



Document No.	GP 24-21
Applicability	Group
Date	26 March 2009

GP 24-21

Fire Hazard Analysis

Group Practice

**BP GROUP
ENGINEERING TECHNICAL PRACTICES**

Foreword

This revision of GP 24-21 has been made consistent with GP 24-20 (Fire and Explosion Hazard Management) and reorganized to align with the flowchart and place technical methods in the annex. Because the reorganisation of this GP was so extensive, revisions have not been identified by bars in the margin as in normal practice.

Copyright © 2009 BP International Ltd. All rights reserved.

This document and any data or information generated from its use are classified, as a minimum, BP Internal. Distribution is intended for BP authorized recipients only. The information contained in this document is subject to the terms and conditions of the agreement or contract under which this document was supplied to the recipient's organization. None of the information contained in this document shall be disclosed outside the recipient's own organization, unless the terms of such agreement or contract expressly allow, or unless disclosure is required by law.

In the event of a conflict between this document and a relevant law or regulation, the relevant law or regulation shall be followed. If the document creates a higher obligation, it shall be followed as long as this also achieves full compliance with the law or regulation.



Table of Contents

	Page
Foreword	2
1. Scope	6
2. Normative references.....	6
3. Terms and definitions.....	6
4. Symbols and abbreviations.....	8
5. Fire hazard types, sources, and characteristics	9
6. FHA process.....	9
7. Identify the fire hazard sources	13
7.1. General.....	13
7.2. Define control measure performance	13
7.3. Select and analyze representative scenarios	14
7.4. Assess the impact.....	15
7.5. Assess the need to reduce hazard severity and consequences	16
7.6. Identify options to optimise the process, layout, and control measure performance ..	16
7.7. Document FHA and hazard management	17
7.8. Further analysis	17
Annex A (Normative) Development and use of hazard source	18
A.1. Wells.....	18
A.2. Pipelines and risers.....	18
A.3. Process.....	19
A.3.1. Release rate modelling	19
A.3.2. Control measures and limitations on fire size and severity	20
A.4. Fuel and chemical storage and transfer	22
Annex B (Normative) Basic methodology for FHA.....	23
B.1. General.....	23
B.2. Gas fire sources and characteristics	23
B.2.1. General.....	23
B.2.2. Jet fires	23
B.2.3. Low momentum gas fires	24
B.2.4. Cloud fires.....	24
B.2.5. Release rate calculations	25
B.2.6. Transient release rates following isolation.....	27
B.3. Liquid fire sources and characteristics	28
B.3.1. General.....	28
B.3.2. Pool fires.....	28
B.3.3. Spray fires.....	29
B.3.4. Two phase fires	29



B.3.5. Release rate calculations	29
B.3.6. Spray fire dimensions	31
B.3.7. Pool fire dimensions.....	32
B.3.8. Fireball.....	35
B.3.9. Flash fire.....	36
B.3.10. BLEVE	36
B.3.11. Blowout	36
B.3.12. Thermal radiation	38
B.4. Confined fires.....	39
B.4.1. General.....	39
B.4.2. Internal effects	39
B.4.3. External flaming	40
B.4.4. Smoke generation.....	40
B.4.5. Calculation methods for confined fires and external flaming.....	40
B.5. Smoke from fires.....	44
B.5.1. General.....	44
B.5.2. Outdoor smoke concentration	44
B.5.3. Smoke impairment.....	47
B.5.4. Smoke ingress into accommodation, TR and control spaces	48
Annex C (Normative) Impact criteria	49
C.1. General.....	49
C.2 Personnel exposure	49
C.2.1 Personnel exposure to fire	49
C.2.2. Personnel exposed to radiant heat.....	49
C.2.3 Personnel exposed to smoke and heat	49
C.3. Equipment and structural response.....	50
C.3.1. General.....	50
C.3.2. Process equipment response.....	50
C.3.3. Structural response.....	51
Bibliography	52

List of Tables

Table B.1 - Gas jet and liquid spray fire hazard ranges.....	39
Table B.2 - Obstruction attenuation factors	39
Table B.3 - Plume compositions - open or well ventilated fires.....	45
Table B.4 - Plume compositions - poorly ventilated fires	45
Table B.5 - Typical burn rates for hydrocarbon fuels	47

List of Figures

Figure 1 - FHA process.....	11
Figure 2 - Application of fire hazard analysis throughout the project lifecycle	12



Figure B.1 - Typical initial release rate for methane at 10 °C (50 °F).....	26
Figure B.2 - Methane gas jet fire flame dimensions.....	27
Figure B.3 - Transient release rate of gas as a function of initial inventory	28
Figure B.4 - Crude oil release rate as a function of vessel pressure.....	30
Figure B.5 - Example liquid releases.....	31
Figure B.6 - Crude oil liquid spray fire flame dimensions.....	32
Figure B.7 - Pool fire flame height as a function of pool diameter.....	34
Figure B.8 - Flame deflection (degrees from vertical) for gasoline pool fires as a function of wind speed.....	35
Figure B.9 - Downwind heat flux from stabilised crude oil fires of various diameters	38
Figure B.10 - Smoke dilution factors for seven representative fires.....	46



1. Scope

- a. This Group Practice (GP) gives requirements on an approach for fire hazard analysis (FHA) in capital projects and existing operations. This provides the level of understanding needed to make informed decisions regarding the most effective combination of fire hazard management strategies.
- b. FHA is applicable to offshore and onshore facilities.
- c. FHA is applicable to:
 1. Design of a new facility during each of the CVP stages, and
 2. Design changes to an existing operating facility in accordance with a management of change process.
- d. For an existing facility where the BP entity determines that fire hazards need to be better understood, the general principles of FHA should be implemented.
- e. This GP is intended to conform to the requirements for continuous risk reduction defined in GP 48-50.
- f. Fires not within the scope of this GP are:
 1. Fires resulting from cellulose, electrical, metal fires, etc.
 2. Fires inside buildings.

2. Normative references

The following referenced documents may, to the extent specified in subsequent clauses and normative annexes, be required for full compliance with this GP:

- For dated references, only the edition cited applies.
- For undated references, the latest edition (including any amendments) applies.

BP

GP 24-22	Gas Explosion Hazard Analysis.
GP 48-50	Major Accident Risk (MAR) Process.

3. Terms and definitions

For the purposes of this GP, the following terms and definitions apply:

Capital Value Process (CVP)

The CVP contains a number of distinct stages between project appraisal and facility operation. The majority of these stages address project development while the last one, “operate” addresses the majority of the facility lifecycle. The following sections describe the FEHM in the CVP. For an existing operation whose development did not follow CVP, these same FEHM activities will be applicable, but not necessarily in stages and timeline documented in the following sections.

Cause

Event, situation, or condition that results, or could result, directly or indirectly in an accident or incident.



CIRRUS

BP suite of consequence modelling tools. Can be found at <http://sunapps.bpweb.bp.com/cirrus/>

Consequences

Direct, undesirable result of an accident sequence usually involving a fire, explosion, or release of toxic material. Consequence descriptions may be qualitative or quantitative estimates of the effects of the accident in terms of factors such as health impacts, economic loss, and environmental damage.

Escalation

This occurs when the fire from the original source burns long enough to cause hazardous fire conditions (at tanks, vessels, piping containing flammable substances), or weaken structures supporting such systems and equipment. When loss of containment occurs, the released inventory adds fuel to the original fire, enlarging the fire envelope and putting more adjacent equipment at risk of fire.

External flaming

External flaming is the effect that occurs outside a roofed module when the fire size or ventilation conditions are such that a significant proportion of the flames extend beyond the module boundary affecting the areas to either side and above.

Facility

General term for a complete onshore or offshore installation, vessel or rig.

Fire and explosion hazard management (FEHM)

FEHM is the active management of fire and explosion hazards during each of the CVP stages from knowledge of the causes, likelihood, severity, and consequences of major accidents that could arise. It delivers a strategy for each hazard such that a major accident can be preferentially prevented, controlled such that evacuation is not necessary, or in extreme cases, that safe evacuation can be achieved.

Hazard

Condition or practice with the potential to cause harm to people, the environment, property, or BP's reputation.

Hazard identification (HAZID)

Brainstorming approach used to identify possible hazards. HAZID studies are very broad in their scope. The HAZID is sometimes called a preliminary hazard analysis.

Modification

Changes to existing facilities.

Muster location

Designated place where personnel can muster and survive the effect of a major hazard accident while awaiting evacuation.

Pool spray transition point

The pressure below which an ignited pressurised liquid release will burn as a pool and above which, a significant portion will burn as a spray.

Radiant heat flux

Amount of radiant heat from a heat source, such as a fire, which flows through a unit area of a piece of equipment or structure per unit time



Risk

A measure of loss/harm to people, the environment, compliance status, Group reputation, assets, or business performance in terms of the product of the probability of an event occurring and the magnitude of its impact. Throughout this GP the term “risk” is used to describe health, safety, security, environmental, and operational (HSSE&O) undesired events.

Safety critical design measure (SCDM)

Those safety systems, devices, and controls which are designed to prevent, detect, control, or mitigate a major accident, or facilitate the escape and survival of people. These are also referred to as ‘safety critical elements’ in some regions and ‘protective systems’ in GDP 5.0-0001 and GRP STD 01. Three function categories are:

Prevention

Design measures to prevent a major accident through effective monitoring and process safety systems, with automatic executive action to remedy abnormal plant behaviour where appropriate.

Control

These are the active and passive measures to prevent escalation of a major accident and to bring the plant to a stable condition over a defined time period without operator intervention. Operator intervention should be possible, but not relied upon to carry out essential incident control.

Mitigation

These are measures that provide reliable protection for personnel and critical equipment or structure from the effects of a major accident. It is often through barriers, structural strength and active fire protection.

Temporary refuge (TR)

A location (typically in an enclosure or building) that will enable occupants to survive defined major accidents, including fire or blast events. Other commonly used names are “protected muster location” or “safe muster location”, or less commonly used term “safe refuge”. A temporary refuge could be the living quarters and is generally where the majority of personnel reside.

4. Symbols and abbreviations

For the purpose of this GP, the following symbols and abbreviations apply:

BLEVE	Boiling liquid expanding vapour explosion.
BOP	Blowout preventer.
CFD	Computational fluid dynamics.
CVP	Capital value process.
D	Diameter.
DHSV	Downhole safety valve.
ESD	Emergency shutdown.
FCCU	Fluid catalytic cracking unit.
FEHM	Fire and explosion hazard management.



FHA	Fire hazard analysis.
HAZID	Hazard identification.
HCU	Hydro cracking unit.
HDS	Hydrodesulfurization.
HVAC	Heating, ventilation, and air conditioning.
IM	Integrity management.
LPG	Liquefied petroleum gas.
P&ID	Piping and instrumentation diagram.
PHAST	Process hazard analysis software tool.
RHU	Resid hydrotreater unit.
SCBA	Self contained breathing apparatus.
SCDM	Safety critical design measure.
TR	Temporary refuge.

5. Fire hazard types, sources, and characteristics

- a. Types of fire that may result from accidental releases of process, pipeline, or well hydrocarbon inventories are defined below.
- b. Detailed characteristics and analysis methods are given in the Annexes.
- c. This GP does not address the analysis of nonhydrocarbon fires, however the principles are similar.
- d. Fires within the scope of this GP are classified as follows:
 1. Gas fires - jet fires and low momentum releases.
 2. Liquid fires - pool fires and pressurised spray fires.
 3. Two phase fires - flashing liquids or gas with entrained liquid droplets.
 4. Blowout - drilling, workover, well service or subsea.
 5. Flash fire - combustion of flammable gas cloud without developing any explosion overpressures.
 6. Fireball - fire from a catastrophic release of a large quantity of pressurised gas or volatile liquid.
 7. BLEVE - catastrophic failure of a vessel containing volatile liquids following sustained fire exposure.
 8. Boilover - sudden steam generation in atmospheric storage tanks throwing tank contents high in the air.

6. FHA process

- a. The objectives of conducting FHA are to:



1. Provide opportunities to reduce the risks from fire hazards.
 2. Provide an understanding of the scale, intensity and duration of credible fires.
 3. Provide a dynamic picture of the fire hazards as a capital project design evolves.
 4. Identify the impact of fires on operating personnel, plant equipment, and facilities.
 5. Provide a process and tools to optimise the design to minimise fire severity.
 6. Define the performance of SCDMs which control or mitigate the effects of fires.
- b. FHA process is described in Figure 1 and each step is described in further detail in the following clauses.
- c. For capital projects, fire hazard management shall begin during the early stages in the CVP to be the most effective. Figure 2 describes FHA process through the CVP stages.
- d. If the FHA identifies a fire hazard that is larger than that considered in the MAR analysis for the site, the MAR shall be updated to include the FHA fire hazard.



Figure 1 - FHA process

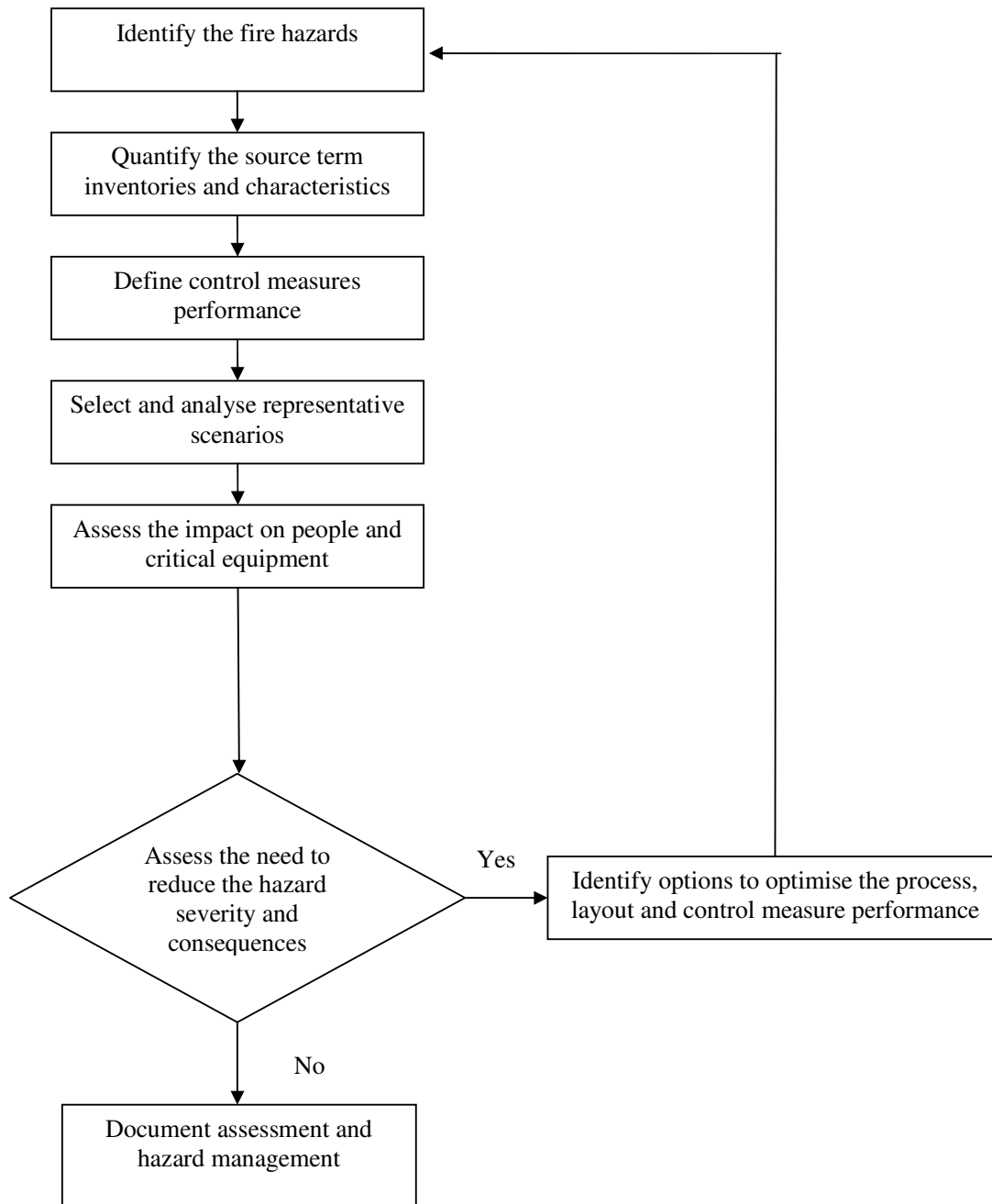
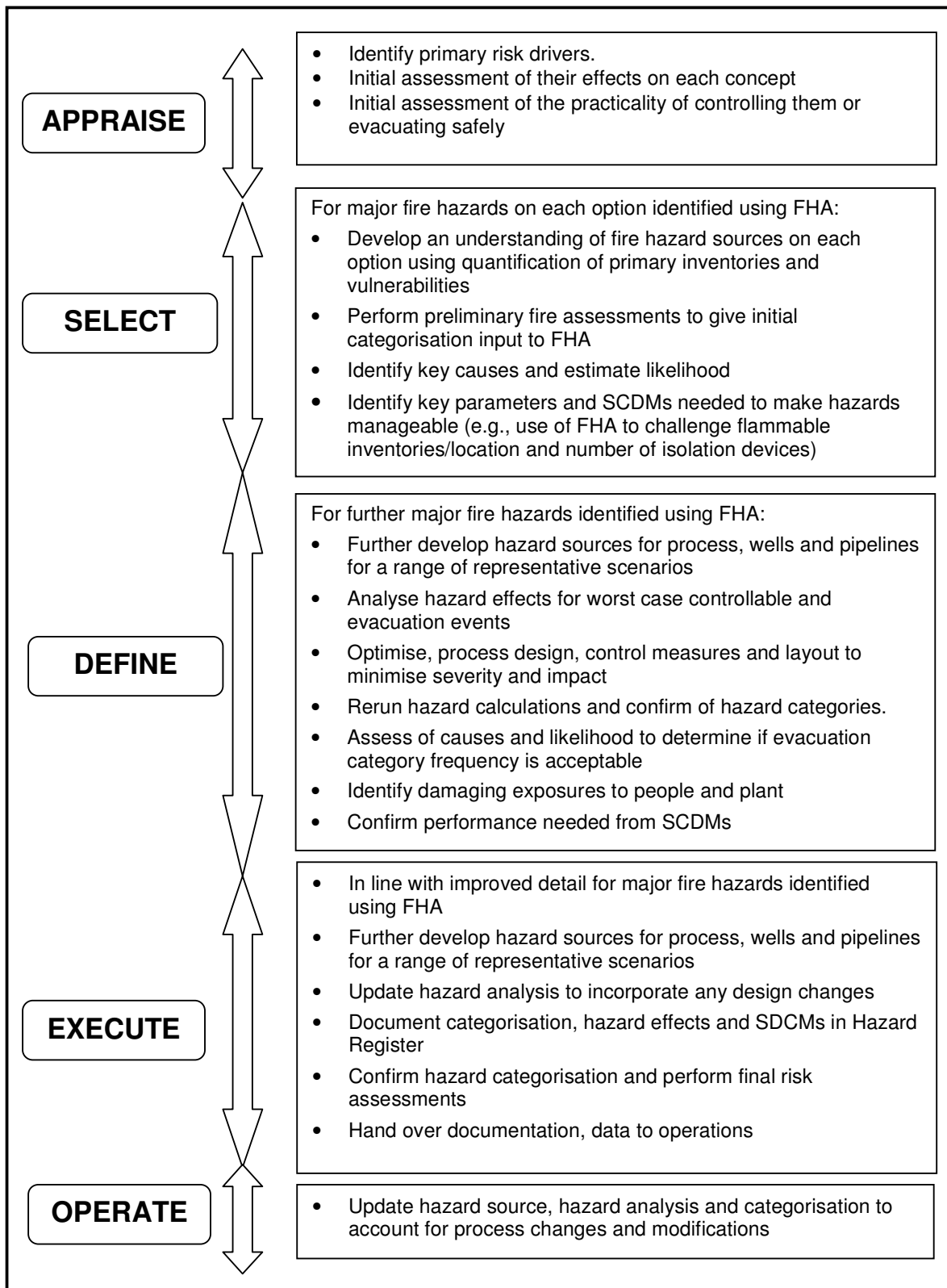


Figure 2 - Application of fire hazard analysis throughout the project lifecycle



7. Identify the fire hazard sources

7.1. General

Fire hazard sources shall be modelled as defined below.

- a. Dynamic modelling of hazard sources with the input data being progressively updated as greater detail is defined or understood.
- b. Fire hazard sources are hydrocarbons with the potential for release and fire being handled in operations including production, delivery, storage, processing, packaging, and shipping.
- c. Properties (e.g., volume, mass, pressure, temperature, and location) of each of the identified hazards are accurately quantified so that the type, location, and rate of release over time can be modelled for a range of scenarios.
 1. Models should be created which have the capability of simulating the performance of measures to control the severity.
 2. Such models should be developed for the wells, process inventories, and pipelines. The development and requirements of these hazard sources are described in Annex A.
- d. The potential for harm is determined by the fuel source and the way in which it is released.
 1. An accurate model should be developed for each of the primary sources; isolated process inventories, pipelines, and the wells.
 2. The hazard source is a definition of the possible hydrocarbon release rates over time associated with each process system, pipeline, or well, taking into account the isolatable sections, the riser capacity (e.g., export pipeline), or the reservoir. This is described in more detail in Annex A.
- e. The following time dependent characteristics of fire are quantified to the extent necessary to manage them:
 1. Release rate vs. time.
 2. Fire type, size, shape, and location.
 3. Heat flux.
 4. For offshore facilities:
 - a) External flaming beyond the source module or process area.
 - b) Smoke location and density throughout the platform.
- f. Annex B presents some simple calculations that may be used to analyse fire hazards.

7.2. Define control measure performance

- a. Hazard sources include control measures which limit the rate of release and severity of fires.
 1. In early stages of the FHA, assumptions about their provision and performance may be made based on default design standards and good engineering practice.
 2. Thereafter, these may be optimised based on greater understanding and definition to give an enhanced reduction in severity.
- b. The following systems should be included. These are discussed in Annex A together with their performance standards:
 1. Inherent breaks in the process plant.
 2. ESD valves.
 3. Depressurisation.



4. Containment and disposal of liquid spills.
5. Limitation of hole size.

7.3. Select and analyze representative scenarios

7.3.1. General

- a. Fire hazards should be analysed by initially analyzing a range of release rate calculations and selecting the bounding cases with release rates which may cause the greatest impact.
- b. In analysis of offshore facilities, these cases should be subject to scoping fire hazard calculations to show the effects on the facility at different times during each scenario. This data is then used to consider escalation and exposure to TR and evacuation systems.
- c. Fire analysis calculations may be repeated several times in order to optimise inherently safer design and control system performance. In cases where the hazard severity warrants, more sophisticated modelling should be applied.

7.3.1. Release rate analysis

- a. Fire hazard source information should be used to predict time dependent hydrocarbon release rates for a series of representative scenarios, as defined below.
- b. Release rates at the varying times should be recorded, i.e., 0, 2, 5, 10, 20, 30, 60, and 120 minutes. In the case of low pressure oil releases with a lower ignition probability, the case of an unignited pre-release building up in the bunded (diked) area should be considered. It should be assumed to build up to a depth of 50 mm (2 in) or to continue for 30 minutes before ignition whichever is smaller.
- c. Release rate modelling should cover the following range of events:
 1. A range of credible hole sizes; typically this would be based on pipe sizes, equipment connections or possible leak routes through equipment seals, etc. The range should be sufficiently wide to model a release from small to full bore in order to obtain knowledge of potential fire effects right up to the worst case.
 2. Scenarios taking credit for control measures such as ESD and depressurisation operating to their intended performance standard.
 3. Scenarios taking no credit for the control measures such as ESD and depressurisation operating to their intended performance standard.
 4. Full bore pipe rupture scenarios shall be modelled for the following units:
 - a) Crude and vacuum distillation units.
 - b) Fluid catalytic cracker units.
 - c) Delayed coker.
 - d) Hydrotreatment units (including HCU/RHU/HDS).
- d. Pipeline events with the following conditions.
 1. Full bore release.
 2. Small bore failures of cases representative of the relevant types of causes.
- e. Well or blowout events.
 1. Drilling blowout.
 2. Well service blowout.
 3. Gas lift annulus backflow through the injection port diameter.
 4. Wellhead blowout at the Christmas tree through the swab valve joint.



7.3.2. Selection of release cases for fire analysis

- a. The following cases should be identified from the release rate analyses:
 - 1. Liquid release and gas fire cases with the greatest potential impact on health, safety, and environment.
 - 2. For offshore facilities, liquid release and gas fire cases with the greatest potential for escalation.
- b. It may be necessary to model escalating scenarios. These can arise from initial explosions or fire.

7.3.3. Fire hazards effects analysis

The selected release cases should be analysed using the methods described in Annex B to give the following data:

- a. Location, shape, and size of the fire.
- b. Preparation of schematic drawings with the dominant case fire effects overlaid upon them.
- c. Heat fluxes within the fire.
- d. Radiation contours from fires with effects beyond the source and into other areas of the facility.
- e. Smoke effects from large sustained oil fires.

7.4. Assess the impact**7.4.1. General**

Detailed methods and criteria for impact assessment for people and plant are given in Annex B and Annex C.

7.4.2. Personnel

Personnel present in or adjacent to the source, those evacuating, and those in adjacent buildings should be considered.

7.4.3. Structures and equipment

- a. Analysis of the effects of flame impingement on structures and equipment should be carried out to determine whether any critical structure could fail or deform and lead to escalation through further loss of hydrocarbon containment or impairment of emergency response provisions.
- b. FHA should define the extent and duration of the flame envelope for leaks from significant hydrocarbon inventories.
- c. In offshore analysis, fire exposure, the size and strength of the plant, and the consequences should be considered. Those items with a significant risk of failure and a consequence which could require evacuation or impair the TR and evacuation systems should be subjected to more accurate response analysis if effective protection has not been specified.
- d. A list of equipment and structures that, on failure, could lead to escalation of fire hazard should be developed by FHA. Typical items to be considered include:
 - 1. Significant process inventories.
 - 2. Risers and pipelines.
 - 3. Wells.
 - 4. Hydrocarbon storage and associated piping.



5. SCDMs including:
 - a) Valve actuators.
 - b) Flare lines and equipment.
 - c) Active fire protection systems, including piping.
 - d) Firepumps and emergency generation.
6. Critical structures including:
 - a) Primary structures including:
 - Those supporting process modules, drilling modules, or the TR.
 - Offshore jacket members.
 - Elevated process decks
 - Refining reactors and towers with large inventories.
 - b) Secondary structures supporting major inventories including:
 - Tall structures including the derrick and flare.
 - Vessel supports and skirts.
7. Vessels with the potential for catastrophic failure (BLEVE).

7.5. Assess the need to reduce hazard severity and consequences

- a. The need to reduce hazard severity and consequences may be dependent on the type of or reason for FHA.
- b. The need to reduce consequences as prompted by a MAR analysis.
- c. The need to reduce the hazard severity may simply be based on the principal of continuous risk reduction and knowledge gained through FHA.
- d. A risk matrix may be used to prioritize fire scenarios for further risk reduction.

7.6. Identify options to optimise the process, layout, and control measure performance

- a. In a capital project, there should be progressive efforts to reduce the severity of the events through process design and optimisation of control measures. As project and thus hazard source details are defined, consequences should be analyzed, and control measures optimized.
- b. In both existing facilities and those in capital project design, the knowledge gained during FHA should provide the focus for risk reduction through optimizing the process, layout, and control measures. Approaches may include the following:
 1. Minimisation of the inventory that can be released. This includes minimising the exposure of large inventories to explosion overpressures.
 2. Optimisation of the layout and ESD location such that the number of release points is limited and that their location is restricted to a single area where the effects are controllable.
- c. Minimisation of release pressure.
- d. Minimisation of release rate.
- e. Minimisation of the burn rate of pool fires.
- f. Fire containment to origin.
- g. Minimisation of the impacts including those to occupied buildings and, on offshore facilities, exposure of the TR and evacuation systems to flames, heat, and smoke.

