires or explosions. Regular testing of fire pumps, fire main pressures/flows and deluge or other water or foam systems is essential if these systems are to be available when required.

Maintenance schedules should aim at keeping the firewater availability at the level set by FES performance criteria. Actions required in case the firewater supply or fire pump availability is significantly impaired should be described in the Manual of Permitted Operations (MOPO) for the facility. This will detail any resultant restriction on operations activities where this is appropriate and may cover other control and recovery systems. Firepump availability may be covered by legislation.

5.5.3 Fire control and extinguishment (active fixed systems)

Active fire protection systems may be actuated manually or automatically upon detection of a fire. Normally automatic operation is required to provide rapid response to a fire.

Active fire protection systems are quiescent for most of their operational lives but are required to work first time when actuated. These systems need regular maintenance and testing to ensure their availability. Service and maintenance schedules or the permit-to-work system should ensure that systems cannot be left in a locked off state after work has been carried out on them.

Active fire protection can be used to prevent escalation and assist recovery from fires. The mechanisms available are as follows:

- cooling (deluge systems on jet fires are effective outside fire impact zone)
- control of burning (deluge systems on hydrocarbon running or pool fires)
- extinguishment (film forming foam on pool fires)
- inerting (fixed roof tank vapour spaces)

- total flooding (use of inert gases or halon alternatives in discrete enclosures)
- local application (first shot foam systems on floating roof tanks).

When a major protection system is taken out of service, for maintenance or remedial work, the impact on risks in the affected area should be assessed to see if adequate resources still exist to respond to a fire and/or explosion incident. The Manual of Permitted Operations should detail any resultant restriction on activities if required.

General information on active fire protection systems is given in Appendix I.

5.5.4 Fire control and extinguishment (mobile systems and fire vehicles)

Mobile fire protection equipment may be deployed to back up fixed systems or in some cases provide a primary response to fires.

Mobile systems such as foam generators should be stationed, serviced and ready for use in areas of low risk. They should be easy to reach and put into service during an incident and should not have to cross high risk plant areas. Operators should be trained in their deployment and use.

Fire vehicle and equipment requirements are dealt with in Chapter 12 and Appendix X of this document.

5.5.5 Combustion product control and containment

Should a fire incident occur measures should be in place to prevent the control room, escape routes and any safe refuges from being engulfed in smoke and other combustion production.

Consumable storage areas should have clearly marked escape and evacuation routes and ventilation measures to vent smoke combustion products. This permits the escape routes to be viable for as long as possible.

5.6 PASSIVE FIRE PROTECTION

5.6.1 Coatings

Passive fire protection coatings, of one sort or another, that delay the transfer of thermal energy from a fire to other adjacent areas, have the advantage that they are always available. They do, however, need regular maintenance to check their integrity and adhesion to the plant or equipment they are protecting.

5.6.2 Barriers

Passive fire protection system barriers have the advantage that they are always available. They may form part of a composite fire/blast wall barrier designed to resist certain explosion overpressures. In common with coatings they need regular inspection to check their integrity has not been compromised. Whenever apertures are made in fire or blast walls (eg cable or pipe penetrations or access doors) they

should be maintained at equal or greater fire resistance than the wall itself. Passive fire protection systems are dealt with in more detail, with references, in Appendix I of this document.

5.7 EMERGENCY RESPONSE

5.7.1 Plans and procedures

Emergency response plans and procedures are an important part of the recovery from fires and explosions. They incorporate the pre-planning necessary to efficiently employ recovery measures such as an in-house fire service. Pre-fire planning is dealt with in detail in Chapter 6 and Appendix III of this document. The guiding principles of effective emergency management as they apply to fires and explosions are to:

- create an awareness of the emergency situations that come about as consequences of ignited releases, examine how they could arise from operations and how best to recover from them
- develop an organisation, based on the internal line organisation, of teams and individuals with clearly defined responsibilities
- provide the resources required to fulfil these responsibilities, especially for firefighting, and support all other aspects of emergency response
- develop and define procedures that will deliver an effective and appropriate level of response to fire and explosion events and other aspects of ignited releases
- conduct training, practice and review activities.

Control room executive actions, for example, should have a clear strategy behind them, so operators have a pre-planned shutdown procedure which minimises risks to personnel and prevents escalation of a fire to adjacent plant. These actions should be integrated with the response by an in-house or external fire service. They will need to be familiar with the following:

- ESD and EDP duration
- likely duration of a release
- operational controls such as pump out of storage tanks during a fire
- the type of fire that may need to be tackled such as seal fire on a floating roof tank, vent fire on a fixed roof tank, full surface tank fire or major fires near storage vessels with the potential for BLEVE.

Planning and emergency response group organisation and responsibilities are dealt with in more detail in both Chapter 6 Pre-fire planning, Chapter 7 OPU fire and explosion response groups and Chapter 10 Salvage.

Further details on the development of emergency response groups, plans and procedures can be found in PTS 60.2306 Emergency Management Plan.

5.7.2 Training and drills

Training and drills ensure that personnel understand their responsibilities in a fire situation. This is dealt with in 6.3 of this document and Appendix III.

5.7.3 Salvage

Salvage is a specialised activity and should normally be planned with the assistance of companies specialising in this field. Some basic information on salvage and reinstatement measures are dealt with in Chapter 11 of this document.

6. **PRE-FIRE PLANNING**

6.1 **GENERAL**

Pre-fire planning is essential for all OPU's and should be integrated with measures in PTS 60.2306 Emergency Management Plan.

Pre-fire planning may be described as the advance preparation of documentation and practical rehearsals based on potential credible fire scenarios, which can assist fire department and line management personnel to respond to and control fire events within company facilities.

Pre-fire planning sets plant control (e.g. pump out), safeguarding and firefighting, objectives and strategies, so that in the case of a potential incident critical time is saved, should hazardous events come about. It also identifies particular fire and explosion scenario resource requirements and hazards which may be encountered during an incident. The appropriate actions to be employed when applying mitigation and recovery measures are then developed. The measures should meet the requirements of the operations section of the FES.

Pre-fire planning is an essential function for all fire response groups if they are to be effective. Properly prepared and studied, they can greatly assist company personnel in controlling the incident and achieving fire damage mitigation objectives.

6.2 **PLANNING CONSIDERATIONS**

Pre-fire plans need to be scenario specific. They should not be overly detailed or inflexible since it is not possible to predict with accuracy the precise events or impact which may occur from any given scenario.

The written scenario for a pre-fire plan should be credible and realistic, with emphasis on what fire response groups and operations personnel may encounter on arrival at the incident. This approach provides a clear picture for participants during exercises and drills and allows evaluation by observers to be more precise. It also permits the plan to be included in the FES as part of the operational HSE Case for the facility or installation.

When preparing pre-plans it should be remembered that the objective is not to produce individual documents of considerable detail and volume. For any pre-plan to work effectively it should:

- be realistic and credible
- be informative
- provide guidance
- be easy to read

- be easy to understand
- have a viable control and extinguishing plan.
- be as brief as possible.

In establishing pre-plans it is necessary to prepare a list of company facilities, then list the processes, plants, operation, structures, equipment and personnel within the facilities. From this list the numbers and types of potential (moderate, serious and major fire) incident scenarios should be further listed. It is anticipated that minor or incipient fires would be dealt with by company personnel in the vicinity and therefore such incidents should not be used for pre-plans.

The scenarios generated from a FIREPRAN study of a facility can form a starting point for pre-plan development. This plan should also address issues of escalation, operational actions and their third party impact.

After confirming the credibility of the draft fire scenarios with line management supervisors actions to prepare for the event can be developed in the line with emphasis on impact upon operations, facility, plant and equipment, to ensure accuracy of planning.

A final list of scenarios should then be converted into fully prepared pre-fire plans with further investigative work on impact on environment and the public.

Establishing a pre-fire plan for every single potential fire incident in all company facilities serves little useful purpose since it would take many years to exercise the response to these incidents. Operators preplans should be prepared as well as those for firefighters and co-ordinated on a scenario basis. Details of the components needed to prepare a pre-fire plan are contained in Appendix III.

6.3 REHEARSALS/TRAINING

Once pre-fire plans have been prepared they should be exercised to ensure involved personnel are familiar with them, that they are applicable to the scenarios, that the strategies and tactics are correct and that their objectives can be realised in practice.

For exercises or drills, a small team of observers should be used to evaluate the operation and highlight problem areas. Post exercise discussions should be held to identify and rectify errors, faults and misunderstandings which may have occurred during the exercise. This should ensure continuous improvement and effective fire and explosion response group performance.

Aspects of the exercise which should be observed in detail include the following:

- speed of response (equipment and manpower)
- site evacuation and mustering

- communications (radio/telephone/personnel - clarity and frequency)
- access to incident and vehicle/equipment positioning
- initial and subsequent actions of fire response group leader
- equipment availability and operability
- fixed systems condition and operability
- fire response personnel overall ability (knowledge/actions/tasks and communications)
- physical fitness of fire response personnel.

During exercises or drills, fixed systems, water supplies, fire vehicles and equipment should actually be used to ensure operability. However, it is advisable to ensure that process operations are not unduly affected by the use of fixed systems and to prevent clean up problems, water instead of foam may be used through fixed systems.

Since fire simulation is always difficult during exercises, the affected or involved area should be clearly identified to prevent misunderstandings and provide observers with proper evaluation. In an actual incident, for example, radiant heat levels may reduce access to the incident area.

The frequency of exercises depends on the facility and manning but they should normally be conducted so that shift personnel on site participate in sufficient exercises to develop and maintain their competency in all major scenarios. Typically this should be once during a tour of duty. Consideration should be given to infrequent unrehearsed exercises some of which can be held during shift changeovers, late evening and night shift to ensure alertness and readiness.

Full training records should be maintained for each pre-fire plan exercise with comments on performance and improvement recommendations.

6.4 UPDATING

Once all pre-fire plans are prepared, the list and contents should be reviewed and updated in line with operational changes such as expansion, revamping and upgrading projects.

The responsibility for updating plans should be clearly defined within fire response groups. Out-of-date plans should be destroyed to prevent confusion and operational errors.

Revised or additional pre-fire plans should be further exercised to ensure they work in practice.

7. OPU IN-HOUSE FIRE AND EXPLOSION RESPONSE GROUPS

7.1 COMPETENCE

Competence is the ability in terms of skill, knowledge and awareness to perform activities within an occupation or function to specified standards. It implies that a person possesses the essential skills, knowledge, awareness and attitudes and can apply them in a particular working environment. It represents the threshold of performance which personnel must cross before being allowed to perform the work involved, unsupervised.

Whilst competence standards need to be established for all operations personnel, those for fire response group personnel are critical for effective implementation of fire and explosion response measures. Precise and detailed individual standards of competence should be prepared for all the positions within the response groups, according to individual needs, and should include any specialist requirements that may be needed in order to meet the group responsibilities. Many of the roles will be HSE-critical and all the roles HSE-related. Further information can be found in PTS 60.0304 HSE Competence Assurance.

Details of the responsibilities and competence standards required for OPU in-house fire and explosion response group personnel are given in Appendix V.

7.2 ROLES

Firefighting groups form the back up to active fixed fire systems or in the case of residential facility fires form the core of active response and are an integral part of fire and explosion emergency response measures. Operational control and recovery measures are integrated within the overall strategy and included in the facility FES. Manual firefighting may be defined as the tasks or actions performed by trained personnel to control and extinguish fires and related incidents

Such actions normally include the use of:

- on-site portable fire equipment
- on-site fixed fire systems
- on-site semi-fixed fire systems
- mobile fire vehicles and equipment
- breathing apparatus and rescue equipment.

Personnel in any working location should, on discovering a fire, raise the alarm and if safe to do so, tackle the fire. This applies particularly to incipient fires where the risk to personnel is comparatively small. Training should be provided to all personnel on how to use 'first aid' firefighting equipment. Specific firefighting responses should be aimed at fires where escalation is likely to occur, bringing with it subsequent additional risks.

Individual fire scenarios should be developed for facilities to determine the type and size of firefighting response required and availability of personnel on site. The selection of the most appropriate group and numbers of people should be made based on the guidelines within this document.

The level of firefighting response possible can vary from trained operations personnel working as a fire team which can tackle minor or moderate sized fires, to a full time fire department capable of tackling serious or major incidents. These can be assisted by an auxiliary fire brigade and/or external fire brigade assistance. For convenience, firefighting response groups can be given the following classifications:

Usually manned by in-house groups or fire teams:

- offshore fire teams
- helideck fire crews
- marine fire units
- onshore fire teams.

Usually manned by fire service personnel:

- fire departments
- airfield fire units
- auxiliary fire brigades.

Details of the composition and classification of the above fire response groups are given in Appendix IV. Responsibilities of these groups are included in Appendix V.