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OIL, GAS AND BIOFUELS SECTOR COMPANIES
IN LATIN AMERICA AND THE CARIBBEAN

Fire Protection Systems in Transportation and Storage Facilities

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Introduction

All professionals of the oil industry who are carrying out activities related to the management of Fire Protection Systems (FPSs), either in the early stages of a project or on facilities in operation, should consider very varied aspects depending on their specific objective. They may have to conduct a risk analysis and need to know the basics of management, practices and principles used in the operational and process risk management of the industry. They should also know and discern the different process areas where they are working to adopt a specific criterion, and where they might need to perform the design or set the design bases of the fire protection systems that these facilities require, according to the technical standards and good practices in the industry. They may also be focused on the management of inspections, testing and maintenance of such systems to keep them in proper condition for fire prevention, control and extinguishment in optimum, efficient condition throughout time. In all of these tasks, they should consider the economic aspects involved, knowing the methodology to evaluate fire protection systems projects or the bases for technical and economic assessments, cost-benefit analysis of the investment, risk tolerability assessment, and operational and maintenance costs.

These Guidelines are designed for these professionals, so that they can have an introductory document and point of reference in all these aspects, which will serve as a starting point in their analysis that may potentially be very wide and varied depending on how to address it.

Objective

To have technical guidelines for the management, implementation, optimization and maintenance of fire protection systems in facilities and land transportation systems for hydrocarbons in compliance with technical standards and best practices in the industry, without disregarding economic aspects, and with the vision of the Latin American oil companies that are members of ARPEL.

Scope

These Guidelines include fire protection management of facilities typical of the onshore/downstream sector in the oil industry. They do not include considerations with respect to facilities of the upstream sector or refineries, nor offshore facilities.

Fire Protection Systems in Oil and Liquid Hydrocarbons Transportation Facilities

Chapter 1: Risk Analysis

RISK MANAGEMENT OVERVIEW

I. INTRODUCTION

This Section seeks to describe the fundamentals of risk management, and the practices and principles used for operational and process risk management in the oil industry.

II. SCOPE

The concepts and main tools used for risk assessment and analysis in the oil industry are described in detail.

III. GENERAL DEFINITIONS

Hazards

Hazards are defined as any situation with potential to cause harm, and that may have adverse effects such as:

- Illness, injury or death of personnel
- Property affected
- Interruption of production and/or business
- Environmental impact
- Adverse consequences for reputation

Upstream activities in the oil industry present the following hazards:

- High power equipment that could work improperly or stop functioning, causing the loss of capital or production, as well as damage to the personnel close to the operation
- Use of explosive devices that can result in major damage if applied incorrectly
- Operations or pressurized fluids that could generate potential consequences (fire, explosion, breakage-breakdown) for all the elements of an installation in the event of an undesired event
- Extreme environmental conditions, especially in offshore operations, can increase the probability of occurrence of an undesired event (earthquake, tsunami, storm, ice formation, etc.)

Downstream activities are also associated with many hazards, such as:

- Large inventories of hydrocarbons represent an immediate fire and explosion threat in a facility if they are not managed and maintained properly
- The potential discharge of toxic substances (hydrogen sulfide, chlorinated components, etc.) can seriously threaten the safety of the personnel and possibly of the community.

Especially in the transportation of hydrocarbons, the following hazards may occur:

- Oil pipelines, combination pipelines and/or gas pipelines that transport flammable substances (crude oil, naphtha, gasoline, natural gas, LPG, etc.) can spill their contents as a result of corrosion or due to external shocks, causing harmful effects to the surrounding population.

Risk Analysis

Risk is defined as the measure of the probability and severity of damage that result from exposure to a specific set of hazardous events. Risk analyses take into account the characterization of likelihood and severity of consequences.

In simple terms, risk analyses consider three basic questions:

1. What can go wrong? (Identification of hazards)
2. What are the consequences? (Impact analysis)
3. How often does this happen? (Analysis of frequency or probability)

Installation Risk

Installation risk is the total risk to which a receiver is exposed due to the presence of an installation, and as such, it takes into account the sum of all risks related to all the potential events. The installation risk can never be lower than the event risk. For example, an oil pipeline may be subject to the risk of unplanned discharges of the product transported. These discharges may have consequences, such as leaks in the accessories or breakage, which considered as a weather condition, define an event. Each type of event has a frequency and associated consequences, which can be combined to determine the event risk. The installation risk for a receiver exposed is the sum of the event risks due to leaks plus the event risks due to breakage, in all weather conditions. If some oil pipelines occupy a corridor, the total installation risk for a receiver is the sum of the installation risk of each pipeline.

Individual Risk

Individual risk is the likelihood that an individual who lives near an industrial facility may suffer a certain level of damage as a result of potential accidents in the facility. The individual risk is calculated on the basis of the product of the event frequency and its consequences for a given receiver, and does not depend on the number of inhabitants living in the area. The individual risk is often presented as a curve that generally decreases with the distance to the source of the risk.

Societal Risk

Societal risk is the relationship between the probability of occurrence of accidents in one year and the number of individuals affected due to accidents in an industrial facility. The societal risk is then a function of the population in the vicinity of the facility. This measure of risk can be expressed as event frequency (events per year) and event consequences (fatalities or damage per event) as pairs of data for each event. Alternatively, the product of event frequency and event consequences (number of fatalities or damage per year) can be used to express the societal risk of a facility.

The difference between individual risk and societal risk is material in risk assessment and management. For example, an individual exposed may be more concerned about his/her personal risk than about the number of neighbors who may be exposed to the same levels of risk. The community, however, will be more concerned about accidents with multiple fatalities and may decide that although the individual risk is acceptable, the probability of an accident with multiple fatalities is unacceptable. Different options may be applicable to the management of individual and societal risks. For example, an unacceptable high-level individual risk may be resolved by implementing preventive requirements on the use of land that establish restrictive distances that may be similar to the distances stated for individual buildings adjacent to hazardous industrial facilities. However, this approach may not adequately address the social risk, and additional measures may be required to prevent exposure.

Risk Perception

The term *Risk* can have different meanings for different people, depending on the context of the situation and the activity of each individual. In general, the industry sees its activities as safe as it is familiar with its products, processes and hazards. It also receives direct benefit of the activities that it voluntarily undertook. It has experience in the design, construction and operation of similar facilities and is familiar with its products and processes. The personnel are trained and experienced in monitoring and responding to a variety of situations, including emergencies, and know how to manage them.

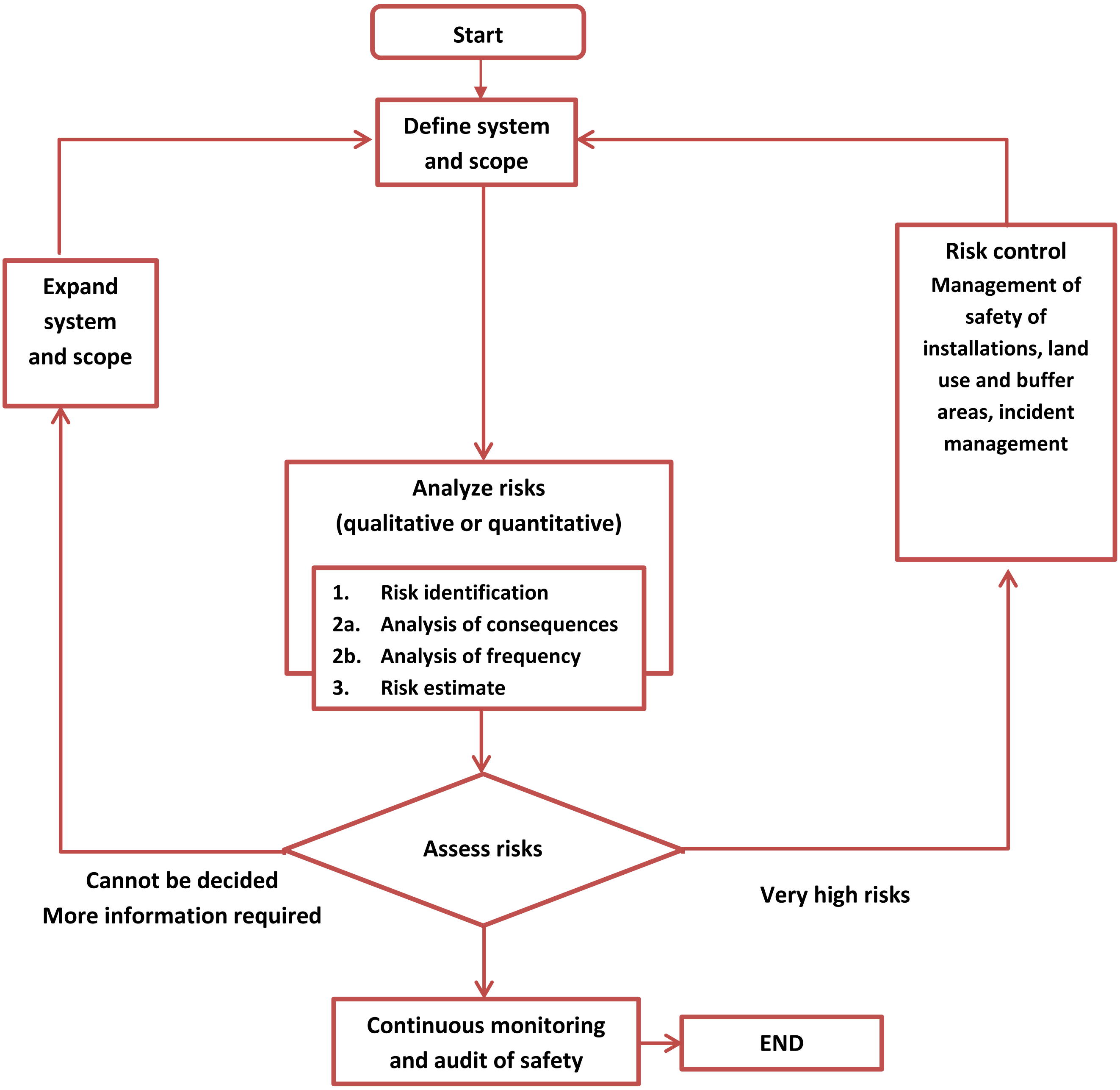
The concept of risk perception is a reality, and it has to be dealt with accordingly. While the industry and the community as a whole may receive direct benefit of its development, the surrounding neighbors may receive little benefit of these activities and may be adversely affected by inconveniences, such as smell and noise. Processes, products and the relationships between the industry and the community are often not very well understood, as development can be seen as negative by the population, and risk unacceptable.

Risk perception also considers the scale of the individual factors used to calculate the risk (e.g., probability vs consequences). High-probability/low-consequence events can imply the same level of risk as low-probability/high consequence events. However, the results of the risks can be judged very differently. For example, there is a large number of individual car accidents that cause a low number of fatalities and damage by accident. This type of accidents are generally more accepted by the community than aircraft accidents, which are rare (very low probability) and usually result in more fatalities by accident.

Risk Management

Risk management is a systematic way of assessing technical information and social values to take actions and make decisions regarding safety. The process involves the development and evaluation of options with respect to public safety and economic, social and political consequences before taking actions and making decisions. The main stages of a risk management process are:

- Hazard identification
- Risk analysis
- Risk assessment
- Hazard control


Start
Define system and scope
Expand system and scope
Risk control
Management of safety of installations, land use and buffer areas, incident management
Analyze risks
(qualitative or quantitative)
1. Risk identification
2a. Analysis of consequences
2b. Analysis of frequency
3. Risk estimate
Assess risks
Cannot be decided
More information required
Very high risks
Continuous monitoring and audit of safety
END

RISK EVALUATION TOOLS

Qualitative and/or quantitative methods may be used for conducting a risk assessment (see also Guideline for Risk Analysis Methodologies - Refining and Fuels Committee - MP 01_2015).

The first step is to identify the hazards of the facility, recognize hazardous materials, their quantities and their storage, processing and handling conditions. The identification of hazards describes the characteristics of an accidental discharge and summarizes the effects of exposure, in addition to the mechanisms by which individuals can be adversely affected. Techniques for the identification of hazards and risks in order to prioritize the risks of a facility according to the activity of the area being examined (transportation, storage, wharves, among others) are recommended.

The main hazards are the immediate and short-term adverse effects of thermal radiation, overpressure or toxicity. The purpose of identifying hazards is to define the potential hazards in sufficient detail to support and establish priorities with respect to subsequent analysis.

***The qualitative* approach** is based on the application of various methods to identify, understand and control risks. The interpretation of the results of this type of risk assessments usually rests in the judgment and experience of those involved, and it is commonly used to define if risks are acceptable or not.

The safety check is a qualitative technique used to identify hazards and deviations of procedures. This requires a description of processes, procedures and standards that are implemented in an installation.

In addition, the structured and systematic approach of ***Process Hazard Analysis (PHA)***is mainly used to identify potential hazards related to the design and/or operation of oil and liquid hydrocarbons transportation and storage facilities. This methodology serves as a continuous improvement tool that ensures that operations are carried out safely and diligently.

The selection of the PHA methodology will first depend on the nature of the process analyzed, the stage of progress of the project and the availability of information. The main PHA methodologies are:

- Checklist
- What-if Analysis
- Failure Modes and Effects Analysis (FMEA).
- Hazard and Operability Analysis (HAZOP)

Hazard Identification (HAZID)

This technique is usually applied during the conceptual design of a plant. It covers hazards not only related to the process itself, but also hazards derived, for example, from the location of an installation in a particular place, so that deployment, advantages and disadvantages of the land, environmental impacts on the installation, common causes of environment-related failures of equipment, accessibility to the installation, physical safety of individuals, etc. can be analyzed and defined. This study requires a multidisciplinary team. Guide words are used by the team to conduct the analysis as a trigger to help ***brainstorming*.**

CHECK LIST

This is a list with details of the aspects related to safety expected of a system (equipment, process, procedure, etc.). It is generally written from the experience and used to assess the acceptability or the condition of the installation or operation in comparison with established standards. This technique is based on the prior knowledge of potential hazards in a system and enables checking if these have been taken into account in the design.

WHAT IF?

This technique is carried out in sessions with a multidisciplinary team. Unlike the HAZID, there is no trigger for the analysis, such as guide words, which help brainstorming. It requires a deep knowledge of the process that is being analyzed. Possible deviations in the process are raised by asking the question What if...?

It is usually applied to simple, low-risk processes, or in small changes that do not warrant the use of another more rigorous technique, as the HAZOP analysis. It is worth mentioning that the question What if…? is common to all techniques; the difference lies in the fact that in others, such as HAZID or HAZOP analysis, these are directed by triggers or guide words. The What if…? technique calls on directly to the imagination from the knowledge of the process or operation being assessed.

Hazard and Operability (HAZOP)

It is a systematic method to be carried out by a multidisciplinary team. A premise of the HAZOP is that accidents occur due to deviation from the normal parameters of operation and/or design. These deviations are systematically analyzed with the help of guide words. The methodology reviews the entire process rigorously. Instrumentation and pipe diagrams are the basic contributions in this technique, so it is usually applied during basic engineering, detail engineering and during plant operation.

The HAZOP technique analyzes hazards resulting from process, non-occupational risks or maintenance problems (such as equipment with thicknesses out of specification or electrical installations not suitable for the classified areas where they are located). These aspects, usually identified in safety audits and inspections, and included in the HAZOP, can cause deviations from the parameters of the process, but are not analyzed in depth.

Failure Modes and Effects Analysis (FMEA)

This is a method to evaluate the effects of the failure modes of components and generally does not take operational errors into account. Due to its characteristics, it is applied to electromechanical systems. The components of a system are evaluated in terms of the ways in which they can fail and what the consequences or effects of such failures are. It does not have guide words that will induce the analysis, and all components of the system to be analyzed shall be previously listed.

This technique helps to determine what the most critical components are, and identifies and tends to eliminate the causes of failure. For this reason, its use is recommended in the field of equipment maintenance, supervised by a process safety department.

Meanwhile, the ***Quantitative Approach*** is the most sophisticated technique available to predict the risk of accidents, in addition to providing a guide with the appropriate means to minimize them. However, it is recommended that the quantitative risk assessment should not be considered as the only means of data contributing to decision making with respect to safety; it shall be accompanied by other techniques based on experience and judgment.

The tool recommended for this approach is the analysis of consequences, where hazards are defined in sufficient detail to establish the flow rates during an accidental discharge, the discharge configuration and the weather conditions. This analysis is used to determine hazardous characteristics, such as impact of radiation, impact of flammable vapor cloud, impact of overpressure by explosion and impact of toxic dispersion.

In addition to the analysis of consequences, the frequency analysis estimates the probability that an accident may occur, quantifies the probability that a given event occurs, and sometimes is expressed in terms of accidents per year. The frequency analysis is performed to establish aspects such as:

- The frequency with which a hazardous event may occur
- The probability of a particular hazardous outcome after the occurrence of an event
- The probability that there may be individuals exposed and/or injured

The main techniques used to estimate frequency are:

- The use of historical data of frequency of failures, which include the grouping and analysis of recorded data on accidents and incidents over time
- The detailed modeling of frequency, using the fault tree analysis and event tree
- Estimates based on judgment and experience

To determine the frequency of an event, the frequency of a disturbing condition shall be multiplied by the probability of occurrence of the particular set of circumstances. These results are estimates of a probability and are expressed as averaged or uniform over time.

Once frequencies and the consequences of each event modeled are estimated, they can be combined to form a measure of risk in general. Risk estimates contribute in the best attempt by the analyst to calculate advance statistics, recognizing that assigning a value to risk does not imply that an event and its consequences will occur, but anticipates that they will occur in an estimated frequency based on the criteria included in the analysis.

TECHNOLOGICAL RISK ANALYSIS GUIDE FOR THE HYDROCARBON SECTOR

1. OBJECTIVE

To provide a framework of reference for the development of the risk analyses applicable to production, transportation, storage and processing of hydrocarbons to help standardize the criteria and guidelines to carry out the technological risk analysis, ensure objectivity in the development of analyses and obtain traceability in their results. Its scope involves industrial accidents of a technological nature that can be present in an onshore infrastructure and some aspects in an offshore infrastructure. Similarly, although the scope does not include the entire risk analysis for an offshore infrastructure, the same schema defined in these Guidelines can be used for the special characteristics of the offshore operation and its environment.

2. RISK ANALYSIS AND ASSESSMENT

Consideration of the causes and sources of risk, its consequences and the likelihood that such consequences may occur. Model by which the threat is related to the vulnerability of the exposed elements in order to determine the potential adverse social, economic and environmental effects and their probabilities. The value of damages and potential losses is estimated and compared with the safety criteria established, with the purpose of defining types of intervention and scope of risk reduction and preparedness for response and recovery.

3. GENERAL CONDITIONS

It applies to the performance of the risk analyses of industrial accidents to be developed by the oil and gas transportation and storage industry.

4. IDENTIFICATION OF SCENARIOS

All hazardous substances transported or stored should be considered for the performance of a risk analysis. Hazardous substances are to be understood as those substances that are flammable, explosive and harmful to the environment. For equipment that operate with different substances, it is modeled according to the substance that represents a greater risk according to its classification. The infrastructure and operation description shall include the identification of all equipment, their dimensions and operation conditions, their operation times and the substances handled.

5. CRITERIA FOR SELECTION OF SUBSTANCES TO BE MODELED

In the case of having substances with the same classification (equal number of flammability or risk phrase), a single representative substance may be selected to carry out the modeling of consequences. In the case of flammable substances, the most volatile substance shall be selected. In the case of toxic substances, an analysis shall be made taking into account their toxicity and volatility, so that if a reduction of substances is to be carried out, the substances resulting in a worst-case scenario shall be selected.

The safety label shall be attached for each selected chemical. It shall contain the hazard classification according to the safety diamond (NFPA 704 Standard and/or DOT Classification). In the case of oil and liquid hydrocarbons, the label shall contain information on its composition and physicochemical properties.

6. INFRASTRUCTURE AND PROCESS DESCRIPTION

The infrastructure and operation description shall be made identifying all equipment, dimensions and operation conditions, the times and the substances with which such equipment operates.

7. IDENTIFICATION OF INITIATORS

Initiators are the initial situations of loss of containment or exposure that may be present in different equipment and shall be included in the risk analysis. There are two types of initiators: generic or specific. Generic initiators involve a loss of containment due to nonspecific causes of the process or operation, such as corrosion, errors in construction, failures of welding, etc. Specific initiators are characterized by specific causes due to process conditions, design, materials used, etc.

Types of Generic Initiators

All generic initiators present in an installation shall be considered for the performance of a risk analysis.

- Piping: well transfer pipes, trunk lines, hoses (underwater, floating and load), loading and unloading arms, underwater pipes, transportation pipes and other internal and external piping
- Pumps, compressors, energy generators
- Traps of scrapers, measurement and filtration systems
  - Type of loss of containment or exposure:
    - G1 Complete breakage (100 % of diameter)
    - G2 Partial breakage (20 % of diameter)
    - G3 Minimum breakage (1/4")
- Gas flare:
  - Type of loss of containment or exposure:
    - G1 Maximum possible discharge with liquid expulsion (it will be considered to be three times the normal discharge during one minute).
- Containers, process areas (reactor, distillation column, filter, heat exchangers, etc.)
  - Type of loss of containment or exposure:
    - G1 Instantaneous leak of the entire contents
    - G2 Continuous leak through the connection with a larger diameter. In the event of a biphasic operation, both phases shall be studied
    - G3 Continuous leak through a hole of up to ¼"
- Atmospheric storage tank
  - Type of loss of containment or exposure:
    - G1 Leak of the entire contents
    - G2 Fire in the tank surface
- Storage tank pressure.
  - Type of loss of containment or exposure:
    - G1 Instantaneous leak of the entire content (catastrophic breakage)

        - G2 Continuous leak through the connection with a larger diameter
        - G3 Continuous leak through a hole of up to ¼"
- ❖ Sinks, separators, fluid traps
    - Type of loss of containment or exposure:
        - G2 Fire in the exposed surface
- ❖ Tank trucks
    - Type of loss of containment or exposure:
        - G1 Instantaneous leak of the entire contents
        - G2 Leak of the entire contents through the connection with a larger diameter
- ❖ Inland waterway transportation convoy
    - Type of loss of containment or exposure:
        - G1 Total dumping of a ship (all holds)
        - G2 Partial dumping of a ship
- ❖ Tanker (maritime transportation)
    - Type of loss of containment or exposure:
        - G1 Dumping of 50 % of ship capacity
        - G2 Partial dumping of a hold

The values of failure frequency for each initiator depend on factors such as the size of the orifice and the type of equipment.

➢ Specific Initiators

Different specific initiators that may be present in installations

Specific initiators may be identified by:

- Updated prior drills (that include the current infrastructure at the time of completion/update of the Emergency Plan), process risk analyses conducted by using tools such as HAZOPS, What if?, FMEA
- Workshops with operational personnel

Some examples of specific initiators to be considered depending on the installations and the process are:

- Overfill of tanks
    - Reactions out of control (runaway)
    - Mechanical explosion of process containers
    - Leak of the contents of a container and later reaction with water, generating toxic and/or flammable gases. This initiator applies in the case of substances that can generate this type of gases when reacting with water.

8. IDENTIFICATION OF FINAL EVENTS

The identification of the final events that may occur as a result of the initiator can be determined by using event trees. These trees allow seeing the behavior of the substance after discharge and estimating the probability of occurrence of each final event, taking into account the intermediate events that determine the evolution of the initiator to the final event.

- Event tree for a continuous discharge
- Event tree for an instantaneous discharge

9. IDENTIFICATION AND EVALUATION OF FAILURE CAUSES IN PIPELINE SYSTEMS

Potential threats that may affect the integrity of a fixed pipeline system for liquid hydrocarbons and produce a loss of containment can be classified into groups, as follows:

- External corrosion
- Internal corrosion
- Stress corrosion cracking (SCC)
- Operational failures
- Erosion
- Fatigue
- Involuntary third-party damage
- Voluntary third-party damage
- Climate and external forces (natural causes/earth movement)

10. IDENTIFICATION AND EVALUATION OF FAILURE CAUSES IN PROCESS AREAS

The assessment of threats in process areas is different from the assessment of threats in pipelines. The reason for this is that in process areas there are other elements and a variety of conditions that change the analysis overview.

The causes of damage are assessed within a more extensive risk analysis procedure following the API Standard 581. This factor that is defined as a damage factor "Df" is used to statistically evaluate the amount of damage that may be present in an element or equipment in the process area as a function of time in service and inspection effectiveness. The damage factor modifies the basic failure frequency to reach a modified value according to the threat present.

- Internal thinning (general and localized)
- External corrosion
- SCC-H2S (stress corrosion cracking)
- HIC-SOHIC (corrosion - cracking)
- Vibrational fatigue
- Corrosion under insulation (when applicable)

In addition to the above, consideration shall be given to the assessment of other threats that may be present in process areas. Climate and external forces can represent a significant threat in terms of potential flooding, seismic (considered in the geotechnical zoning) and keraunic activity. As regards involuntary third-party damage, consideration shall be given to the potential technological threat posed by nearby industries. This is included within the consideration of the domino effect and/or involuntary third party damage.

11. ESTIMATE OF THE AFFECTED AREA

➢ Modeling Conditions

In order to determine the consequences of the final events, it is necessary to define the conditions inherent in the environment of the infrastructure that will serve as the basis for modeling the effects. The criteria and thresholds of the effects associated with the different final events that may have an environmental impact shall also be established.

- Meteorological parameters
  - Average temperature
  - Average relative humidity
  - Wind stability, speed and direction
  - Atmospheric pressure
- Impact levels
  - The purpose is to establish the criteria and threshold values to determine a potential environmental impact as a result of a loss of containment and materialization of a final event. On this basis, the criteria and threshold values are those to be considered for modeling consequences and determining the impact distances, according to the typology of possible final events, such as:
    - *Fire*
    - *Flash fire*
    - *Explosion*
    - *Toxic dispersion*
    - *Suffocating atmosphere*
- Impact of radiation

  The areas affected by radiation from a pool fire, jet fire or a BLEVE/fireball on people are defined in Table 1 according to the Probit methodology, and can be seen in Figure 1.

Area	Thermal radiation (kW/m^2)	Description
Severe	> 37.5	Enough intensity to cause damage to process equipment
	> 20.9	Area of 90 % of probability of death for exposure periods longer than 30 seconds
	> 14.50	Area of 50 % of probability of death for exposure periods longer than 30 seconds No personnel are expected in this area.
Moderate	> 9.50	Above this value there is ignition of the wood subject to the heat flow for an excessive period Enough intensity to melt plastic pipes Fatalities may be caused by third-degree burns after 100 seconds of exposure Second-degree burns after 12 seconds of exposure
	> 7.27	Limit area of 1 % of probability of death for exposure periods longer than 30 seconds
	> 5	Maximum exposure period of one (1) minute without adequate protective clothing First-degree burns after 30 seconds of exposure Second-degree burns after 180 seconds of exposure The estimated consequences of the accident produce a level of damage that warrants the immediate implementation of the safety measures
Minor	> 1.6	Maximum exposure period of three (3) minutes without adequate protective clothing First-degree burns after 120 seconds of exposure The consequences of the accident at this level cause effects that, although perceptible by the population, do not warrant the immediate implementation of protection measures for the people Limit area of heat intensity in areas where emergency actions lasting up to several minutes may be used by personnel wearing adequate clothing

Table 1. Thermal Radiation Impact Levels

Source: Guidelines for Chemical Process Quantitative Risk Analysis. AICHE. Second Edition. 2000.

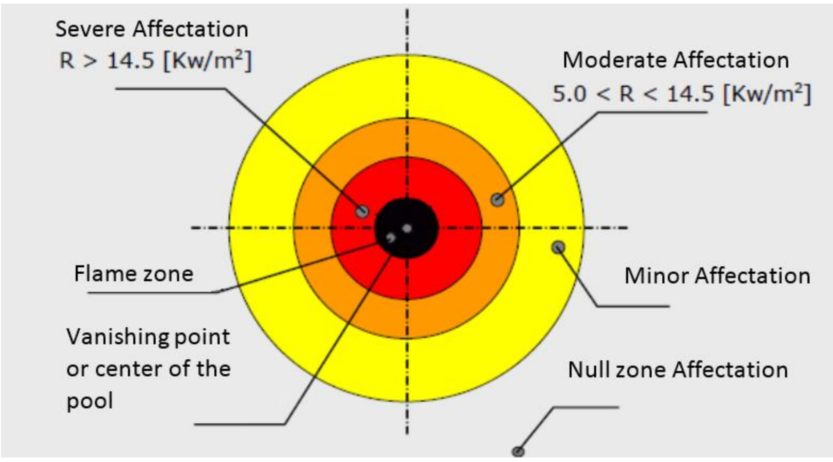


Figure 1. Distance of Concern Selected for Pool Fire, Jet Fire and BLEVE/Fireball

➢ Impact of Flammable Vapor Cloud

The effects derived from flash fire are thermal radiation, mainly caused by direct contact of the flame within the limits of flammability of the hydrocarbon vapor cloud.

To this end, it is established that the vapor cloud can ignite up to a maximum distance from the leak point, given by the distance at which the concentration of the cloud has diluted until the lower flammability limit (LFL) of the product. Death of all individuals in this area is considered.

Since radiation can be transmitted by convection outside the distance set by the LFL, an additional distance until the cloud is diluted to ½ of the LFL is considered. With regard to the radiation transmitted by convection to areas below the lower flammability limit, while subjected to radiation, though for a short duration, the damage is very limited and, therefore, considered negligible.

Table 2 describes the affected corridors for the final event of flash fire. This information is shown, in addition, in Figure 2.

Area	Condition	Description
Severe area	LFL	Area where there shall be no sources of ignition; 100 % probability of death of a person is assumed
Moderate area	LFL/2	Corresponds to the distance at which the cloud is diluted up to ½ of LFL

Table 2. Impact Levels of Flash Fire

Source: Adapted from CPR 16E (GB: Green Book). Methods for the determination of possible damage to people and objects resulting from releases of hazardous materials.First edition. 1992.

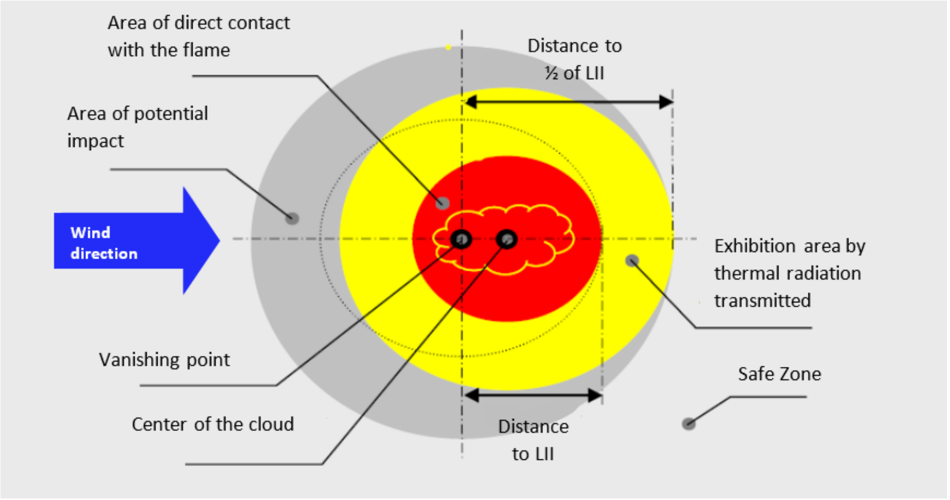


Figure 2. Distance of Concern Selected for Flash Fire

➢ Impact of Overpressure Due to Explosion

Table 3 shows the effect produced by different levels of overpressure which are reached in radial form with respect to the point at which the explosion occurs, as illustrated in Figure 3.

Area	Range of shock wave (psi)	Description
Severe	14.0	Maximum peak of shock wave that an unconfined explosion of hydrocarbon vapor may develop This level of shock wave does not cause mortality, but a 45 % probability of impact may cause eardrum rupture
	> 6.4	Above this value, there is almost complete destruction of houses Possible damage to storage tanks and process equipment 10 % probability of impact due to eardrum rupture
Moderate	< 3.25	The threshold of eardrum rupture (1 % probability) is present at this shock wave.
	> 3	Severe damage to steel structures and masonry (industrial building) are produced within this area
	> 2	From this overpressure, there is partial collapse of roofs and walls of houses
Minor	> 0.4	Sufficient levels of shock wave to cause minor damage to structures of houses and buildings

Table 3. Impact Levels of Overpressure

Source: Guidelines for Chemical Process Quantitative Risk Analysis. AICHE. Second Edition. 2000.

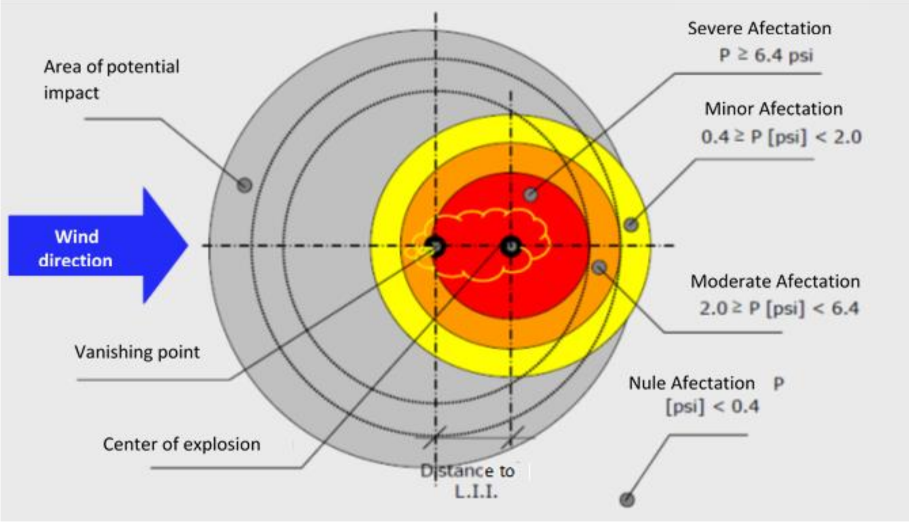


Figure 3. Distance of Concern Selected for Explosion

➢ Impact of Toxic Dispersion

The vulnerability of people to the inhalation of toxic substances is related to the nature and dose of the substance, i.e., depends on the concentration and exposure period.

Similarly, to assess levels of minor impact that can be used for emergency response planning, the EPA has developed the AEGL and ERPG values, which also define scenarios associated with toxic dispersion of substances expressed in 3 levels. Table 4 details the threshold limit concentrations for different degrees of impact to be considered in the risk analysis.

Area	Concentration	Description of impact
Severe	90 % lethality	Concentration to which one would expect a 90% lethality in the general population
	50 % lethality	Concentration to which one would expect a 50 % lethality in the general population
Moderate	1 % lethality	Concentration to which one would expect a 1% lethality in the general population
	>AEGL-3	Concentration at/above which it is predicted that the general population, including susceptible individuals but excluding hypersusceptible individuals, could experience life-threatening effects or death Concentration below AEGL 3 but above AEGL 2 represent exposure levels that can cause long-lasting, serious or irreversible effects or an impaired ability to escape.
Minor	>AEGL-2	Concentration at/above which it is predicted that the general population, including susceptible individuals but excluding hypersusceptible individuals, can experience long-lasting, serious or irreversible effects or an impaired ability to escape Concentrations below AEGL 3 but above AEGL 1 represent exposure levels that can cause notable discomfort
	>AEGL-1	Concentration at/above which it is predicted that the general population, including susceptible individuals but excluding the hypersusceptible individuals, can experience notable discomfort Concentrations below AGEL 1 represent exposure levels that produce light odor, taste or other mild sensory irritation

Table 4. Impact Levels of Thermal Radiation

Source: AEGL concentrations shall be selected based on the period of exposure to the cloud and can be found at: http://www.epa.gov/opptintr/aegl/pubs/humanhealth.htm

If final AEGL values are not available for the substance being evaluated, the ERPG values shall be used. These values are also presented in three tiers (according to severity of the health effect on exposed individuals). These values are updated annually. Table 5 describes the ERPG.

Concentration	Description
ERPG-3	Maximum airborne concentration below which it is believed that nearly all individuals could be exposed for up to 1 hour without experiencing or developing life-threatening health effects
ERPG-2	Maximum airborne concentration below which it is believed that nearly all individuals could be exposed for up to one hour without experiencing or developing irreversible or serious health effects or symptoms which could impair an individual's ability to take protective action
ERPG-2	Maximum airborne concentration below which it is believed that nearly all individuals could be exposed for up to one hour without experiencing other than mild transient health effects or perceiving a clearly objectionable odor

Table 5. Description of ERPG Tiers

Source: ERPG concentrations are found at: http://www.aiha.org/insideaiha/GuidelineDevelopment/ERPG/Documents/2011erpgweelhandbook_table-only.pdf

➢ Impact of Suffocating Atmospheres

The effects associated with oxygen-poor atmospheres can vary considerably from one individual to another. Table 6 shows the concentrations of concern to take into account to set relevant impact distances.

Area	% oxygen concentration	Description
Severe	12	Impairment of physical or intellectual ability
Moderate	16	Dangerous situation

Table 6. Impact Levels of Suffocating Atmospheres

Source: Casal J., et al; Análisis de riesgo en instalaciones industriales, 1999.

It is considered that to reach a concentration of oxygen below normal in the air (21 %), there must be a volumetric displacement of oxygen due to the dispersion of another substance. In this case, it is estimated that, at a concentration of 42.85 % of a substance (428570 ppm), the oxygen concentration is reduced to 12 %, which corresponds to an impact threshold where there is an impairment of the physical and intellectual ability of a human being. Similarly, for a concentration of 23.84 % of a substance (238400 ppm), the oxygen concentration is reduced to 16 %, which indicates the start of a dangerous condition for human health.

12. CRITERIA TO ESTIMATE DISCHARGES

The following criteria established to estimate discharges for transportation systems and process areas shall be considered in a differentiated way.

➢ Pipeline Systems

Pipeline systems include the pipeline infrastructure, underwater and floating hoses, combination pipelines, gas pipelines used to transport hydrocarbons and their derivatives.

- **Operational response time**

The operational response time corresponds to the time it takes to detect the loss of containment plus the action time (automatic, semi-automatic, manual.). The action time in the event of a complete breakage is understood as the time when the product flow stops either by closure of valves or shutdown of the pumping operation.

- **Spill volume**

First, the spill volume corresponding to each specific segment of the pipe shall be estimated taking into account the following criteria for total and/or partial breakage.

- Total breakage

The spill volume corresponds to the dynamic volume, i.e. the pumping volume during the time of operational response (detection + action), plus the hydrostatic volume drained.

- Partial or minimum rupture

The spill volume will be equal to the leak rate multiplied by the time of operational response, plus the volume corresponding to the hydrostatic drain in the event that the operation stops.

- **Leak rates**

The average rate in a total breakage is the average discharge rate of the first 20 % of the total mass drained.

In the case of partial or minimum breakage, the calculation of the flow of fluid through orifices shall be made taking into account the pressure loss due to friction in the line. The leak rate to be estimated is the average discharge rate of the first 20 % of the total mass drained.

➢ Operational Areas

Operational areas involve the industrial facilities where product handling and transformation processes are carried out, such as fields, production areas or blocks, batteries, stations, plants (including internal plants of a complex), terminals and platforms, among others.

- **Leak rate**

The following criteria shall be taken into account to calculate the leak rate for the different equipment in the operational area:

- Maximum storage capacity of equipment
- For broken pipes and pumps, and tank leaks, the hydraulic calculation is made through an orifice. A discharge coefficient (for the Bernoulli equation) of 1 for total breakage in the case of liquids, of 0.61 for partial discharges in the case of liquids and of 1 in the case of gases shall be considered.
- In the case of pumps, it is assumed that total breakage occurs at the suction side of the pump. The leak rate is determined by hydraulic calculation, which depends on the level of liquid in the supply container and the piping length.
- The leak rate is the average discharge rate of the first 20 % of the total mass drained.

- **Operational response time**

The response time is the time that the operation takes to develop the planned control measures and actions in the event of occurrence of an event until the loss of containment stops. It is conditional on several factors such as environmental conditions, operation capacity and efficiency to deal with the event, control instrumentation, etc. The response times to consider depending on the type of valve are listed in Table 7. These times shall be validated by the operators, especially in those cases where times may be longer.

Type of valve	Description	Total time: detection + action
Automatic	• The detection is fully automatic and specific. • The detection results in an automatic order to close the valve. • The intervention of an operator is not required.	5 minutes
Remotely operated	• The detection is fully automatic and specific. • The detection results in an alarm signal (in the field or control room), audible, visual or both. • The operator validates the signal, locates the pushbutton on the valve and acts from the field or from the control room.	15 minutes
Manually operated	• The detection is fully automatic and specific. • The detection results in an alarm signal (in the field or control room), audible, visual or both. • The operator validates the signal, goes to the place, locates the valve and closes the valve manually.	30 minutes

Table 7. Operational Response Time

Notes:
1. A shorter time could be considered if technically warranted (e.g. excess flow valves).
2. In the event that broken equipment is emptied and cannot be blocked, the discharge time is equal to the time of emptying the equipment.

13. DIRECT IMPACT DISTANCES

The development of a consequence analysis is recommended for modeling different final events and estimating the distances over which the impact levels are reached. For this purpose, modeling software, such as PHAST, CAMEO, ALOHA and similar software, should be used. The following criteria and calculation models should be taken into account, except that different models and parameters may be used when duly warranted.

➢ Product to Model

In the event that the product is not a pure substance, but a mixture, such as liquid hydrocarbons, it is recommended that the composition of the mixture be obtained from chromatography of distillation data of the products, to model the effects of radiation, overpressure and dispersion.

If this information is not available, it should be consulted with the technical fire protection authority of each area.

The consequences modeled for each area shall be the starting point for the definition of the passive and active fire protection systems required (see Chapter 3 of –*ARPEL Guidelines on Fire and Explosion Protection Systems*).

Modeling shall include, as a minimum, the analysis of the following scenarios, depending on the case:

- Pool fire
- Jet fire
- Dispersion: Flash fire, toxic or suffocating cloud
- Explosion
- Atmospheric dispersion

14. INDIRECT IMPACT DISTANCES

Indirect impact distances shall be estimated on the basis of spill trajectory and the modeling of effects of possible final events that may occur along this path.

➢ Spill Trajectories

Spill trajectories shall be estimated to determine the indirectly affected areas. In transportation systems, they are estimated taking into account, as a minimum, all previously identified breakage points. In process areas, the spill trajectories are present when the spill of the substance exceeds the capacity of the containment system of the operation (dikes, traps, etc.) and the spill extends to the rain water drainage system of the plant and subsequently to the natural drainage.

- Spill on land
- Spill on water bodies

15. AFFECTED AREAS

Areas that may be impacted by final events, which may be classified as a directly affected areasor indirectly affected areas. These areas are calculated on the basis of the results of the modeling of different final events and the estimate of distances to which the impact levels of concern extend for each type of event.

- ➢ In transportation systems, the directly affected area is determined by a corridor measured from the central axis of the pipeline.
- ➢ In process areas, the directly affected area is the surrounding area resulting from drawing circles with the center in each equipment involved in the risk analysis.

16. IDENTIFICATION OF VULNERABLE ELEMENTS

On the basis of the modeling of the effects of possible final events and the determination of the directly and indirectly affected areas, the vulnerable elements existing within these areas can be identified. In the case of linear transportation infrastructure, this identification shall specify the piping section where vulnerable elements for the directly affected area are found (initial and final abscissa of the section), and for the indirectly affected area shall specify the section where a breakage would cause the impact. This identification shall be carried out by checking the pipeline system from the start. The following are considered vulnerable elements: human settlements, social infrastructure, assets of cultural interest, productive activities, companies that handle hazardous substances, environmental sensitive areas, sites of water catchment and aquifers.

- **Criteria of Tolerance**

Once the risk, both individual and social, has been estimated, it is necessary to define the levels of tolerance to risk, i.e., establish the risk values that the company or industrial facilities will accept in exchange for the benefit it receives from such activity. For this purpose, the levels of maximum and minimum risk shall be determined, where the first of them, "unacceptable risk", corresponds to the threshold for which no higher value can be justified and, therefore, mechanisms to decrease it immediately shall be implemented, and/or the area included within this level of risk shall be managed in such a way that there is restriction on the use of the land and the existence of vulnerable elements exposed to this level of risk shall be restricted. The second "acceptable risk" corresponds to the level for which all lower value may be regarded as negligible and therefore, no mechanism of reduction is required. *According to the above, an acceptable risk is defined as one below the criterion of minimal risk, and an unacceptable risk is that which is above the criterion of maximum risk*.

Fire Protection Systems in Oil and Liquid Hydrocarbons Transportation Facilities

Chapter 2: Process Areas

1. INTRODUCTION

The oil industry is undoubtedly one of the most important industries in the world. A wide variety of products are obtained from the extraction of crude oil, its transportation and different refining processes, such as propane, butane, products for production of plastics or asphalts, and fuels - gasoline, diesel, kerosene -, all of which are transported through multi-modal systems.

In these processes, the term *Fire Protection* refers to the precautions that must be taken to prevent or reduce the possibility of a fire that may cause death to operators, injuries, property damage, impact on the environment and on communities near the facilities. The purpose of these measures is to allow taking actions to minimize the potential impacts or consequences of a fire.

Fire protection measures include those that were planned in the plant layout, design of ports, fire engineering, equipment specification, analysis and assessment of risks inherent in the operational process of hydrocarbon transportation and storage, preparation of SOPs (Standard Operating Procedures), personnel training plans, equipment inspection and maintenance programs, and interaction with neighboring communities.

2. OBJECTIVE

To define the process areas of a typical pumping plant, product delivery to third parties, delivery/receipt points, and oil and liquid hydrocarbon storage. For each of these areas, a specific FPS shall be designed, based on the recommendations of Chapter 3 of ARPEL Guidelines, and applicable rules and standards.

3. DEFINITIONS

3.1. Combination Pipelines

Pipe networks intended for the transportation of hydrocarbons or finished products. They may transport gasoline, diesel, fuel oil, kerosene, naphtha, gas oil etc.

3.2. Oil Pipeline

Pipe network intended for the transportation of crude oil.

3.3. Gas Pipelines

Pipes used to transport combustible gases on a large scale.

4. TYPICAL AREAS OF A TRANSPORTATION PLANT

- ✓ Atmospheric storage tanks
- ✓ Cryogenic storage tanks
- ✓ Pressurized storage tanks
- ✓ Main pumps
- ✓ Booster pumps
- ✓ Launching and receiving traps
- ✓ Launching and receiving multiple

- ✓ Filtering, measurement and marking area
- ✓ Gas flare system
- ✓ API and/or CPI separator
- ✓ Tanker truck loading and/or unloading facilities
- ✓ Electric substation and/or transformers
- ✓ Operations room
- ✓ Motor control room
- ✓ Communications room
- ✓ Battery room and/or UPS room
- ✓ Warehouses and workshops
- ✓ Administrative buildings
- ✓ Heliport
- ✓ Generator and compressor area
- ✓ City gate
- ✓ Sump
- ✓ Seaports

4.1. Atmospheric Storage Tanks

4.1.1. Fixed Cone Roof or Dome Roof Tanks

Vertical cylinder-type atmospheric storage tanks, with roof welded to the body or with a self-supporting dome resting on the top edge of the tank casing, designed to operate at maximum internal pressures close to atmospheric pressure.

4.1.2. Fixed-Roof Tank with Internal Floating Roof

Vertical cylinder-type atmospheric storage tanks, as described under 4.1.1, which have an internal floating roof.

4.1.3. Open Floating Roof Tanks

Vertical cylinder-type atmospheric storage tanks, with floating roof, pontoon or double deck, in order to reduce the emissions of vapors from stored products, designed to operate at maximum internal pressures close to atmospheric pressure.

4.1.4. Cryogenic storage tanks

Thermally insulated tanks, cylindrical and vertical, that require a liquefaction and cooling system to reduce the storage pressure, keeping in a liquid state, at a temperature close to -40 °C and pressures close to the atmospheric hydrocarbons that, under ambient conditions, are in a gaseous state. They are intended for the storage of liquefied petroleum gases (LPG).

4.1.5. Containment Dikes

Enclosures surrounding a tank or group of tanks in order to retain the spill of a stored product in the event of leaks or cracking of the tank.

4.3. Pressurized Storage Tanks

Spherical or horizontal cylindrical tanks for storage of very light hydrocarbons, which at atmospheric pressure are in a gaseous state, such as propane, butane and propylene. Taking into account that some facilities handle liquefied petroleum gas (LPG), which in practice is a mixture of propane and butane, NFPA 58 shall be considered as a reference document for fire protection.

4.4. Main Pumps

Pumping equipment whose function is to drive the products handled in the plant (flammable or combustible liquids), in order to transport them by a pipe (oil pipeline, combination pipeline or gas pipeline) to the plant or distribution facilities. The main pumps are generally located in a metal structure house.

4.5. Booster Pumps

Pumping equipment whose function is to transport the products handled in the plant from storage tanks to the main pumps, delivering them with positive head pressure.

4.6. Launching and Receiving Traps

Pipes, valves and appurtenances used for receiving or launching pigs for cleaning or periodic inspection of pipes, oil pipelines, gas pipelines or combination pipelines, as applicable.

4.7. Launching and Receiving Multiple

Pipes, valves and appurtenances used for receiving and distributing products from the transportation line (oil pipelines, gas pipelines or combination pipelines).

4.8. Filtering, Measurement and Marking Area

Area where filtering, measurement and marking of products received and distributed in the plant are performed.

4.9. Gas Flare System

System used to eliminate the gases resulting from overpressure safely and in an environmentally responsible manner.

4.10. API and/or CPI Separator

Rectangular horizontal pool at atmospheric pressure with dividing partitions. This is a gravity separation device designed to separate water/product. All oily waters of the plant are carried to the separator.

4.11. Tanker Truck Loading and/or Unloading Facilities

Area with the necessary infrastructure to deliver and/or receive flammable and combustible liquids to/from tanker trucks.

4.12. Electric Substation and/or Transformers

Electrical facilities necessary to transform the voltage of the distribution system to that required in the plant.

4.13. Operations Room

A room where operational staff, consoles and equipment needed to develop control, supervision and operation actions related to the process of the plant are located.

4.14. Motor Control Room

A room where power and control panels required for the operation of the plant are located.

4.15. Communications Room

A room where the equipment required for voice and data communications of the plant are located.

4.16. Battery Room and/or UPS Room

An uninterruptible power supply is a device to provide power for a limited time during a failure of the main power supply, by means of batteries or other energy storage elements.

4.17. Warehouses and Workshops

- ✓ Warehouse: An area where inputs, equipment, spare parts and tools required in the plant are stored.
- ✓ Workshop: An area intended for the electrical, mechanical and instrumentation maintenance required in the plant.

4.18. Administrative Buildings

An area for the staff and the offices required for the administrative activities of the plant.

4.19. Heliport

A place intended for landing and takeoff of helicopters.

4.20. Generator and Compressor Area

An area where industrial air compressors and backup generators for power supply are located.

4.21. City Gate

A package unit that measures, reduces and regulates gas pressure. It supplies gas to the plants at the required pressure.

4.22. Sump

A tank or container for collection of products through drains, thermal reliefs.

5. SEAPORTS

Maritime terminals for liquid products differ depending on whether hazardous or non-hazardous liquid products are handled. The location of the storage areas shall make reference to the facilities required to handle and store hazardous liquid products, i.e. those that are normally considered flammable, such as liquefied petroleum gas, natural gas, butane, propane, vinyl acetate, hexane, acetone, toluene, etc., or toxic products, such as phenols, nitric acid, carbon tetrachloride, etc. In port facilities, the only non-hazardous products are inert gases such as nitrogen.

The types of wharves are:

- A platform to the side, in cases where the ship draft is appropriate for positioning the ship next to the platform for loading or unloading through flexible hoses or fixed lines.
- Single point mooring (SPM): A floating platform located offshore, which allows large ships to load or unload liquid products or liquefied gases through a system that includes underwater pipelines and underwater and floating hoses.

Side loading

Single point mooring buoys

5.1. Seaport Facilities

Seaports comprise:

- Wharves and related facilities
- Lines for transfer of products from mooring to the storage plant, and if applicable, from the storage plant to the consumption centers
- Storage plant
- Facilities related to the specific features of the exploitation carried out at the terminal

5.2. Mooring

Considering the nature and hazard of products, mooring points are generally at the most distant areas from the main core of the ports.

- ✓ Single Point Mooring (SPM) outside the port
- ✓ Offshore structure, outside the port, which allows loading and unloading products
- ✓ Docks sheltered artificially in navigable waters as anchorage or for easy loading andunloading.

5.3. Types of Wharves

Wharves are not substantially different from conventional wharves, except that no immediate esplanades or areas for maneuvers of vehicles or cranes, nor warehousing areas, are required for liquid products. Pile wharves and concrete caisson wharves are the most usual types for loading and unloading liquid products.

The mooring dock contains the whole system of valves of the terminals of the piping reaching the wharf, together with other control and security elements, such as pressure gauges, drains, records, water inlets, etc. To facilitate the management of the flexible hoses that connect the heavy land pipes with the ship, small props are installed for hoisting and drawing.

The lighting of the wharf, regardless of the lighting of the ship, and given the security conditions required, is usually implemented through high towers away from the mooring point which achieve the required light with high power projectors.

Between the mooring point and the storage or processing plants the connection is established through a set of pipes commonly referred to as "rack".

5.4. Storage Plant

Sites where product tanks are located while waiting for the ship or land destination, designed for installation in the most distant areas of ports and, of course, far from urban or work centers.

The hazardous liquids storage plants arrangement in the same area has the additional advantage of simplifying specific surveillance, monitoring of vehicle traffic, lightning, etc. The simplification of common services such as fire protection, alarms, decanting tanks, services of ocean outfalls, etc. is another reason to take into account.

5.5. Distribution of Areas

With reference to security conditions, there are two types of areas in the plant: on the one hand, those where there may be flammable or explosive vapors occasionally or in abnormal circumstances, and on the other hand, those where there may be gas or other fuels in the course of the operations of the plant.

a) **Loading and Unloading Areas:** Areas where products from transportation units to storage areas and vice versa are handled. They comprise distribution elements, loading arms, pumps located in loading areas, compressors, sampling areas, stations for filling and emptying of drums and, if these are placed in a closed building, the whole of the building, although other functions are carried out in it.
b) **Pumping Areas:** Pumping areas are specifically those that are not intended for loading and unloading, or those located outside the loading and unloading area, even if they are intended for these purposes. These areas are similar to gas compression areas in the gas storage plant. If the pumps are placed in a closed building, the pumping area shall be the entire building.
c) **Areas with Open Fires:** Areas where there may be flames or sparks, as well as any place in the open air where flames or sparks may occur, or that feature surfaces that may reach a high temperature. Furnaces, boilers, forges, fixed or mobile gasification units, even those in gas flares, explosion motors, internal-combustion motors, even if no safety features are provided, electrical installations and sites or premises where fires or smoking are allowed, are examples of these areas.
d) **Other Areas:** Other areas are those for mixtures of products similar to pumping products, fire protection water pumps, sludge deposits and neutralizers deposits in hazardous reagents storage plants, etc.

5.6. Tanks

Storage can be made in aboveground or underground tanks. Aboveground storage tanks can be with open fixed or floating roof, or transportable containers that may be outdoors.

5.7. Containment Dikes

Enclosures that surround a tank or group of tanks in order to retain the spill of a stored product in the event of leaks or cracking of the tank.

5.8. Sundry Facilities

- ✓ Administration buildings
- ✓ Safety lighting
- ✓ Waiting area for freight vehicles
- ✓ Protective separation fences between plant and the outside and between different areas of the plant

Cables are usually sheathed (aluminum braid and metal strip), with fire-resistant fitting installed, i.e. sheaths in the form of short caps, made of special material, that melt and interrupt the spread of the flame. Flameproof or increased safety systems are applied to all electrical elements.

Fire Protection Systems in Oil and Liquid Hydrocarbons Transportation Facilities

Chapter 3: Fire Protection Systems

1. INTRODUCTION

The term *Fire Safety and Protection* refers to the passive and active fire protection systems, and to the skills of the brigades that shall be implemented to mitigate or control a fire that may affect people, the environment, communities and facilities. The purpose of these measures is to take actions to minimize the potential impacts or consequences of a fire.

Fire protection measures are implemented through actions that are based on:

- Analysis and evaluation of the risks of the processes involved
- Fire protection engineering
- Supply and installation of fire protection systems
- Inspections, testing and maintenance
- Personnel training

This document is intended to be a technical guide to facilitate the conceptualization of the engineering designs for fire protection systems at oil and liquid hydrocarbons transportation and storage facilities of ARPEL member companies.

2. OBJECTIVE

To provide technical guidelines and definition of the minimum criteria to be taken into account for the design of fire protection systems in facilities for transportation and storage of oil and liquid hydrocarbons, allowing the definition of the minimum regulatory requirements based on the standards of NFPA (National Fire Protection Association), API (American Petroleum Institute) and the good practices of the oil & gas industry.

3. SCOPE

- Establishing the requirements and minimum parameters for the design of fire protection systems
- Defining the level of fire protection required according to the type of facility
- Listing the main types of fired protection systems and equipment
- Evaluating the philosophies of operation of fire protection systems.

4. REFERENCED PUBLICATIONS

The latest or equivalent edition of the following documents has been used as reference for the development of these Guidelines.

Standard	Title
NFPA	**NATIONAL FIRE PROTECTION ASSOCIATION (NFPA)**
NFPA 1	Uniform Fire Code
NFPA 10	Standard for Portable Fire Extinguishers
NFPA 11	Standard for Low, Medium, and High-Expansion Foam
NFPA 12	Standard on Carbon Dioxide Extinguishing Systems
NFPA 13	Standard for the Installations of Sprinkler Systems
NFPA 14	Standard for the Installation of Standpipe, Private Hydrant, and Hose Systems
NFPA 15	Standard for Water Spray Fixed Systems for Fire Protection
NFPA 16	Standard for the Installation of Foam-Water Sprinkler and Foam-Water Spray Systems
NFPA 20	Standard for the Installation of Stationary Pumps for Fire Protection
NFPA 22	Standard for Water Tanks for Private Fire Protection
NFPA 24	Standard for the Installation of Private Fire Service Mains and Their Appurtenances
NFPA 30	Flammable and Combustible Liquids Code
NFPA 58	Liquefied Petroleum Gas Code
NFPA 70	National Electrical Code
NFPA 72	National Fire Alarm Code
NFPA 101	Life Safety Code
NFPA 251	Standard Methods of Tests of Fire Resistance of Building Construction and Material
NFPA 497	Recommended Practice for the Classification of Flammable Liquids, Gases, or Vapors and of Hazardous (Classified) Locations for Electrical Installations in Chemical Process Areas
NFPA 551	Evaluation of Fire Risk Assessments
NFPA 850	Recommended Practice for Fire Protection for Electric Generating Plants and High Voltage Direct Current Converter Stations
NFPA 2001	Standard on Clean Agent Fire Extinguishing Systems
NFPA HANDBOOK	Fire Protection Manual
API	**AMERICAN PETROLEUM INSTITUTE (API)**
API 580	Risk-Based Inspection
API 581	Risk-Based Inspection Base Resource Document
API RP 2021	Management of Atmospheric Storage Tank Fires
API RP 2030	Application of Fixed Water Spray Systems for Fire Protection in the Petroleum and Petrochemical Industries
API RP 2218	Fireproofing Practices in Petroleum and Petrochemical Processing Plants
API STD 2510	Design and Construction of LPG Installations
API RP 2510A	Fire-Protection considerations for the Design and Operation of Liquefied Petroleum Gas (LPG) Storage Facilities

Table 1 Referenced Publications

5. GENERAL REQUIREMENTS

The adoption of the criterion shall be defined in each installation according to technical and economic considerations in order to achieve the best results on the basis of a risk analysis of the areas to be protected. The guidelines for the adoption of a specific design criterion for fire protection systems is based on the evaluated risk analysis, the technical and economic evaluation and the compliance with the minimum criteria set out in these Guidelines, following a recommended order of compliance:

1. Applicable law, without exception
2. Corporate standards of the company
3. NFPA and API standards, when there are gaps in the above-mentioned criteria
4. Design by performance, when particular situations of the installation are not covered by the regulations

5.1. COMPETENT AUTHORITY

For the purposes of these Guidelines, each facility shall have an organization, office or individual responsible for enforcing the requirements of codes or standards, and for the adoption of equipment, materials, installation or procedures. The fire protection specialists (Technical Authority) should have a minimum specific experience in design, installation, operation, inspection, testing and maintenance (ITM), equipment and fire protection systems in the oil and gas industry, in order to ensure the availability, maintainability and continuous improvement of the same.

In addition to managing, directing and controlling the internal and corporate guidelines, policies and regulations with regard to Integral Fire Protection Management, the fire protection specialists shall review and endorse new projects and refitting, improvement and maintenance processes that involve acquisitions, extension and/or modifications to the existing fire protection systems. They shall participate in the fire risk analysis and in the development of operational procedures.

They shall also guarantee the technical assurance of conceptual, basic and detail engineering for new projects, extensions and modifications, based on the recommendations defined by this Chapter and the applicable recommendations of NFPA and API, as the case may be, the best practices of the oil and gas industry and other fire protection regulations. These professionals shall coordinate and ensure the implementation of training and strengthening of skills in fire emergency care and shall have the authority to enforce domestic requirements and standards for the development of precommissioning and commissioning of fire protection equipment and systems.

6. PASSIVE FIRE PROTECTION SYSTEMS

6.1. DESIGN BASES FOR PASSIVE FIRE PROTECTION SYSTEMS

Passive fire protection systems are one of the options to mitigate fire damage, offering protection against radiation for a limited time and a specific degree of exposure. They are mainly related to the initial design of an installation, where factors such as equipment selection, location, separation distances and drain points are of great importance to reduce the levels of risk and establish an adequate control of the emergency. However, it is necessary to ensure the implementation of additional protection mechanisms in order to improve the ability to maintain the mechanical integrity of the equipment and structures during a fire.

The main value of fire protection is carried out during the early stages of a fire, when efforts are directed mainly to the shutdown of process units, the insulation of the fuel flow and the actuation of the fire extinguishing systems of the affected area. Based on the foregoing, it shall be ensured that the equipment and structures exposed to the effects of radiation by fire do not collapse and generate damage to the installation and injuries to personnel, and also to prevent the escalation of the fire to an unacceptable level, offering protection for a limited period of time, which ensures the implementation of fire control and extinguishment measures.

The performance of an analysis of the consequences to examine the different fire scenarios and determine the equipment and structures that will be affected by radiation during a fire event is recommended. The selection of the levels of protection required shall be based on the likelihood of a fire and the potential impact of damage on each analyzed scenario.

It is recommended that passive fire protection systems comply as a minimum with the following:

- Preventing or delaying the transfer of heat from the site of the fire to adjacent areas, equipment and structures
- Keeping the load capacity of the supports of a fireproof structure or barrier for a minimum period of thirty (30) minutes or more, depending on the operating conditions and design
- Maintaining the integrity of the fire barrier in anticipation of the transmission of flames, smoke, heat and hot gases, (sealing of intakes of electrical lines, etc.)

Some of the elements to be protected are the following:

6.1.1. ATMOSPHERIC STORAGE TANKS

For this type of storage tanks, the following recommendations should be taken into account:

- With regard to the control of spills, the NFPA 30 standard shall be complied with to determine the size and capacity of the containment dikes around the tanks.
- With regard to spacing between tanks, it is important to take into account the levels of radiation obtained from the analysis of consequences, which will determine the minimum distance between hydrocarbon storage tanks to avoid the need to implement cooling rings.

6.1.2. TRANSFORMERS

For the installation of transformers, the following recommendations should be taken into account:

- The recommendations of NFPA 850 regarding the minimum clearance and fire walls between transformers and for separation between neighboring buildings shall be complied with.

6.1.3. PROTECTION OF METAL STRUCTURES

- For the protection of the columns of the main process pumps houses, the definition of the type of material to be used shall be in accordance with the recommendations of API 2218 in order to prevent or delay the transfer of heat from the burned area to the structure of the pump house.
- For prevention of the transmission of flames, smoke, heat and hot gases, the installation of fire barriers (fire seals) ensuring the sealing of electrical conduits, cable trays, trenches (ditches), etc. is recommended inside areas such as operations room, cable tray basement, motor control room, communications room, batteries or UPS room.

6.1.4. DESIGN CONSIDERATIONS

- The extension of the fireproof areas around equipment and structures, including the fire protection level, shall be indicated by the designer on construction schemes and drawings.

- The type of fire-resistant material and its construction method shall be specified by the designer. Heat transfer calculations shall be performed to determine the insulation thickness according to the radiation radii.
- The competent authority, with the support of the designer, shall determine if structural elements or reinforcements are required in fire protection areas.

7. ACTIVE FIRE PROTECTION SYSTEMS

Protection forms which purpose is to extinguish the fire through physical - chemical mechanisms. They are classified as follows:

7.1. WATER-BASED SYSTEM

This Section establishes the design bases for water-based fire protection systems for a typical pumping and storage plant for oil and liquid hydrocarbons.

7.1.1. WATER SUPPLY

The following aspects shall be considered regarding water sources:

- The water source shall be reliable over time and allow the replenishment of the volume required in accordance with NFPA recommendations. The time defined shall be validated by the competent authority.
- Any water source is adequate in quality, quantity and pressure and can constitute a fire protection water supply (rivers, lakes, wells, aqueducts, sea water etc.).

It is recommended that the use of sea water be considered only as a backup against major fires.

7.1.2. WATER STORAGE

The water stored for the fire protection system shall be exclusively used for this purpose.

The volume of fire protection water shall be dimensioned in accordance with the consumption in the most critical scenario, according to the results of the analysis of consequences and the development of engineering for a minimum operation time of four hours for crude oil, refined oil or LPG storage facilities in tanks of greater capacity than 20KBl. The storage limit shall be checked according to the laws of the area of application of these Guidelines.

For pumping facilities, facilities for delivery of the product to a third party and delivery/receipt of product whose storage capacity is less than 20 KBl, it is recommended that the volume of fire protection water be dimensioned in accordance with the consumption in the most critical scenario, according to the results of the analysis of consequences and the development of engineering for a minimum operation time of one hundred and thirty minutes (130 min), pursuant to API 2021 (API states 55 minutes and 10 additional minutes for cooling and assurance for emergency brigades, for a total of 65 minutes, which added to a safety factor of 100 % over the established time of 65 minutes results in a fire protection water volume for 130 minutes).

Fire protection water volumes may vary depending on an analysis approved by the competent authority. Compliance with any of the above specifications is recommended.

Compliance with NFPA 22 is recommended for the design, construction and maintenance of fire protection water tanks.

Minimum requirements for fire protection water storage tanks:

- Water level indicator for atmospheric tanks according to NFPA 72
- Water level indicator for pools and atmospheric tanks
- Discharge piping (control valve and check valve)
- Fill piping
- Overflow piping
- Opening for cleaning
- Drainage piping
- Anti-vortex plate (suction tanks)
- Ladders shall be installed for atmospheric storage tanks in accordance with the requirements of NFPA 22

The location of the tank shall comply with the distances resulting from the risk analysis (levels of thermal impact of thermal radiation and explosion) in such a way that it is not exposed to fire or located in areas of risk that may affect its integrity.

In areas where there are stations, the installation of a cover is recommended; however, this can be omitted in tropical areas provided that the generation of microbial life is avoided in accordance with the recommendations of NFPA 25.

Mechanisms should be implemented to ensure that the water supplied by the fire service main is clean.

Each case may be analyzed with the competent competent authority to determine the volume of water required for each particular case.

7.2. FIRE PUMP UNITS

Fire pump units are governed by NFPA 20, which addresses the selection and installation of stationary pumps for the supply of water for private fire protection and related issues, such as:

- Suction, discharge and auxiliary equipment
- Energy supply
- Electric motor and controller
- Internal combustion motor and controller

7.2.1. DESIGN AND INSTALLATION REQUIREMENTS

- The design and installation of fire pump units shall comply with the provisions of NFPA 20. Pump unit components shall be listed and/or approved for use in fire protection systems.
- Pump units shall be available at all times, even in emergency conditions, so it is recommended that each unit be equipped with an auxiliary pressure pump or jockey pump for automatic startup.
- The fire pump system shall be designed to prevent the common failures stated in NFPA 20.
- The construction materials for fire pump units shall be suitable for safe and efficient operation in case of exposure to marine environment if required. These materials shall be capable of withstanding the environmental conditions and shall not deteriorate at a pace that will impair the efficiency of the unit within its specified life.
- The performance of the fire pump unit shall ensure the supply of water required for the most critical scenario within the installation evaluated.
- The selection of the horizontal and vertical fire pump unit shall not be lower than 90 % of its nominal capacity, nor exceed 120 % of its nominal capacity (e.g. A 1000 unit @ 100 psi could be selected for scenarios that require between 900 and 1,200 gpm). When the scenario demands a flow higher than 120 % of the rated capacity of the pump in existing installations, additional pumps shall be used in accordance with NFPA 20 in order to complete the full flow requirement.

- The discharge head of each pump unit shall be sufficient to ensure a minimum residual pressure of 100 psi at the hydraulically most remote point.
- The suction shall be designed to comply with the regulatory requirements of NFPA 20, and the suction speed shall not be greater than 15 ft/s.
- The discharge rate of the pump unit shall not be greater than 20 ft/s.
- A piping section not shorter than ten diameters equivalent to the suction with no direction changes measured from the pump suction flange shall be available.
- It is recommended that the diameter of the suction pumping in the upstream stretch of the pump suction flange, with a length equivalent to 10 diameters, be larger than the diameter of the unit flange in at least one commercial diameter. This shall be checked hydraulically and according to the particular conditions of each installation.
- The maximum pressure at zero flow, plus the elevation-adjusted static pressure (maximum height of static head of storage tank for fire protection water) shall not exceed the working pressure of the system components.
- The mounting of fire pump units (pumps, controllers, motors and piping) shall allow access for operation and maintenance.
- Horizontal centrifugal pumps shall not be used where there is a condition of negative suction.
- Horizontal centrifugal pumps shall be selected considering that the minimum level of suction shall be 1 ft above the pump shaft.
- When no positive suction head is available, vertical pumps whose drivers are below the dynamic level should be selected.
- According to NFPA 20, no alternative energy source will be required for the main pump units driven by electric motors if there is a backup pump driven by a diesel motor, steam turbine or electric motor with an alternative source of power.
- The main pump units shall be operated with electric motors when the source of power is reliable and powered by a separate circuit.
- When no reliable source of power is available, the pump units shall be operated by diesel motors or steam turbines.
- A pressure maintenance jockey pump shall be available for pump units according to the recommendations of NFPA 20.
- The main fire protection pump and the redundant fire protection pump shall not be considered pressure maintenance pumps.
- With regard to the design of the suction head that feeds several fire protection water pumps installed to operate simultaneously, these shall operate at 150 % of the rated nominal flow of the sum of all the main pumps.
- For the design of a suction head feeding more than one pump, a symmetric configuration in accordance with the parameters established by NFPA 20 is recommended.
- The design should consider two or more fire pump units in parallel to meet the water demand required for the most critical scenario within the installation evaluated, provided that in scenarios of lower requirement in the installation the system operating pressures are not exceeded. The set point values shall be adjusted in order to avoid the simultaneous start up of all pumps when the flow requirements are low.
- The pressure relief valves shall not be used as mechanisms for not exceeding the working pressure of the components of the fire service main.
- The design shall include the location and type of brackets required to prevent pipes from transferring stress to the pump housing.
- It is recommended that one or several fire pump units be protected against weathering by means of a housing or cover suitable for this purpose.
- In suction piping in horizontal pumps, air pockets and the formation of vortex shall be avoided.

- The minimum suction pressure of the pump units shall be 0 psi (0 bar) when these are operating at 150% of their rated capacity.
- Dimensioning of the piping hydraulically from the discharge flange at the pump housing to the outlet of the head valves for no less than 150 % of rated flow is recommended for testing pump head design.
- When fire pump units are to be operated with diesel or electric motor with variable speed control, a listed or approved pressure relief valve shall be installed when the closing pressure at 121 % of the maximum pressure without flow plus the elevation-adjusted suction static pressure exceed the maximum working pressure of the elements (pipes, valves, discharge equipment, etc.). The probability of over speeding of these motors is currently very low, so the relief valve may discharge to a rain water ditch at the pump housing or may return to the tank, in both cases remaining visible to the equipment operator.
- No shut-off or check valves shall be installed before or after pressure relief valves in units with diesel or electric motor with variable speed control.
- Any deviations found during the design and installation process shall be consulted with the competent authority in each area to define the technical and economic feasibility of each installation.

7.3. PRIVATE FIRE SERVICE MAIN

NFPA 14 and NFPA 24 establish the design requirements for private service mains and standpipe and hose systems.

7.3.1. DESIGN AND INSTALLATION REQUIREMENTS

- In accordance with NFPA 24, pipe smaller than 6 in. in diameter shall not be installed as a private service main, and it should be laid aboveground, and only underground at joints or areas where the effects of radiation from a fire may compromise its integrity.
- The selection of the private fire service main material shall be in accordance with NFPA 24. The use of carbon steel is recommended for systems using fresh water, and listed plastic pipes are recommended for those using salt water.
- The private fire service main shall be dimensioned to provide the flow and pressure required in the highest demand scenario for the installation (critical event).
- A hydraulic calculation shall ensure that the private fire service main has the capacity required for the critical event; it is recommended that the software used for this purpose be listed or approved for fire protection systems.
- The selection of quick-acting shut-off valves (less than 5 seconds) is not allowed in the private fire service main, as they generate water hammer, which deteriorates fire protection elements and units. It is recommended that the private fire service main valves be gate valves with extension rod or listed or approved throttle valves.
- The installation of block valves in the private fire service main is recommended in order to enable the use of at least half of the discharge devices protecting against different risks to the installation in case of fire or during maintenance.
- The minimum pressure at the base of the hydrant(s) at the hydraulically-farthest point from the private fire service main with respect to the pumping units shall not be less than 100 psi, in accordance with the specifications of API RP 2001.
- The use of wye-shaped joints or underground pipe sections (using 45° elbows) is recommended to prevent the formation of air pockets.

- The recommended depth for underground pipes is 0.9 m in areas without vehicle traffic and 1.2 m with respect to the highest part of the pipe in the case of joints. The recommended configuration of block valves is as a stand and aboveground, in order to facilitate the inspection and operability of the private fire service main.
- If the private fire service main consists of metal pipes (such as carbon steel pipes) and it is necessary to bury it in case of joints or for protection, it shall be protected against corrosion following the most effective method as required by the National Association of Corrosion Engineers (NACE).
- The private fire service main shall be arranged as rings around the different areas to be protected, guaranteeing the supply to equipment or secondary service mains (cooling rings, foam proportioning rings, etc.), by two lines.
- The location of hydrants in accordance with the levels of radiation obtained from the risk analysis shall be considered in the design: In order to minimize the risks of radiation, overpressure by explosion, impacts by vehicles or other factors that put the mechanical integrity of the piping at risk, the installation of underground piping is recommended.
- The private fire service main layout shall not cross through storage tank dikes, constructions, warehouses, buildings, process ways or process areas.
- The aboveground service main piping shall be properly anchored and supported, and guides shall be available to minimize the effects of the horizontal and vertical oscillatory movement caused during the operation. The installation shall be done in accordance with the parameters set by standards and best practices of the oil and gas industry.
- When the Fire Department has been defined as a secondary protection method for the installation, inlets for fire trucks with compatible fittings as defined by NFPA 1962 and 1963 shall be implemented.
- The design of the private fire service main shall include monitor nozzle hydrants, and these should comply with the following features:
  - Approved one way or Cobra monitor with 1,250 gpm capacity
  - Listed or approved dual jet nozzle (jet and mist mode)
  - Listed or approved shut-off valve with extension rod
  - Listed or approved hose inlet(s) with nominal diameter of 2 1/2" with listed or approved shut-off valve with cap and chain
  - Inlet for fire truck of nominal diameter of 4" to 6" (only applies to facilities where these vehicles are available or have the support of the local Fire Department)
  - Hydrant with a diameter of 4" to 6"
- The capacity of monitor nozzle hydrants shall be determined upon a study of the water consumption in different fire scenarios of the installation, and its location shall be supported by the impact corridors determined upon the consequences stated by the risk analysis. NFPA 24 states that it shall be no less than 40 ft (12.2 m) from the area to be protected. It is recommended that nozzles for pumping installations, delivery of the product to third parties and delivery/receipt points of product whose storage capacity is less than 20 KBl have a minimum capacity of 250 gpm.
- Monitor nozzle hydrants shall be identified with a tag for easy identification in the private fire service main and in the operations room in the system P&ID.
- NH threaded inlets, or inlets used by the Fire Department, are the preferred inlets.

7.4. SPRAY SYSTEMS

NFPA 15 and API 2030 establish the design requirements for water spray systems for fire protection.

7.4.1. DESIGN AND INSTALLATION REQUIREMENTS

- The design of these systems shall be considered for any of the following purposes:
  - Fire extinguishment
  - Combustion control
  - Protection against exposure
  - Control of flammable vapors
- System components shall be selected for a maximum working pressure of 175 psi.
- System components shall be listed and/or approved for use in fire protection systems.
- System components installed outdoors or under corrosive atmospheres shall be made of corrosion-resistant materials, or have corrosion-protection mechanisms shall be in place.
- Water spray systems are not intended to replace the installation of automatic sprinklers. These may be independent or complement other forms of protection, and their use is limited by the nature of the equipment to be protected.
- The specifications of the equipment to be protected and the physical and chemical properties of flammable materials should be considered for the selection, design and installation of the most convenient water spray system for the analyzed scenario.
- The distribution system shall be dimensioned to supply the flows and pressures required in the shortest possible time with all sprinklers open, as the case may be, ensuring a minimum pressure of 30 psi at the most hydraulically-remote point of the main.
- The sprinkler discharge patterns shall overlap, and the discharge should be perpendicular to the surface of the area or equipment to be protected.
- The design shall be based on a hydraulic calculation according to NFPA 15 and/or API 2030, and it is recommended that the software used for this purpose be listed or approved for fire protection systems.
- The design of the sprinkler system shall be calculated according to the equipment or area protected and to the application density defined by NFPA 15 and/or API 2030. The number of sprinklers, their location and the discharge angles shall be calculated on this basis.
- The positioning of the sprinklers shall consider:
  - The shape and size of the area or equipment to be protected
  - The sprinkler design and the characteristics of the water spray model to implement
  - The effect of wind and draft (upward force) of fire on very small or larger drops of water with low initial speed
  - The obstruction or potential loss of the surface to be protected and the increase in the waste of water.
  - The effects of the orientation of the sprinkler on the characteristics of coverage
  - Mechanical damage potential
- Each spray system shall be fitted with a wye-shaped strainer listed and/or approved for use in fire protection systems, in order to retain materials that may obstruct the operation of the sprinklers.
- The installation of a drain valve with a minimum diameter of ¾" at the lowest point is recommended for each sprinkler system in order to drain water to a dumping site for proper treatment before their delivery to a main tributary. The drain valve shall be listed and/or approved for use in fire protection systems.
- Sprinkler systems should be configured with deluge valves and gate valves with extension rod listed and/or approved for use in fire protection systems.
- The location of the gate valves or deluge valves for each sprinkler system should be defined in accordance with the levels of radiation obtained from the risk analysis in order to minimize the factors that put the mechanical integrity of the equipment at risk, in addition to guaranteeing a secure area for the manual operation of the valves.

- The selection of quick-acting shut-off valves (less than 5 seconds) in sprinkler systems is not allowed.
- All spray system valves shall be identified on a permanent basis with weathering-resistant materials.
- Spray system pipes shall be located at sites where there are no possibilities of damage by impact of vehicles in motion or operational conditions. Moreover, mechanisms shall be provided for the dismantling of the system during the execution of protected areas or equipment maintenance routines.
- The selection of the material for the spray system service main shall be in accordance with NFPA 15.
- The materials of the sprinklers shall be bronze, stainless steel or other material ensuring resistance to corrosion.
- The selection of the type and size of sprays shall be based on the following factors, among others:
    - Risk characteristics
    - Discharge pattern and characteristics
    - Environmental conditions
    - Combustible material of the area or equipment
    - System design purpose
- Sprinklers can be installed in any location for suitable coverage of the protected area or equipment, and with this purpose, the spacing between sprinklers shall not exceed 3 m (10 ft).
- The use of listed/approved open-type sprinklers with their main characteristics marked in their body is recommended.

7.5. FOAM SYSTEM

Foam systems are governed by NFPA 11 and NFPA 16, which establish the requirements for the design, installation, operation and maintenance of foam systems of low, medium and high expansion for fire protection.

7.5.1. DESIGN AND INSTALLATION REQUIREMENTS

- Low expansion foam concentrates are recommended for fire protection of the areas where flammable and combustible liquids are handled. The purpose of the design of these systems shall be exclusively the extinguishment of a fire through the formation of bubbles generated by the mixture of water and a low expansion foam concentrate which surface floats on the hydrocarbon burned and at the same time eliminates the air and cools the surface, thus allowing the elimination of the vapors burned to avoid reignition of the surfaces where the fire has already been extinguished.
- The design shall not be applicable to the extinction of three-dimensional oil or gas fires.
- Components and equipment, including foam concentrates, shall be listed and/or approved for use in fire protection systems.
- Foam concentrates shall be certified and compatible with the proportioning and discharge devices selected for each specific case, and they shall not be mixed, in order not to lose their fire-extinguishment properties.
- The foam system shall be dimensioned to provide the flow and volume of foam required in the highest demand scenario for the installation analyzed, taking as a reference the application time and density and the selected proportioning equipment.

- The location of foam proportioning should be established in accordance with the radiation level determined by the risk analysis, so as not to place them in areas exposed to fire or radiation that put their mechanical integrity at risk and may prevent their operation.
- The use of fixed foam proportioning systems is recommended, and these shall include as a minimum a foam concentrate storage tank, a foam concentrate pumping system and/or injection system, and a foam proportioning. These can be classified into the following types:
  - Standard balanced pressure proportioner
  - In-line balanced pressure proportioner (ILBP)
  - Bladder tank proportioner
  - Balanced pressure foam proportioner (BPP)
  - In-line eductors
- If a fixed system protects two or more fire scenarios, a foam distribution head shall be provided to allow isolating the equipment and/or scenarios that do not require protection in case of fire through deluge valves and/or gate valves with extension rod. It is recommended that the head be located as close as possible to the foam proportioning system in order to minimize the loss of foam solution.
- The foam distribution system should not be a ring-type network, and the time of transportation of the foaming solution to the protected areas should be as short as possible, depending on the system configuration and in accordance with the response times established by installation (the best practices of the oil and gas industry recommend times shorter than five minutes). A hydraulic simulation should be carried out to validate the response time for the most hydraulically-unfavorable area with regard to the location of the foam proportioning system.
- The water supply for the foam systems shall be of a quality that does not have adverse effects on the formation and stability of the foam. There shall be no corrosion inhibitors, emulsion of chemicals or any other additive that has not been previously endorsed by the foam concentrate manufacturer.
- A hydraulic calculation shall ensure that the foam distribution system has the capacity required for the critical event; it is recommended that the software used for this purpose be listed or approved for fire protection systems.
- It is recommended to have a reserve of foam concentrate in the quantities and volumes required for each installation, or an external supply with a replacement time of not more than 24 hours, which shall be stored in containers different from the foam concentrate storage tank of the proportioner.
- The selection of foam concentrate, densities and times of application shall be in accordance with the provisions of NFPA 11.
- The selection of the material for the spray foam distribution system shall be in accordance with NFPA 11.
- Drain valves listed and/or approved for fire protection systems shall be available in the lowest points of the foam solution piping to perform the drainage of the piping.
- The installation of a wye-shaped strainer, a check valve, a deluge valve and/or a gate valve with extension rod to the inlet of the selected foam proportioning system is recommended. All accessories and elements shall be listed and/or approved for fire protection systems.
- It is recommended that the foam distribution head and the selected foam proportioning system be protected against the weather by means of a housing or cover suitable for this purpose.
- The use of semi-fixed foam systems is permitted as long as the facility has automotive fire apparatuses equipped to provide the range and volume of dosage required for the largest fire event defined.
- The residual pressure of the private fire service water main at the inlet of the selected foam proportioning system shall not exceed 175 psi.

- To ensure the availability of the standard balanced pressure foam proportioner and the in-line balanced pressure foam proportioner in packaged units, it is recommended to have two pumps driven by an electric motor and a diesel motor, respectively.
- Checking the minimum working pressures required by the manufacturers of the proportioning system is recommended for the design of the foam system, with the purpose of ensuring the range of work required in accordance with the risks to be protected against.
- The maximum allowable pressure in the discharge devices of the proportioning system shall not exceed the value recommended by the manufacturers of the equipment or devices.
- In the case of in-line balanced pressure proportioners, a pressure maintenance pump is recommended for the foam concentrate system.
- The use of new technologies that are not defined by these Guidelines or by the codes and standards applicable to each installation shall be endorsed by the competent authority in the area.

7.5.2. TYPES OF FOAM CONCENTRATES

The low expansion foam concentrate selected shall be listed and approved for use in fire protection systems. The selected concentrate shall not be mixed with different types or brands of concentrate in the storage tank, however, under special conditions, the NFPA 11 standard allows the mixture of different low expansion foam concentrates generated separately during an emergency, which may be applied simultaneously or in sequence.
The recommended foam concentrates are the following:

- Fluoroprotein foam concentrate
- Aqueous film forming foam
- Alcohol-resistant foam concentrate

7.5.3. TYPES OF FOAM DISCHARGE DEVICES

Any deviation from these Guidelines or from the codes and standards applicable to each installation shall be endorsed by the competent authority in each area.

7.5.3.1. Foam Chambers

- Foam chambers shall be listed and/or approved for use in fire protection systems.
- They shall be specified for storage tanks for flammable or combustible liquids according to the parameters of selection and location established in NFPA 11.
- The application density and times shall be in accordance with NFPA 11.
- For fixed-roof tanks, it is recommended that the foam chambers be installed at a height approximately between 8" and 12" (203 and 305 mm) with respect to the roof seal of the tank to prevent the liquid stored in the tank from overflowing toward the foam solution supply pipes.
- When two or more foam chambers are considered, they shall be placed equidistantly around the tank perimeter, and each chamber shall supply a proportional flow according to the number of chambers installed.
- Foam chambers shall have a deflector installed in the internal wall of the protected tank to prevent the submergence of the foam and the agitation of the hydrocarbon surface.
- Drain valves shall be located at the lowest point of the supply lines of the foam chambers for draining of the line.
- The primary protection consisting in foam chambers shall feature mechanisms of additional protection for small spills in accordance with NFPA 11.

- The design should provide for a discharge speed not higher than 20 ft/s (6 m/s), a minimum working pressure of 40 psi at the chamber inlets and a maximum working pressure of 100 psi, in accordance with the technical specifications of foam chamber manufacturers.
- In fixed-roof tanks, foam chambers shall feature a mechanism to avoid the entry of vapors to the pipes which shall be constructed of durable material and allow breakage at a low pressure (usually the range is from 10 to 20 psi).
- In fixed-roof tanks, each foam chamber shall be supplied by a separate line and shall be provided with a shut-off valve located outside the dike and/or at a minimum distance of 50 ft (15.24 m) with respect to the tank wall.
- The fire protection system for floating roof tanks shall be designed to protect only the area of the roof seal in accordance with NFPA 11.
- In floating roof tanks, foam chambers should be supplied with a ring-shaped piping installed around the perimeter of the tank and close to the edge of the roof. This tank, in turn, shall be fed by a single foam solution supply line.
- In the case of dome roof tanks with internal floating roof, performing a risk analysis based on the criteria of NFPA 11 and API 650 is recommended, in order to determine, together with the competent authority in the area, the most appropriate fire protection method for the installation, i.e. to define if the system shall be rated for the protection of the entire tank roof surface or only for the protection of the seal area of the internal floating roof.
- It is recommended that the discharge deflectors installed inside geodesic dome roof tanks with internal floating roof be designed to allow the roof to pass above the deflector with no damage.
- For protection of tanks containing flammable or combustible liquids that require alcohol-resistant foam concentrates, the application rates and time required shall be those established by foam manufacturers.
- In cone roof tanks, the supply lines of the foam chambers should be laid underground in order to avoid breakdowns caused by the detachment of the roof.
- In semi-fixed systems, the supply lines of the foam chambers should feature siamese check valves with cover located in such a way as to enable the positioning of the fire truck on various fire-fighting fronts.
- Connections for 2 ½" hose with cap and chain at the top of the floating roof tanks are recommended for the development of fire-fighting maneuvers with hoses, in accordance with the recommendations of NFPA 11.

7.5.3.2. Foam Monitors

- Foam monitor components shall be listed and/or approved for use in fire protection systems.
- The application rate and the times shall be in accordance with NFPA 11, according to the specific type of foam concentrate.
- Monitors shall be located outside the dike when designed as a means of protection against fire of storage tank dikes.
- Foam monitors can be used as a means of primary protection for storage tanks of flammable or combustible liquids with a diameter not larger than 60 ft (18 m).
- According to the type of foam concentrate selected for the application with monitors, Hydrofoam nozzles shall be selected for synthetic foams and handline low-expansion foam nozzles for application of fluoroprotein foam concentrates. In all cases, the components shall be listed and/or approved for use in fire protection systems and shall be compatible with the specific foam concentrate.
- Hydrofoam nozzles have the advantage of reaching farther than handline foam nozzles, therefore, when selecting the type of foam concentrate and its application with foam monitors

- hydrants, the certifications and listing of equipment should be checked to ensure the coverage of the protected area.
- For fire protection of marine and river loading terminals, foam monitors - hydrants should be installed on towers of at least 1,000 gpm (3800 L/min) remotely operated for protection of the wharf and the ship deck. The installation of oscillating monitors is recommended for protection of the wharf in case of spill.
- The application rate and time for protection of areas or equipment containing flammable or combustible liquids that require alcohol-resistant foam concentrate shall be those established by foam manufacturers.

7.5.3.3. Foam-Water Sprinkler Systems

The installation of fire protection foam-water sprinkler systems is recommended for protection of main pump houses and tanker truck loading and unloading facilities, and their installation shall comply with the provisions of NFPA 11, NFPA 13 and NFPA 16.

7.5.3.4. Design and Installation Requirements

- A hydraulic calculation shall ensure that the foam distribution system has the capacity required for the critical event; it is recommended that the software used for this purpose be listed or approved for fire protection systems.
- System components shall be listed and/or approved for use in fire protection systems.
- The selection of the material for the spray system service main shall be in accordance with NFPA 13 and NFPA 16.
- Upright or pendent foam-water sprinklers with a parabolic discharge pattern in the downward direction are recommended. They shall be aspiration open-type sprinklers with deflectors to produce the required discharge pattern.
- The foam system shall be dimensioned to supply the flows and pressures required in the shortest possible time with all sprinklers open, as the case may be, ensuring a minimum pressure of 30 psi at the most hydraulically-remote point of the sprinkler system.
- The extinguishment rate and times shall be in accordance with the recommendations of NFPA 16.
- Foam-water spray systems shall be fitted with a wye-shaped strainer listed and/or approved for use in fire protection systems, in order to retain materials that may obstruct the operation of the sprinklers.
- Drain valves shall be located in the lowest point of the supply lines of the spray system for draining of the line.
- The sprinkler discharge patterns should overlap, and the discharge shall be perpendicular to the surface of the area to be protected.
- The maximum area of design for a sprinkler system shall not be larger than 5,000 ft^2 (465 m^2). The use of two or more sprinkler systems fed from independent lines shall be considered for larger areas.
- The separation between sprinklers shall not be larger than 100 ft^2 (9.3 m^2), and the separation between branches of sprinklers shall not exceed 12 ft (3.7 m).
- System components installed outdoors or under corrosive atmospheres shall be made of corrosion-resistant materials, or corrosion-protection mechanisms shall be in place.
- Foam-water sprinkler systems should be configured with deluge valves and gate valves with extension rod listed and/or approved for use in fire protection systems.

- The operation valves of the foam-water sprinklers shall be located in safe areas in accordance with the radiation level determined by the risk analysis, so as not to place them in areas exposed to fire or radiation that put their mechanical integrity at risk and may prevent their operation.
- The application rate and time for protection of areas or equipment containing flammable or combustible liquids that require alcohol-resistant foam concentrate shall be those established by foam manufacturers.

7.6. FIRE AND GAS DETECTION AND ALARM SYSTEM

The purpose of fire and gas detection and alarm systems is to supervise, monitor, alert, control and prevent events and/or disasters caused by the presence of flammable gas mixtures from hydrocarbons that could eventually come into contact with ignition sources in process areas. These systems must also control and monitor signals from detection devices, fire pumps, foam proportioners, deluge valves and clean agent systems, and generate signals by means of notification and alarm equipment. They shall feature a control panel to notify and record the signals to operators by means of a human-machine interface to observe the protected areas and the location of equipment on a graphic format that shows the complete installation with the same ability to notify, monitor and control the equipment and devices in the field. The entire system must be fully functional in accordance with NFPA 72.

- The basis for the design of a fire and gas detection and alarm system should be a risk analysis enabling the identification of radiation, explosion and gas dispersion levels to which the equipment will be exposed, based on a qualitative and quantitative analysis of each installation.
- A method of operation should be established to ensure the safety of people, the protection of the facilities and the environment, and the definition of the location of the equipment and devices of the fire and gas detection and alarm system in the installation evaluated.
- The equipment and devices of the fire and gas detection and alarm system shall be listed and/or certified for installation in high-risk areas in accordance with NFPA 70, they shall be compatible to function as a system, and if possible, they should be from the same manufacturer.
- The control panel of the fire and gas detection and alarm system shall be listed and/or certified for fire detection, alarm and water, foam and clean agent fire extinguishing systems.
- All equipment and devices shall be properly identified, and the attachment of tags and/or labels shall be in accordance with the specifications of each company.
- The fire and gas detection and alarm system shall be fitted with a secondary power source with a minimum of 24 hours and 5 minutes of standby operating power, which shall provide the necessary power to feed all the elements of the system and shall be for the exclusive use of the fire protection system.
- The transfer between the main and the secondary power source shall be automatic, and in no case shall this cause a disruption in the settings of any system components.
- The results of the risk analysis and the impact corridors defined in such document (radiation and gas dispersion levels) shall be used as the basis for selection of the detector type and coverage, with the purpose of minimizing false alarms and covering all areas of risk of the plant.
- A cause-effect matrix shall be developed for each project, and it shall be approved prior to its implementation by the fire protection specialist of each company.

7.6.1. FLAME DETECTORS

A flame detector is an infrared and/or ultraviolet wave-sensing fire detector that detects the radiant energy emitted by a flame. Its activation confirms the start of a fire on process units or equipment in operation.

- The location and installation of flame detectors shall be the result of an evaluation that includes all areas of coverage. Any interference shall be avoided and the area to be protected shall be fully covered.
- Flame detectors should have mechanisms to avoid the condensation of moisture on the lens of the sensors.
- Detectors should have a minimum range of vision of 90° horizontally and 90° vertically.
- Flame detectors shall not be affected by solar radiation, radiation generated by arc welding, X-rays and hot surfaces, and their actuation time in case of fire shall be within 10 seconds.
- It is recommended that detectors be installed in such a way that the access of personnel for maintenance and calibration be enabled. In addition, during the installation, it shall be checked that the cone of vision is not blocked by structural elements or equipment.
- It is recommended that detectors be fitted with a swivel stand to facilitate their rotation and adjustment in the field to direct them toward the areas under risk to be protected, and that materials be resistant to the environmental conditions of the installation area.
- Detectors shall be listed and/or approved for use in fire protection systems.

7.6.2. LINE-TYPE HEAT DETECTORS

A heat-sensitive cable is a line-type device comprising two current-carrying wires individually isolated with a heat-sensitive polymer and twisted to create pressure between them. When the rated temperature is reached, the polymer gives way to this pressure, allowing the contact of the current-carrying wires and activating the alarm signal.

- It is recommended that heat-sensitive cables be installed in the seal perimeter in floating roof tanks.
- A line-type heat detector should be installed in cable trays requiring heat detection in accordance with the design and installation criteria of the manufacturer.
- It is recommended that an end-of-line device fitted with alarm and pre-alarm test switches, and duly certified for classified areas, be installed in the field.
- The selection, supply and installation of the line-type heat detector should be based on the requirements of the manufacturer and of NFPA 72.

7.6.3. SPOT-TYPE HEAT DETECTORS

Rate compensation detectors that actuate when the surrounding temperature reaches a predetermined level, and the rate-of-temperature rise does not affect the response.

- They are recommended for installation in battery rooms and closed areas, such as electrical generator rooms.

7.6.4. RATE-OF-RISE DETECTORS

Detectors that respond when the temperature rises at a rate exceeding a predetermined value, regardless of the initial level. Another example are combination rate-of-rise and fixed-temperature heat detectors.

- They are recommended for installation in transformers that require a fixed fire protection system, according to design and installation criteria of the manufacturers.

7.6.5. PHOTOELECTRIC AND IONIZATION SMOKE DETECTORS

This type of detectors are used for indoor environments, they allow early smoke detection through the scattering of a beam of light or the conductivity of combustion particles.

- Detectors shall be listed and/or approved for use in fire protection systems.
- Smoke detectors shall only be installed in the direction for which they have been certified.
- The following factors about the area to be protected shall be considered for the location and distribution of smoke detectors: materials and shape of roof and walls, height of the area, air conditioning system and ventilation, classification of process, and fumes that occur in the area (dust, normal smoke part of the welding process), among others.
- Each sampling port of an air sampling–type smoke detector shall be treated as a spot-type detector for the purpose of location. Maximum air sample transport time from the farthest sampling port to the detector shall not exceed 120 seconds.
- The software for calculations of air sampling-type detection systems shall be listed and approved for use in fire protection systems, in accordance with the brand of the specific equipment.
- It is recommended that the piping for the air sampling-type detection system be a CPVC piping duly listed for use in fire protection systems.

7.6.6. EXPLOSIVE GAS DETECTORS

This type of detectors shall be used to monitor and control the presence and accumulation of flammable gases in the atmosphere or environment of an open area, initiating alarm if a certain concentration is reached.

- It is recommended that gas detectors initiate an alarm indicating low concentration when 20 % of the LEL has been reached, and an alarm indicating high concentration when 40 % of the LEL level has been reached.
- The installation of the detectors should facilitate access to them for maintenance and calibration.
- Detectors should feature a protection cover against dust and water.
- Detectors shall be listed and/or approved for use in fire protection systems.
- It is recommended that explosive gas detectors be identified with a tag in a stainless steel plate engraving in low relief.
- The selection of the detectors shall be determined by the type of vapor or gas to detect, and the wind direction shall be identified for proper placement.
- It is recommended that open path-type fuel gas detectors, which are suitable for open areas and offer extensive coverage, be installed in LPG storage areas.
- These detectors are not recommended for Class 1 Div 1 areas, according to NFPA 497.

7.6.7. TOXIC GAS DETECTORS

Toxic gas detection systems are used in potentially hazardous applications or environments where specific protection against toxic or flammable gases is required.

Due to the risks inherent in working in confined spaces, protection and prevention measures are of vital importance to ensure occupational safety. In most cases, atmosphere testing with gas-detection equipment is required. Toxic gas detectors can detect up to eight chemical substances: CO, H_2S, CO_2, SO_2, O_3, CL_2, NO, NO_2.

7.6.8. VISUAL DEVICES

Devices featuring visual mechanisms that warn about a hazard through a flashing light for use in industrial and/or administrative areas. In industrial areas, the use of rotatory or intermittent explosion-proof lights is recommended if the average noise level is equal to or higher than 105 dB. The visual signal shall be intermittent and shall not exceed a rate of two pulses per second or 2 Hz, the maximum duration of the pulse shall be 0.2 seconds and its intensity shall not exceed 1000 candelas. According to NFPA 72, lights are required to be clear or white. Visual signals must be installed throughout the administrative, regardless of the level of noise.

7.6.9. AUDIBLE NOTIFICATION DEVICES

Audible mechanism warning about a hazard with a noise level higher than the normal work environment, serving as the official communication on the occurrence of an emergency and/or the requirement to evacuate the site.

Alarms shall have a sound level at least 15 dB above the average ambient sound level or 5 dB above the maximum sound level, having a duration of at least 60 seconds measured 5 feet (1.5 meters) above the floor, in accordance with NFPA 72. In particular cases where the average level of noise in the area exceeds 110 dB, the use of alarms with a higher capacity shall be considered.

7.6.10. MASS NOTIFICATION SYSTEM

System used to provide information and instructions to people in a building, area, site, or other space using intelligible voice communications and including visible signals, text, graphics, tactile, or other communications methods. If installed in process areas, this system shall be explosion proof. The following recommendations should be followed for full functionality of the system:

- The intensity level shall be 5 dB above the maximum ambient sound level or 15 dB above the average sound level The duration shall be at least 60 seconds
- Mass notification and alarm drills shall be developed and documented
- Weekly operation tests shall be performed and recorded
- The mass notification and alarm system shall cover all areas of concern.
- The audible signals of the mass notification system shall be different from other audible signals associated with the process, in accordance with NFPA 72

Alarm Pattern	Event	Description
Continuous transmission and/or voice message with a duration of more than 30 seconds	Emergency	The activation of a continuous audible alarm with a duration of more than 30 seconds means that there is an emergency. The action plan is adjusted to the contingency plan for each area.

Table 2. Alarm Patterns

7.6.11. MANUAL FIRE ALARM BOXES

A manual fire alarm box is a device intended to provide a means to manually activate the fire alarm system. In operational areas, the fire alarm box shall be explosion-proof. By activating the fire alarm at the manual box, the control panel is notified and activates visual or audible signals. Double-checked activation of the fire alarm box is recommended to prevent any accidental activation. The following recommendations shall be followed for selection and installation of manual fire alarm boxes:

- Using the classification of areas of the facility as the basis for the selection of manual fire alarm boxes
- Identifying the distances between manual fire alarm boxes and designated evacuation routes
- Using addressable manual fire alarm boxes in process areas
- Manual fire alarm boxes shall be visible, red, accessible and without obstructions, and shall be listed and/or approved for fire protection systems. They shall only be used as fire alarm initiating devices in fire and gas detection and alarm systems.
- For proper operation, manual fire alarm boxes should be located no lower than 1.07 m and 1.22 m above ground level, as stated by NFPA 72.
- In non-industrial buildings, manual fire alarm boxes should be within 1.52 m of the exit door of each floor.
- The spacing between two alarm boxes shall not exceed 61 m (200 ft) measured horizontally in the same operational area, or as otherwise determined by the competent authority.

7.6.12. POWER SUPPLY SYSTEMS AND TYPE OF CONNECTIONS

To ensure the continued operation of the mass notification systems, these shall be connected to independent sources of energy with autonomous capacity of 24 hours, in case of drop of the main power supply, and shall be capable of operating all alarm notification appliances for 5 minutes in alarm, in accordance with NFPA 72.

All electrical installations associated with the detection and alarm system shall be in accordance with NFPA 70 - *National Electrical Code*. At least two separate reliable power supply sources (main source and backup source) shall be available for the power supply of the fire and gas detection and alarm system, each one with adequate capacity to support the system. The supply sources shall be in accordance with the specifications of NFPA 72. The main power supply shall be powered by an exclusive circuit of the fire and gas detection and alarm system. For the design, supply and installation of the power systems and connections, the following recommendation should be followed:

- In order to ensure the backup power source for 24 hours, a UPS with autonomy for 4 hours should be used according to NFPA 111, and a back-up generator with autonomy of at least 24 hours, which shall not be for the exclusive use of the fire and gas protection system, should be used in accordance with NFPA 72.
- A loop or point-to-point cabling configuration shall be used on the basis of a cost-benefit analysis to determine the most favorable option for the project as regards area of coverage and number of devices of the system.

7.6.13. CONTROL PANEL OF THE FIRE AND GAS PROTECTION SYSTEM

- The control panel shall be listed and approved for use in fire and gas detection systems and activation of water, foam and clean agent fire extinguishing systems. It shall receive analog signals to indicate concentration of hazardous atmospheres and shall indicate malfunctioning and maintenance requirement of the devices.
- The control panel shall have communications ports to deliver at least monitoring signals and/or system on-off indication.
- The control panel shall feature at least the following functions:
    - Activating alarms
    - Monitoring
    - Supervising
    - Activating security systems

  - Indicating failures
  - Programming maintenance routines
  - Button to indicate alarms, silence alarms, and reset control panel
- The control panel of the fire and gas protection system should include a communications module with communications ports that allow its integration with the control panel of the installation process, in order to notify the status and the supervision of the fire protection system alarms.
- The fire and gas protection system should have free space for a capacity of expansion of up to 20 %, so as not to have an impact on the existing equipment.
- It is recommended that the control panel of the fire and gas protection system be functionally independent from the control panel of the process.

7.6.14. HUMAN-MACHINE INTERFACE (HMI)

- The main function of this interface is to allow direct interaction with the controller and the fire and gas system devices, and to allow the activation of extinguishing systems.
- It consists in a computer and a software compatible with the fire and gas protection system controller and allows the interaction between both components.
- The layouts shall be included in all the plant areas to be supervised by the fire and gas protection system. This shall include the detectors, audible and visual alarm devices, deluge valves, switches, transmitters, among others.
- The human-machine interface shall display detailed information on the control panel of the fire and gas protection systems indicating the signals of detectors, alarms due to system failures, water pump signals, UPS signals, monitoring of clean agent fire extinguishing systems, foam proportioner signals, etc.
- To ensure continuous operation and availability of the HMI, the power shall be supplied from a backup source of power in accordance with the recommendations of NFPA 72.
- The remote activation of fire extinguishment systems should be performed through digital buttons at the HMI.
- Alarms shall be available to distinguish between low level and high level explosive atmospheres, according to the LEL percentages defined for each particular case.
- The HMI configuration shall not allow fire protection water pumps to be stopped remotely.
- It shall be ensured that the HMI features the communication ports required for the control panel of the fire and gas detection and alarm system and that they are fully compatible.
- The HMI shall feature a mechanism for recording the events, and means to alert the operator if there is an alert signal indicating a change in the condition of any elements in the fire protection system. One of the means of notification should be an audible signal which remains on until manually disabled.

7.7. CLEAN AGENT FIRE EXTINGUISHING SYSTEMS

Any room, whether attended or unattended, whose main risk of fire is electrical, shall have a fire detection and alarm system.

The installation of clean agent systems is recommended if the following criteria of safe construction are not met, and in accordance with the decision diagram presented below, which shall be assessed by the competent authority:

1. Electrical equipment are selected on the basis of modeling the electrical system, and there are calculation reports on short circuit current, charge flow and load analysis.

2. There are calculation reports supporting the risk analysis and the shielding against atmospheric discharges from the area of the building.
3. The design considers or there is equipment with metal casing, such as metal clad. Equipment: Motor control room, switchgears, communication panels, control and protection panels, electrical and AC/DC panels.
4. Outdoor oil-insulated transformers are separated from the building by fire walls (IEEE 979, NFPA 850 and NFPA 851).
5. The building does not have oil-insulated electrical equipment (drivers, switches, transformers) and there are no open-type battery modules.
6. There is a calculation report on electrical connections that considers the installation, or there are current-carrying wires with flame-retardant insulating materials and fire barriers in insulating bushings.
7. The assembly site in the newly designed or existing electrical control room is a non-classified area.
8. The design provides for a detection and alarm system that meets the requirements of NFPA 72, or there is already an existing system that complies with such requirements.
9. The design provides for the portable fire extinguishers that meet the requirements of NFPA 10, or there are already existing fire extinguishers that comply with such requirements.
10. The area of equipment is separated from other areas of the building(s) by a construction, with a minimum of two hours of fire resistance.
11. The design provides for the signals, emergency lighting, number of doors and anti-panic plates specified by NFPA 101, or these have already been complied with.
12. There is a fire brigade and a contingency plan for the response to and handling of the emergency.
13. The design provides for safety separation for movement of unqualified and qualified staff according to NFPA 70 E, or these items have already been complied with.

A technical-economic risk analysis shall be developed for each particular project, considering variables of strategic importance for the operation of the equipment to be protected, with time for refitting the system, economic losses considering loss of profits of the installation, etc. This allows defining the need for installing total flooding clean agent systems to protect from risks in enclosures, or total flooding clean agent fire extinguishing systems to protect the equipment, which itself has enclosures to contain the agent.

The following flowchart shows the decision-making process regarding the installation of clean agent systems or not.

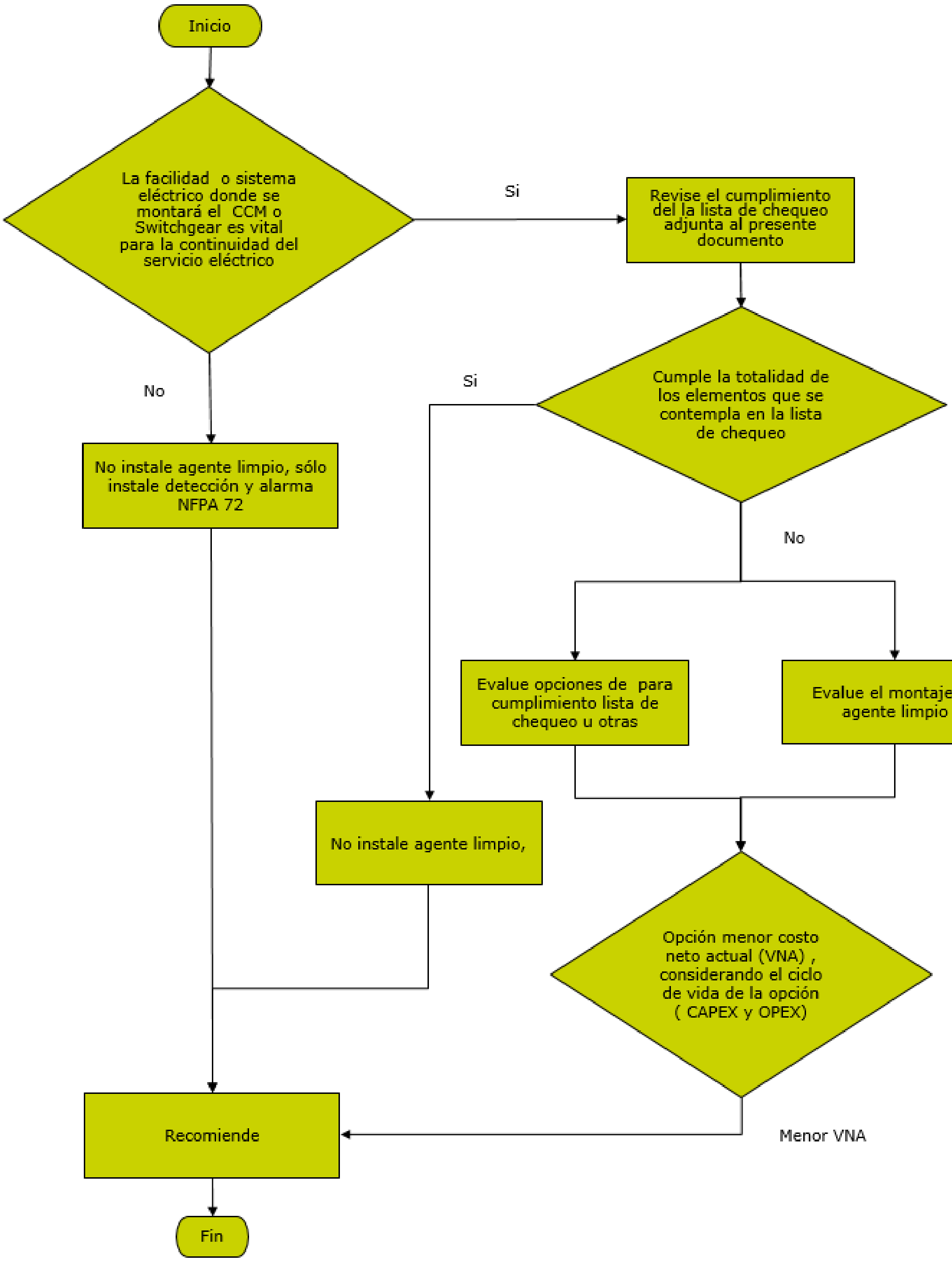


Diagram 1 - Decision-Making Process regarding the Installation of Clean Agent Fire Extinguishing Systems

(taken from document ECP-VIN-P-CIN-GT-001 "Guide for design, procurement, installation of systems, equipment, supplies and accessories against fire" of Ecopetrol S.A. - Colombia)

7.7.1. DESIGN AND INSTALLATION REQUIREMENTS

- The design of clean agent fire extinguishing systems shall be based as a minimum on the parameters and guidelines of the latest edition of NFPA 2001.
- The software for hydraulic modeling shall be listed and approved for use in clean agent fire extinguishing systems.

- All system components, such as nozzles, cylinders, control panel, detectors, manual stations, abort station, audio-visual alarms and other devices and equipment shall be of the same brand in order to ensure the integrity and operational reliability of the system.
- In order to ensure the integrity, quality and functionality of the system, the detailed engineering and installation of a clean agent fire extinguishing system shall be a turnkey project, i.e., it shall cover design, supply and commissioning.
- Clean agent system designers and installers shall have a standing certification of the equipment manufacturer attesting to their design and installation skills, as a minimum.
- The clean agent system shall cover all the areas of fire of the room, i.e., in addition to the main environment, any false floors and trenches (drainage) inside the enclosure evaluated shall be protected.
- CO_2 shall not be used as extinguishing agent in temporarily or permanently attended areas. It may be used as local flooding system in areas such as false floors, trenches (drainage), within cabinets and/or electrical cells and in totally unattended enclosures.
- Simultaneous discharge systems with different types of clean agents shall not be used for protection of the same space and/or room.
- Battery rooms shall be fitted with mechanisms for ventilation to prevent concentrations of hydrogen higher than 1 %.
- For complementary protection, the areas where a clean agent extinguishing system has been installed shall have portable fire extinguishers in accordance with NFPA 10.

7.7.2. DETECTION SYSTEMS

- Detection systems shall be installed to ensure the monitoring of the rooms and to complement clean agent fire extinguishing systems.
- On the basis of the different scenarios that can be found in a plant, listed below are the fire detection systems recommended for each scenario according to their criticality within the process and their applicability.

Area or complex	Conventional smoke detectors	Early smoke detectors	Line-type heat detectors	Spot-type heat detectors
Operations room		X		
Motor control room*	X	X		
Cable tray basements*		X	X	
Trenches (ditches)			X	
False floors		X		
Communications room*	X	X		
Battery room				X

Table 3. Selection of Detection System according to the Area

***One of the two related detection systems may be implemented.**

7.7.3. EXTINGUISHING SYSTEMS

- The extinguishing agent selected shall comply with the specifications defined by NFPA 2001, and shall be listed and approved for use in fire protection systems.
- Performing a cost-benefit analysis before selecting the type of clean agent is recommended, in order to state the economic advantage of the selected agent, both regarding cost per pound of

extinguishing agent and regarding the number of cylinders according to the storage capacity and the area available for their location.

- The designed concentration levels for any type of clean agent shall not exceed the lowest adverse effects level (LOAEL), as defined by NFPA 2001.
- No carbon dioxide-based total flooding clean agent systems shall be installed in temporarily or permanently attended rooms, as this agent reduces the oxygen concentration to levels that can cause injuries to people and even be fatal.
- In order to ensure the tightness of the extinguishing agent in those areas where total flooding clean agent fire extinguishing systems are installed, the tightness of the rooms should be ensured in order to guarantee the minimum concentration as determined by hydraulic calculations. The tightness of the area shall be ensured through the door fan test in accordance with NFPA 2001.
- In addition to the recommendations of the manufacturers of clean agent systems, criteria for design and selection of piping, appurtenances and supports should be applied, in accordance with the *Pipe Design Handbook - For Use With Special Hazard Fire Suppression Systems*.
- Extra cylinders and clean agent in the amount required for each installation should be available. For these cases, the system shall be fitted with check valves according to the required flow and a switch that allows switching the solenoid of the main set of cylinders or the reserve set of cylinders.
- It is recommended that the set of cylinders be configured with the following devices: low pressure switch, discharge pressure switch, liquid level meter, check valves when the system is configured with two or more cylinders, and maintenance switch.
- When the design requires the use of two or more cylinders for the main set of cylinders and the diameters of the pipes are larger than 3", the design should provide for modular discharge, in order to lower the costs associated with larger diameter pipes. For these cases, the system shall feature mechanisms to allow the simultaneous action of the modular systems designed.
- When the room geometry is modified in areas that feature a clean agent fire extinguishing system, the calculation of the extinguishing system shall be checked, and if appropriate, corrective actions shall be taken to ensure the minimum concentration and retention times required for fire extinguishment in accordance with NFPA 2001.
- The maximum discharge time for halocarbon clean agents is 10 seconds, and for inert gases 60 seconds.
- The cylinders and other accessories that make up the discharge header for the clean agent shall feature brackets to resist the force exerted by the pressure of the clean agent when discharged.
- All the clean agent cylinders shall feature a mechanism for electrical and mechanical operation.
- The location of discharge nozzles shall ensure that the clean agent is not discharged directly on the protected equipment. The selection and number of nozzles shall conform to the provisions of NFPA 2001 and the design criteria of the manufacturers of the equipment.
- The set of clean agent cylinders shall be located within the protected area, or as close as possible to the room, and if it is necessary to locate it in external areas, its protection from corrosive atmosphere and constant temperature changes due to the environmental conditions of the installation shall be ensured.
- In accordance with the flowchart on the decision-making process regarding the installation of clean agent systems or not, the special notes for installation in specific areas contained in Table 4 should be checked.

Area or complex	Remarks
Operations room	If a clean agent system is required, it should be implemented only in false floors. The area of consoles does not require a clean agent fire extinguishing system.

Motor control room	If a clean agent system is required, a local flooding system should be implemented in cells and/or electric cabinets that have been determined as critical to business continuity by a technical-economic analysis. If the analysis determines that all equipment are critical, a total flooding system is recommended.
Cable tray basements	A cost-benefit analysis should be performed to implement the most favorable fire extinguishment system for the area, as clean agent systems, automatic sprinkler system, water mist systems or water spray systems may be used in these areas.

Table 4. Special Notes about the Installation of Clean Agent Systems

7.7.4. CONTROL AND ALARM SYSTEMS

- All devices and equipment of the control and alarm system shall be listed and/or approved for use in fire protection systems.
- The control panel of the clean agent system shall be fitted with backup batteries that ensure an autonomy of 24 hours in standby mode and 5 minutes in alarm mode.
- In facilities with fire and gas protection systems, the supervision of the failure, alarm and condition of the control panel of the clean agent system is recommended.
- The control system shall be addressable, in order to optimize its application in case of extensions to the installation, and whenever possible, it shall be installed in the operations room to facilitate the inspection of the system.
- For notification of the pre-discharge period, the installation of audiovisual alarms inside the areas protected with clean agent systems is recommended.
- For notification of the discharge period, the installation of bells outside the areas protected with clean agent systems is recommended.
- Clean agent manual discharge stations shall be located in the exits of protected areas, and shall be accompanied by a dead-man type abort switch.
- Manual discharge stations shall be identified in their body with the sign "Agent Release", and they should be protected with a stopper listed and/or approved for use in fire protection systems, in order to avoid accidental discharges of the clean agent system.
- To ensure the integrity and compatibility of the system, all control and alarm components and equipment shall be of the same brand as the panel of the clean agent system, and/or of a brand approved by the equipment manufacturer.
- The control panel shall monitor all control, detection and alarm devices (cylinder low pressure switch, discharge pressure switch, maintenance switch, early smoke detectors, external power sources, abort switch, among others).
- A loop or point-to-point cabling configuration shall be used on the basis of a cost-benefit analysis to determine the most favorable option for the project as regards area of coverage and number of devices of the system.

8. FIRE EXTINGUISHERS

All fire extinguishers and their distribution and quantity shall comply with NFPA 10 and should be listed and/or approved for use in fire protection systems. The use of fire extinguishers that do not comply with this requirement are not recommended for the protection of oil and liquid hydrocarbons transportation and storage facilities.
It is recommended that the fire extinguishers with a service time exceeding 20 years be replaced, based on performance and reliability criteria.

9. MODIFICATIONS TO EXISTING SYSTEMS

Any modification to an existing fire protection system shall involve the development of an impact analysis to evaluate the effects of fire, explosion or dispersion of gas from the new infrastructure on the existing areas. In addition, a technical study is recommended to analyze the results of performance tests to equipment and existing fire protection systems, records of the inspection, testing and maintenance program, and planned extensions of the installation.
This study shall recommend the different actions required to ensure that the fire protection system provides the flow and pressure required. The modifications of the systems should be in accordance with the recommendations of ARPEL guidelines and applicable NFPA and API standards.
Any modification to an existing fire protection system shall be previously approved by the competent authority in the corresponding area, in order to ensure that the most favorable technical-economic option for the installation is selected.

10. PHILOSOPHIES

10.1. RELIABILITY PHILOSOPHY

All activities shall be designed to ensure the reliability of the equipment and components of fire protection systems, on the basis of the following recommendations:

- Fire protection systems shall be dimensioned to cover the risk of large-scale fire analyzed within the installation.
- Fire protection systems shall have the capacity to operate properly within the times and parameters established for the risk that is farthest from the installation with regard to the fire protection water pumps.
- Fire protection systems shall be available and operational at all times.
- Fire protection systems shall be designed to make a rational use of the resources available, without neglecting the risk.

10.2. OPERATIONAL PHILOSOPHY

Each installation is autonomous as regards the conception of the fire protection philosophy in accordance with the conditions of the area and the type of oil or hydrocarbon that is being managed. However, it is recommended that all systems comply at least with the following aspects:

- The operations staff shall know in advance the operating procedures of the fire protection systems corresponding to each installation, as appropriate.
- The equipment and facilities of the fire protection system shall be for the exclusive use of the system, and shall not be adapted for any other activities.
- As the equipment and components of the fire protection system are an element inherent to the operational infrastructure of a storage or pumping facility. They shall be under the direct responsibility of the highest authority in the area, who shall ensure the inspection, testing and maintenance together with the fire protection specialist of the area in order to ensure the reliability and availability of the system.
- Routine inspection and continuous monitoring of the equipment and components of the fire protection system are recommended. They shall be recorded in documents associated with the quality management system of each company.
- In order to mitigate the uncontrolled losses of water, foam and excessive consumption of energy, control mechanisms should be implemented to monitor the fire protection system on a permanent basis.

11. SUMMARY OF PROTECTION RECOMMENDED PER TYPICAL AREA OF A FUEL TRANSPORTATION AND STORAGE PLANT

ANALYZED AREA	TYPE OF FIRE PROTECTION SYSTEM	RECOMMENDED PROTECTION
Fixed-roof atmospheric storage tanks with a diameter larger than or equal to 60 ft (18 m)	Foam-water	- Foam chambers covering the entire roof surface
		- Hydrants-monitors for application of foam in the dike or hose inlets
		- Cooling rings. Check need with analysis of consequences
	Fire and gas detection	- Audible and visual alarms
		- Manual fire alarm boxes
	Passive fire protection systems	- Spacing between tanks - Containment dikes
Fixed-roof atmospheric storage tanks with a diameter smaller than 60 ft (18 m)	Foam-water	- Hydrants-monitors for application of foam in the tank and dike or hose inlets
		- Cooling rings. Check need with analysis of consequences
	Fire and gas detection	- Audible and visual alarms
		- Manual fire alarm boxes
	Passive fire protection systems	- Spacing between tanks - Containment dikes
Dome roof atmospheric storage tanks with internal floating roof	Foam-water	- Foam chambers covering the entire surface of the roof, or only the area of the roof seal, in compliance with the requirements of NFPA 11
		- Hydrants-monitors for application of foam in the dike or hose inlets
		- Cooling rings. Check need with analysis of consequences
	Fire and gas detection	- Audible and visual alarms
		- Manual fire alarm boxes
	Passive fire protection systems	- Spacing between tanks - Containment dikes
Floating roof atmospheric storage tanks	Foam-water	- Foam chambers covering the roof seal
		- Hose inlets for application of foam in tank roof
		- Hydrants-monitors for application of foam in the dike or hose inlets
		- Cooling rings. Check need with analysis of consequences
	Fire and gas detection	- Line-type heat detection in the roof seal area
		- Audible and visual alarms
		- Manual fire alarm boxes
	Passive fire protection systems	- Spacing between tanks - Containment dikes
Cryogenic LPG storage tanks	Water	- Water spray system - Hydrants - monitors
	Fire and gas detection	- Spot-type explosive gas and/or open path detectors
		- Manual fire alarm boxes
	Passive fire protection systems	- Containment dikes

ANALYZED AREA	TYPE OF FIRE PROTECTION SYSTEM	RECOMMENDED PROTECTION
Pressurized storage tanks	Water	- Water spray system - Hydrants - monitors
	Fire and gas detection	- Spot-type explosive gas and/or open path detectors
		- Open flame detectors
		- Manual fire alarm boxes
	Passive fire protection systems	- Fire proofing of support structures
Main pump house	Foam-water	- System of open sprinklers if they are located in a house, otherwise, hydrants - monitors
		- Hydrants-monitors - Foam-water protection shall be used for liquid hydrocarbons. Only water shall be used for gaseous hydrocarbons.
	Fire and gas detection	- Open flame detectors and/or spot-type explosive gas detectors, as appropriate, and according to the nature of the hydrocarbon, liquid or gaseous
		- Spot-type explosive gas detectors
		- Audible and visual alarms
		- Manual fire alarm boxes
	Passive fire protection systems	- Fire proofing of metal columns of the house
	Fire extinguishers	- Dry chemical powder and CO_2
Booster pumps	Foam-water	- Hydrants-monitors - Foam-water protection shall be used for liquid hydrocarbons. - Only water shall be used for gaseous hydrocarbons.
	Fire and gas detection	- Open flame detectors and/or spot-type explosive gas detectors, as appropriate, and according to the nature of the hydrocarbon, liquid or gaseous
		- Spot-type explosive gas detectors
		- Audible and visual alarms
		- Manual fire alarm boxes
	Fire extinguishers	- Dry chemical powder and CO_2
Launching and receiving traps	Foam-water	- Hydrants-monitors - Foam-water protection shall be used for liquid hydrocarbons. Only water shall be used for gaseous hydrocarbons.
	Fire and gas detection	- Spot-type explosive gas detectors and/or flame detectors, as appropriate
	Fire extinguishers	- Dry chemical powder and CO_2
Launching and receiving multiple	Foam-water	- Hydrants-monitors - Foam-water protection shall be used for liquid hydrocarbons. Only water shall be used for gaseous hydrocarbons.
	Fire and gas detection	- Spot-type explosive gas detectors and/or flame detectors, as appropriate, and according to the nature of the hydrocarbon, liquid or gaseous
	Fire extinguishers	- Dry chemical powder
Filtering, measurement area	Foam-water	- Hydrants-monitors with foam application facilities
	Fire and gas detection	- Spot-type explosive gas detectors and/or flame detectors, as appropriate
		- Manual fire alarm boxes
	Fire extinguishers	- Dry chemical powder

ANALYZED AREA	TYPE OF FIRE PROTECTION SYSTEM	RECOMMENDED PROTECTION
Gas flare system	Water	- Hydrants-monitors
	Fire and gas detection	- Spot-type explosive gas detectors and/or flame detectors, as appropriate, in buffering tank
		- Audible and visual alarms
		- Manual fire alarm boxes
	Fire extinguishers	- Dry chemical powder
API and/or CPI separator	Foam-water	- Hydrants-monitors with foam application facilities
	Fire and gas detection	- Manual fire alarm boxes
		- Open flame detectors
	Fire extinguishers	- Dry chemical powder
Tanker truck loading and unloading facilities	Foam-water	- Sprinkler system, when they are located in a house
		- Hydrants-monitors - Foam-water protection shall be used for liquid hydrocarbons. Only water shall be used for gaseous hydrocarbons.
	Fire and gas detection	- Open flame detectors and/or spot-type explosive gas detectors, as appropriate, and according to the nature of the hydrocarbon, liquid or gaseous
		- Spot-type explosive gas detectors in discharge flange of process pumps
		- Audible and visual alarms
		- Manual fire alarm boxes
	Fire extinguishers	- Dry chemical powder and/or CO_2
Electric substation and/or transformers	Water	- Water spray systems for transformers with storage of over 500 gal of dielectric oil, avoiding the projection on energized parts
	Fire and gas detection	- Rate-of-rise detectors for transformers with storage of over 500 gal of dielectric oil
	Passive fire protection systems	- Separation between transformers and buildings through fire walls
	Fire extinguishers	- CO_2
Operations room	Clean agent	- In accordance with Diagram 1 on clean agent choice
	Fire and gas detection	- Early smoke detection system
		- Audible and visual alarms
		- Manual fire alarm boxes
	Passive fire protection systems	- Fire seals in areas protected with clean agent
	Fire extinguishers	- Clean agent and/or CO_2
Cable tray basement	Extinguishment system	- Extinguishment systems according to Diagram 1.
	Fire and gas detection	- Early smoke detection system and/or line-type heat detector on cable trays
		- Audible and visual alarms
		- Manual fire alarm boxes
	Passive fire protection systems	- Fire seals in areas protected with clean agent
	Fire extinguishers	- Clean agent and/or CO_2

ANALYZED AREA	TYPE OF FIRE PROTECTION SYSTEM	RECOMMENDED PROTECTION
Motor control room	Clean agent	- In accordance with Diagram 1
	Fire and gas detection	- Early smoke detection system
		- Audible and visual alarms
		- Manual fire alarm boxes
	Passive fire protection systems	- Fire seals in areas protected with clean agent
	Fire extinguishers	- Clean agent and/or CO_2
Communications room	Clean agent	- In accordance with Diagram 1
	Fire and gas detection	- Spot-type smoke detectors
		- Audible and visual alarms
		- Manual fire alarm boxes
	Passive fire protection systems	- Fire seals in areas protected with clean agent
	Fire extinguishers	- Clean agent and/or CO_2
Battery room and/or UPS room	Fire and gas detection	- Spot-type heat detectors for areas without ventilation system.
		- Audible and visual alarms
		- Manual fire alarm boxes
	Fire extinguishers	- CO_2
Warehouses and workshops	Water	- Automatic sprinklers according to analysis of consequences and/or fire protection cabinets
	Fire and gas detection	- Spot-type heat detectors / Spot-type smoke detectors / Smoke beam detectors
		- Audible and visual alarms
		- Manual fire alarm boxes
	Fire extinguishers	- Dry chemical powder
Administrative buildings	Water	- Automatic sprinklers according to analysis of consequences and/or fire protection cabinets
	Fire and gas detection	- Spot-type heat detectors / Smoke detectors
		- Audible and visual alarms
		- Manual fire alarm boxes
	Fire extinguishers	- Dry chemical powder and/or CO_2
Heliport	Fire extinguishers	- Foam according to NFPA 418
Generators and compressors	Foam-water	- Foam-water sprinkler system for area of generators installed below covers according to analysis of consequences. (This recommendation does not apply to generators powered by natural gas)
		- Hydrants-monitors with foam application facilities
	Fire and gas detection	- Open flame detectors for area of generators
		- Audible and visual alarms
		- Manual fire alarm boxes
	Fire extinguishers	- Dry chemical powder and/or CO_2
City Gate	Water	- Hydrants-monitors
	Fire and gas detection	- Open flame detectors

ANALYZED AREA	TYPE OF FIRE PROTECTION SYSTEM	RECOMMENDED PROTECTION
		- Manual fire alarm boxes
	Fire extinguishers	- Dry chemical powder
Sump	Foam-water	- Hydrants-monitors with foam application facilities or foam-water sprinkler systems if housing is available (when located in pit).
	Fire and gas detection	- Open flame detectors
		- Audible and visual alarms
		- Manual fire alarm boxes
	Fire extinguishers	- Dry chemical powder and/or CO_2

Table 5. Recommended Protections

Fire Protection Systems in Oil and Liquid Hydrocarbons Transportation Facilities

Chapter 4: Inspection, Testing and Maintenance of Fire Protection Systems

1. INTRODUCTION

The term *Inspection, Testing and Maintenance* (ITM) refers to all actions whose purpose is to keep the fire protection systems in proper condition for fire prevention, control and extinguishment in the various oil facilities. These actions include recurring routines necessary for maintaining the equipment, appurtenances and additional elements in optimal condition that allow their use in an efficient manner at all times, combining technical and administrative tasks.

2. PURPOSE

This Chapter of the Guidelines seeks to establish ITM standards, based on NFPA standards and the best practices in the oil industry, such as the OSHA standards, to all processes of inspection, testing and maintenance of fire protection systems and equipment in order to avoid or minimize the damage to oil facilities.

3. REFERENCED PUBLICATIONS

The applicable sections of the latest approved revision of the standards and codes listed below form part of these Guidelines.

The rules and standards are considered to complement each other, but in the case of discrepancy, the most stringent standard shall prevail.

3.1. NFPA Applicable Standards

- **NFPA 10:** Standard for Portable Fire Extinguishers
- **NFPA 11:** Standard for Low, Medium, and High-Expansion Foam
- **NFPA 11 C:** Standard for Mobile Foam Apparatus
- **NFPA 12:** Standard on Carbon Dioxide Extinguishing Systems
- **NFPA 20:** Standard for the Installation of Stationary Pumps for Fire Protection
- **NFPA 25:** Standard for the Inspection, Testing, and Maintenance of Water-Based Fire Protection Systems
- **NFPA 72:** National Fire Alarm Code
- **NFPA 2001:** Standard on Clean Agent Fire Extinguishing Systems

3.2. NFPA Standards for Fire Apparatus

- **NFPA 1901:** Standard for Automotive Fire Apparatus
- **NFPA 1902:** Standard for Initial Attack Fire Apparatus
- **NFPA 1903:** Standard for Mobile Water Supply Fire Apparatus
- **NFPA 1904:** Standard for Aerial Ladder and Elevating Platform Fire Apparatus
- **NFPA 1911:** Standard for the Inspection, Maintenance, Testing, and Retirement of In-Service Automotive Fire Apparatus

3.3. Other Applicable Standards

- **API RP 2001**: Fire Protection in Refineries
- **API RP 2021:** Management of Atmospheric Storage Tank Fires
- **API RP 2030:** Application of Fixed Water Spray Systems for Fire Protection in the Petroleum and Petrochemical Industries

4. GENERAL CONDITIONS

After a fire protection system has been installed, the next step is to keep it in good operating condition to ensure its effectiveness over time.

Inspection, testing and maintenance refer to a work program developed and performed by qualified personnel, designated by the owner or the owner's representative, in which all components of the systems are inspected, tested and maintained according to that program.

The types of components and systems that shall be considered for the application of these Guidelines are:

- Sprinkler systems
- Standpipe and hose system
- Private fire service main
- Fire protection water pump units
- Water supply
- Spray systems
- Water mist systems
- Foam-water sprinkler system
- Valves, valve components and appurtenances
- Detection and alarm systems
- Fire extinguishers
- Automotive fire apparatus

They refer to the operating condition of fire protection systems as well as the management and reporting of equipment deterioration. They apply to fire protection systems that have been installed correctly, pursuant to generally accepted practice. If a corrective action is required, it shall be ensured that the system operates satisfactorily according to its installation code.

4.1. Inspection, Testing and Maintenance for Fire Protection Systems and Equipment

Fire protection systems and components shall be in line with the following ITM principles:

- **Coverage and scope**: Fire protection systems shall cover over time the risk for which they were designed, prioritizing human life over integrity of the equipment and production assets. They shall also be able to operate correctly to deal with all the risks under consideration, including that taking place at the farthest point with reference to the main installation.
- **Availability:** Fire protection system components shall be operational at all times, an inventory of spare parts (generally recommended by the manufacturer) shall be available, and their operation shall be in the shortest time possible, considering the implementation of complementary measures until they are back in service, and according to their criticality within the system of which they are part.
- **Exclusivity:** All fire protection system components are for the exclusive use of that system.
- **Training:** The personnel with an assigned role shall prioritize training in the operation of the fire protection system and in the performance of their role, prior to their appointment and during their duty in the plant or installation.

- **Monitoring:** The visual inspection of the fire protection equipment shall be part of the routine of the operator of the plant or installation according to the inspection program. Records of these inspections shall be maintained.
- **Accessibility and visibility:** The equipment and elements of the fire protection system to be operated shall be marked, easily accessible and free of obstacles and objects that hinder their operation.
- **Responsibility:** Fire protection systems are the direct responsibility of the owner of the installation or the owner's designated representative.
- **Rationality:** A rational use of the resources involved in fire protection systems shall be made in accordance with their design.

4.2. Type of Maintenance

Fire protection equipment are considered as critical for the operation. Their maintenance shall be in line with the best practices in maintenance engineering, the best practices in maintenance of the oil industry, applicable rules and NFPA standards. In order to enforce the maintenance policies established, different types of maintenance are implemented for fire protection systems in the different oil installations.

4.2.1. Maintenance

A set of operations required for fire protection systems to meet the operating condition for fire protection.

- **Preservation maintenance**: Maintenance designed to compensate for the deterioration caused by use, weather or other causes.
- **Corrective maintenance**: Maintenance designed to correct the defects or faults observed.
- **Predictive maintenance:** Maintenance designed to predict when equipment will be out of service by monitoring their operation and determining their evolution and, therefore, the time when repairs are to be carried out. This maintenance is based on measurements of vibration, noise and heating of the relevant equipment.
- **Preventive maintenance:** Maintenance designed to ensure the reliability of in service equipment before an accident or fault due to deterioration occurs. It is a scheduled operation.
- **Upgrade maintenance**: Maintenance designed to compensate for the technological obsolescence or new demands that, at the time of installation and/or purchase, did not exist or were not taken into account, but are currently required.
- **Opportunity maintenance:** Preventive or corrective maintenance performed during periods when equipment are out of use, making the revisions or repairs required to ensure the proper operation of equipment.

4.2.2. Inspections and Testing of Water-Based Systems

The periodic inspection, testing and maintenance of fire detection and extinguishment systems are essential to ensure their correct operation. These inspections seek to ensure that fire protection systems comply with the good practices in the maintenance of fire protection equipment in the oil industry and the standards applicable to each system.

5. INSPECTION, TESTING AND MAINTENANCE OF FIRE PROTECTION EQUIPMENT

Routine inspection, testing and maintenance of water-based equipment shall be primarily based on NFPA 25, *Standard for Inspection, Testing and Maintenance of Water-Based Fire Protection Systems,* NFPA 72, *National Fire Alarm Code, NFPA 10, Standard for Portable Fire Extinguishers,* and NFPA 1901, *Standard for Automotive Fire Apparatus.* Following is a summary of the above provisions.

The frequency of inspections shall be reviewed and may be modified according to the experience of maintenance in each fire protection system according to the specific condition of each installation.

5.1. Automatic Sprinkler Systems

Item	Frequency	What to observe	APPLICABLE / NOT APPLICABLE	Weighted importance
Inspection				
Gauges (dry, preaction, deluge systems)	Weekly/monthly NFPA indicates in which cases frequency is weekly or monthly	Have they been recently activated? (Check the record / reports of system action) Are there any leaks? Are they in good condition? Calibration? (Check the record)		
Control valves	Weekly/monthly	Have they been recently activated? (Check the record / reports of system action) Are there any leaks? Are they in good condition? Are seals in place and in the correct position?		
Gauges (wet pipe systems)	Monthly	Are they in good condition? Pressure values indicated Date when calibration was checked		
Water-flow devices	Quarterly	Have they been recently activated? Are they in good condition? Are they in normal operating condition?		
Valve supervision devices	Quarterly	Have they been recently activated? Are they in good condition? Are they in normal operating condition?		
Supervisory signaling devices (except valve supervisory switches)	Quarterly	Have they been recently activated? Are they in good condition? Are they in normal operating condition?		
Hydraulic nameplate	Quarterly	Are they in good condition?		
Fire department connections	Quarterly	Are they in good condition? Are they accessible?		
Buildings	Annually	Visual structure inspection		
Hanger/seismic braces	Annually	Visual structure inspection		
Pipes and fittings	Annually	Visual inspection Are there any leaks?		
Sprinklers	Annually	Visual inspection Are there any leaks?		

Item	Frequency	What to observe	APPLICABLE / NOT APPLICABLE	Weighted importance
Spare sprinklers	Annually	Are they accessible? Are they available?		
Valves (all types)	5 years	Visual inspection Are there any leaks?		
Obstructions	5 years	Are there any visible obstructions?		
Testing				
Water-flow devices	Quarterly/semiannually	Check correct operation Record pressure Record flow		
Valve supervision devices	Semiannually	Check correct operation		
Supervisory signaling device (except valve supervisory switches)	Semiannually	Check correct operation		
Main drain	Annually	Check correct operation		
Gauges	5 years	Check calibration		
Sprinklers - extra high temperature	5 years	Check correct operation		
Sprinklers - fast response	At 20 years and every 10 years thereafter	Check correct operation Record response time		
Sprinklers	At 50 years and every 10 years thereafter	Check correct operation		
Maintenance				
Valves (all types)	Annually or as needed	Operation at 100 % Interior cleaning Maintenance of gaskets		
Low point drains (dry pipe systems)	Annually or as needed	Start and check		
Obstruction investigation	5 years or as needed	Cleaning Check sources of obstructions found		

Table 1. Inspection, Testing and Maintenance of Sprinkler Systems

5.2. Standpipe and Hose System

Item	Frequency	What to observe	APPLICABLE / NOT APPLICABLE	Weighted importance
Inspection				
Control valves	Weekly/monthly	Are they in good condition? Are there any leaks? Are they in the correct position ready to operate?		
Valve supervision devices	Semiannually	Are they in good condition? Are they ready to operate?		
Pipes	Annually	Visual inspection Are there any leaks?		
Hose connections	Annually	Visual inspection Are there any leaks?		
Cabinets	Annually	Visual inspection of integrity		
Hoses	Annually	Visual inspection Are there any leaks?		
Hose storage device	Annually	Visual inspection of integrity		
Hose nozzles	Annual and after each use	Are they in good condition? Are they ready to operate?		
Testing				
Water-flow devices	Quarterly/Weekly	Do they operate correctly? Do they operate at 100%?		
Valve supervision devices	Semiannually	Do they operate correctly?		
Supervisory signaling devices (except valve supervisory switches)	Semiannually	Do they operate correctly?		
Hose storage devices	Annually	Do they operate correctly?		
Main drain test	Annually	Start and check		
Hoses	5 years/3 years	Check that there is no damage		
Pressure control valves	5 years	Do they operate correctly? Do they operate at 100%? Record pressure		
Pressure reducing valves	5 years	Do they operate correctly? Do they operate at 100%? Record pressures		
Hydrostatic test	5 years	Record pressures		
Flow test	5 years	Record flow and pressure values		
Maintenance				
Hose connections	Annually	Cleaning		
Valves (all types)	Annual/as needed	Operation at 100 % Interior cleaning Maintenance of gaskets		
Obstruction investigation	5 years or as needed	Cleaning Check sources of obstructions found		

Table 2. Inspection, Testing and Maintenance of Standpipe and Hose Systems

5.3. Private Fire Service Main

Item	Frequency	What to observe	APPLICABLE / NOT APPLICABLE	Weighted importance
Inspection				
Hose houses	Quarterly	Visual inspection of integrity		
Monitor nozzles	Semiannually	Are they in good condition? Are they ready to operate?		
Piping (exposed)	Annually	Visual inspection of integrity		
Underground piping	Annually	Visual inspection of integrity		
Hydrants (dry barrel and wall)	Annually and after each operation	Visual inspection of integrity Are they ready to operate?		
Hydrants (wet barrel)	Annually and after each operation	Visual inspection of integrity Are they ready to operate?		
Mainline strainers	Annually and after any considerable use of water	Free of obstructions?		
Testing				
Monitor nozzles	Flow annually (reach and operation)	Do they operate correctly? Record pressure		
Exposed and underground piping (flow test)	Flow annually	Free of leaks?		
Hydrants	5 years	Do they operate correctly? Record pressure		
Maintenance				
Hose houses	Annually	Cleaning Paint		
Hydrants	Annually	Cleaning of components		
Mainline strainers	Annually and after each operation	Cleaning Replacement (if required)		

Table 3. Test Inspection and Maintenance of Private Fire Service Mains

5.4. Fire Protection Water Pump Units

Item	Frequency	What to observe	APPLICABLE / NOT APPLICABLE	Weighted importance
Inspection				
Pump houses, heating/ventilating louvers	Weekly	Visual inspection		
Fire pump systems	Weekly	Check condition Are there alarms in place? Check coolant, oil and fuel levels		
Testing				
Pump operation - no flow condition	Weekly	Do they operate correctly? Record values of pressure, load, voltage, etc.		
Pump operation - flow condition	Annually	Do they operate correctly? Record values of pressure, load, voltage, etc.		

Item	Frequency	What to observe	APPLICABLE / NOT APPLICABLE	Weighted importance
(This activity should be carried out together with fire protection system practices and training to personnel)				
Maintenance				
Hydraulic	Annually	Mechanical maintenance		
Mechanical transmission	Annually	Mechanical maintenance		
Motor	Annually	Mechanical maintenance		
Electrical system	Variable	Electrical maintenance		
Controller, various components	Variable	Electrical maintenance		
Diesel engine system, various components	Variable	Mechanical maintenance		

Table 4. Inspection, Testing and Maintenance of Fire Pumps

5.5. Water Supply

Item	Frequency	What to observe	APPLICABLE / NOT APPLICABLE	Weighted importance
Inspection				
Water temperature	Daily/weekly	Record value		
Heating system	Daily/weekly	Visual inspection		
Control valves	Weekly/monthly	Visual inspection Are there any leaks?		
Tank condition	Monthly/quarterly	Visual inspection of integrity		
Water level	Monthly/quarterly	Check level		
Air pressure	Monthly/quarterly	Record value		
Tank - exterior	Quarterly	Visual inspection		
Support structure	Quarterly	Visual inspection		
Catwalks and ladders	Quarterly	Visual inspection		
Surrounding area	Quarterly	Visual inspection		
Hoops and grillage	Annually	Visual inspection		
Painted or coated surfaces	Annually	Visual inspection		
Expansion joints	Annually	Visual inspection		
Interior	5 years/3 years	Visual inspection		
Check valves	5 years	Visual inspection		
Testing				
Pump operation - no flow condition	Weekly	Check correct operation Record values of pressure, temperature, etc.		
Pump operation - flow condition	Annually	Check correct operation Record values of pressure, temperature, etc.		
Maintenance				
Water level	Semiannually	Check level		
Drain silt	Annually	Cleaning		
Control valves	Annually	Remove silt regularly		

Table 5. Inspection, Testing and Maintenance of Water Storage Tanks

5.6. Spray Systems

Item	Frequency	What to observe	APPLICABLE / NOT APPLICABLE	Weighted importance
Inspection				
Supports	Each shift	Visual inspection		
Water supply piping	Each shift	Visual inspection		
Detectors	Each shift	Check that they are operational		
Controls	Each shift	Check that they are operational		
Valves	Each shift	Visual inspection Are they in the correct position to operate?		
Check valves	5 years	Visual inspection Are they in the correct position to operate?		
Control valves	Weekly (sealed)	Visual inspection Are they in the correct position to operate?		
Suction tank	Monthly	Visual inspection		
Control valves	Monthly (blocked/supervised)	Visual inspection Are they in the correct position to operate?		
Deluge valves	Monthly (blocked/supervised)	Visual inspection Are they in the correct position to operate?		
Detection systems	Monthly (blocked/supervised)	Are they operational?		
Detector check valves	Monthly (blocked/supervised)	Visual inspection Are they in the correct position to operate?		
Drainage	Quarterly	Visual inspection		
Electric motor	Quarterly	Visual inspection Record values		
Engine drive	Quarterly	Visual inspection		
Fire pump	Quarterly	Visual inspection Is it in operating condition?		
Fittings	Quarterly	Visual inspection		
Fittings - rubber- gasketed	Quarterly	Visual inspection		
Gravity tank	Quarterly	Visual inspection		
Pressure tank	Quarterly	Visual inspection		
Steam driver	Quarterly	Visual inspection		
Strainers	Quarterly	Visual inspection		
Hangers	Annually/after each activation of system	Visual inspection		
Heat (each deluge valve)	Annually/after each activation of system	Visual inspection		
Nozzles	Annually/after each activation of system	Visual inspection		
Pipes	Annually/after each activation of system	Visual inspection		
Testing				
Backflow preventer	Annually	Check operation Record values		

Item	Frequency	What to observe	APPLICABLE / NOT APPLICABLE	Weighted importance
Check valves	Annually	Check operation Record values		
Control valves	Annually	Check operation Record values		
Deluge valves	Annually	Check operation Record values		
Detection systems	Annually	Check operation		
Detector check valves	Annually	Check operation Record values		
Electric motor	Annually	Check operation Record values		
Engine drive	Annually	Check operation Record values		
Fire pump	Annually	Check operation Record values		
Vent	Annually	Check operation		
Gravity tank	Annually	Check level		
Main drain test	Annually	Check operation		
Manual release	Annually	Check operation		
Nozzles	Annually	Check operation		
Pressure tank	Annually	Check operation Record values		
Steam driver	Annually	Check operation		
Strainers	Annually	Visual inspection		
Suction tank	Annually	Check operation		
Water spray system test	Annually	Check operation Record values		
Water supply flow test	Annually	Check operation Record values		
Water-flow alarms	Quarterly	Check operation		
Maintenance				
Backflow preventer	Annually	Operation at 100% Cleaning of components		
Check valves	Annually	Operation at 100% Cleaning of components		
Control valves	Annually	Operation at 100% Cleaning of components		
Deluge valves	Annually	Operation at 100% Cleaning of components		
Detection systems	Annually			
Detector check valves	Annually	Operation at 100% Cleaning of components		
Electric motor	Annually	Cleaning of connections		
Motor start	Annually	Cleaning of connections		
Fire pump	Annually	Mechanical maintenance		
Gravity tank	Annually	Structural maintenance		
Pressure tank	Annually	Structural maintenance		
Steam motor	Annually	Mechanical maintenance		
Strainers	Annually	Cleaning / replacement		
Strainers (basket/screen)	5 years	Cleaning / replacement		
Suction tank	5 years	Structural maintenance		
Water-flow alarms	5 years			
Water spray system	Annually	Cleaning of components		

Table 6. Inspection, Testing and Maintenance of Water Spray Fixed Systems

5.7. Foam-Water Sprinkler System

Item	Frequency	What to observe	APPLICABLE / NOT APPLICABLE	Weighted importance
Inspection				
Control valves	Weekly/monthly	Visual inspection Are they in normal operating condition?		
Discharge device position and location (spray nozzle)	Monthly	Visual inspection		
Proportioning systems - All	Monthly	Visual inspection Are the valves correctly aligned?		
Foam concentrate strainer(s)	Quarterly	Visual inspection Are they free of obstructions?		
Proportioning systems - All	Semiannually	Do they operate correctly? Check diaphragm condition Record values An adequate flushing of the system is recommended		
Drainage in system area	Quarterly	Visual inspection		
Discharge device position and location (sprinkler)	Annually	Visual inspection		
Pipe corrosion	Annually	Visual inspection		
Pipe damage	Annually	Visual inspection		
Fittings corrosion	Annually	Visual inspection		
Fittings damage	Annually	Visual inspection		
Supports/hangers	Annually	Visual inspection		
Water supply tanks	Annually	Visual inspection		
Fire pumps	Annually	Visual inspection		
Water supply piping	Annually	Visual inspection		
Deluge/preaction valves	Annually	Visual inspection		
Detection system	Annually	Visual inspection		
Testing				
Water-flow devices	Quarterly/semiannually	Do they operate correctly? Record values		
Discharge device position and location	Annually	Do they operate correctly?		
Discharge device obstruction	Annually	Do they operate correctly? Are they free of obstructions?		
Foam concentrate strainer(s)	Annually	Do they operate correctly? Are they free of obstructions?		
Proportioning systems - All	Semiannually	Do they operate correctly? Check diaphragm condition Record values		
Complete foam-water systems	Annually	Do they operate correctly? Record values		
Foam-water solution	Annually	Does it operate correctly? Record values		
Manual actuation devices	Annually	Do they operate correctly?		
Backflow preventer	Annually	Does it operate correctly?		
Fire pumps	Annually	Do they operate correctly? Record values		

Item	Frequency	What to observe	APPLICABLE / NOT APPLICABLE	Weighted importance
Water supply piping	Annually	Check leaks		
Control valves	Annually	Check operation		
Mainline strainers	Annually	Check that they are free of obstructions		
Deluge/preaction valves	Annually	Check operation Record values		
Detection system	Annually	Check operation Record values		
Flow detectors	Annually	Check operation Record values		
Water supply tanks	Annually	Check level		
Water supply flow test	Annually	Record levels and values		
Maintenance				
Foam concentrate pump operation	Monthly	Check adjustment		
Foam concentrate strainers	Quarterly	Cleaning/replacement		
Foam concentrate samples	Annually	Check adjustment		
Water supply tanks	Annually	Infrastructure maintenance		
Fire pumps	Annually	Mechanical maintenance		
Water supply	Annually	Infrastructure maintenance		
Flow detector	Annually	Internal cleaning		
Relief control valve	Annually	Internal cleaning		
Relief check valve	Annually	Internal cleaning		
Control valve	Annually	Internal cleaning		
Deluge/preaction valves	Annually	Internal cleaning		
Mainline strainers	Annually	Cleaning/replacement		
Detection system	Annually			
Proportioning systems - standard pressure type (ball drip-automatic type)				
➢ Foam concentrate tank - drain and flush	10 years	Infrastructure maintenance		
➢ Corrosion and hydrostatic test	10 years	Record values		
Bladder tank				
➢ Sight glass	10 years	Cleaning		
➢ Foam concentrate tank - hydrostatic test	10 years	Infrastructure maintenance		
Line type				
➢ Foam concentrate tank - corrosion and pickup pipes	10 years	Infrastructure maintenance Cleaning		
➢ Foam concentrate tank - drain and flush	10 years	Infrastructure maintenance Cleaning		
Standard balanced pressure type				
➢ Foam concentrate pumps	5 years	Mechanical maintenance		
➢ Balancing valve diaphragm	5 years	Internal cleaning		
➢ Foam concentrate tank	10 years	Infrastructure maintenance		
In-line balanced pressure type				
➢ Foam concentrate pumps	5 years	Mechanical maintenance		
➢ Balancing valve diaphragm	5 years	Internal cleaning		

Item	Frequency	What to observe	APPLICABLE / NOT APPLICABLE	Weighted importance
➢ Foam concentrate tank	10 years	Infrastructure maintenance		
➢ Pressure vacuum vents	5 years	Cleaning		

Table 7. Inspection, Testing and Maintenance of Foam-Water Sprinkler Systems

5.8. Water Mist Systems

Item	Frequency	What to observe	APPLICABLE / NOT APPLICABLE	Weighted importance
Water tank	Annually	Vent and fill		
System	Annually	Flush		
Filters and strainers	After operating the system	Clean or replace if required		

Table 8. Inspection, Testing and Maintenance of Water Mist Systems

5.9. Valves, Valve Components and Trim

Item	Frequency	What to observe	APPLICABLE / NOT APPLICABLE	Weighted importance
Inspection				
Control valves				
➢ Sealed	Weekly	Visual inspection Are there any leaks?		
➢ Locked	Monthly	Visual inspection Are there any leaks?		
➢ Tamper switches	Monthly	Visual inspection Are they ready to operate?		
Alarm valves				
➢ Exterior	Monthly	Visual inspection Are there any leaks?		
➢ Interior	5 years	Visual inspection Are there any leaks?		
➢ Filters, strainers, orifices	5 years	Visual inspection Are they free of obstructions?		
Check valves				
➢ Interior	5 years	Visual inspection Are there any leaks?		
Preaction/deluge valves				
➢ Enclosure (during cold weather)	Daily/weekly	Visual inspection Are there any leaks?		
➢ Exterior	Monthly	Visual inspection Are there any leaks?		
➢ Interior	Annually/5 years	Visual inspection Are there any leaks?		
➢ Filters, strainers, orifices	5 years	Visual inspection Are they free of obstructions?		
Dry pipe valves/quick-opening devices				
➢ Enclosure (during cold weather)	Daily/weekly	Visual inspection Are there any leaks?		

Item	Frequency	What to observe	APPLICABLE / NOT APPLICABLE	Weighted importance
➢ Exterior	Monthly	Visual inspection Are there any leaks?		
➢ Interior	Annually/5 years	Visual inspection Are there any leaks?		
➢ Filters, strainers, orifices	5 years	Visual inspection Are they free of obstructions?		
Pressure reducing and relief valves				
➢ Sprinkler system	Annually	Visual inspection Are there any leaks?		
➢ Hose connections	Annually	Visual inspection		
➢ Fire pumps	Annually	Visual inspection Record of values		
o Casing relief valves	Weekly	Visual inspection Are there any leaks?		
o Pressure relief valves	Weekly	Visual inspection Are there any leaks? Are they ready to operate?		
Backflow prevention assemblies				
➢ Reduced pressure	Weekly/monthly	Visual inspection Are there any leaks?		
➢ Reduced pressure detectors	Weekly/monthly	Visual inspection		
➢ Fire Department connection	Quarterly	Visual inspection Are they in operating condition?		
Testing				
Main drains	Annually/quarterly			
Water-flow alarms	Quarterly/semiannually			
Control valves				
➢ Position:	Annually	Are they in the correct position?		
➢ Operation	Annually	Operation at 100 %		
➢ Supervision	Semiannually			
Preaction/deluge valves				
➢ Water vent	Quarterly	Does it operate correctly?		
➢ Low air pressure alarms	Quarterly	Do they operate correctly?		
➢ Total flow	Annually	Record values		
Dry pipe valves/quick-opening devices				
➢ Priming water	Quarterly			
➢ Low air pressure alarms	Quarterly	Do they operate correctly?		
➢ Quick-opening devices	Quarterly	Record values		
➢ Trip test	Annually	Does it operate correctly?		
➢ Full flow trip tests	3 years	Do theyoperate correctly?		
Pressure reducing and relief valves				
➢ Sprinkler system	5 years	Does it operate correctly?		
➢ Circulation relief	Annually	Does it operate correctly?		
➢ Relief valves	Annually	Do theyoperate correctly?		
➢ Hose connections	5 years			
➢ Hose racks	5 years	Visual inspection of structure		
Backflow prevention assemblies	Annually	Do theyoperate correctly?		

Table 9. Inspection, Testing and Maintenance of Valves, Valve Components and Trim

5.10. Detection and Alarm Systems

Fire alarm systems are classified according to whether they are operated automatically, manually, or both. The purpose of automatic fire alarm systems is to notify the building occupants to evacuate in case of fire or other emergency, report the fact to a location outside the facilities in order to call the emergency services, and prepare the structure and associated systems to control the spread of fire and smoke.

The inspection shall consist of a visual examination of the system and its components to verify that they are in apparently optimum operating condition and free of physical damage, and is based primarily on NFPA 72, *National Fire Alarm Code,* Chapter 14.

Weekly

The visual inspection shall be performed generally in each facility covering the protected areas.

Monthly

Condition of alarm-initiating devices, such as smoke, temperature, gas and flames detectors, as well as manual warnings and sirens.

Quarterly

Fuses interfaced equipment

Primary energy supply

Panel light indicators

Panel sound indicators

Failure signals from panel itself

Simulation

Network connections

Audio panel for evacuation

Voltage measurement of batteries (secondary power supply)

Connections between central station and each area

Check operation of remote annunciators and their control panel, if any

Phone dialer according to the recommendation of the manufacturer of smoke, temperature, gas, and flame detectors

Visual/audible notification devices

Loudspeakers of the voice evacuation alarm system

Semiannually

Panel battery charger test Battery discharge test

Annually

Operation of devices to ensure they correspond to their function

Control modules and actions

Monitoring modules

Operation of flow detectors

Pipeline detector test

Battery test (24 hours)

Test with design drawings possible changes in structure and/or in the distribution of the plant, which could modify the composition and/or design of the fire detection system

Cleaning of fire alarm control panel

Cleaning of loudspeakers of the voice evacuation alarm system

Calibration of smoke and heat detectors

Calibration of gas detectors

Checking of analog values and replacement of detectors that are outside predetermined values

Cleaning and/or calibration of smoke and/or heat detectors

Cleaning and/or calibration of gas detectors Fire Extinguishing System

5.11. Fire Extinguishers

It is of the utmost importance to ensure the correct performance of these equipment at the time of a fire. For this reason, any acquisition, purchase and maintenance shall be based on the latest edition of NFPA 10, *Standard For Portable Fire Extinguishers*, Section 7.3.

Fire extinguishers shall be listed. Those already existing that do not comply with this requirement shall be replaced by equipment that conform to the above specifications.
Fire extinguishers having a service time of more than twenty years shall be replaced, based on criteria of performance and reliability.

Listed potassium bicarbonate and sodium bicarbonate-based powders are those accepted for the protection of industrial areas.
Offices, administrative areas and all kinds of facilities where there is a risk of Type A fire shall be protected with Class A fire extinguishers, and areas where there is a combined risk of Type A, B fire shall be protected with ABC Class (multipurpose) fire extinguishers.

In the event that a halon fire extinguisher is discharged, it shall be replaced with a clean agent fire extinguisher according to the latest edition of NFPA 2001, *Standard on Clean Agent Fire Extinguishing Systems.*

The extinguishing agent (powder, gas, etc.) shall not be replaced with a different agent to that specified by the manufacturer. Example: A water fire extinguisher shall not be converted into a dry chemical powder fire extinguisher.

The chemical composition of the extinguishing agent (dry chemical powder) for which the fire extinguisher was designed shall not be changed. These changes may have medium-term consequences due to deterioration and poor performance of the fire extinguisher.

Strict enforcement of hydrostatic tests every 5 years shall be ensured in accordance with the test intervals established in the latest edition of NFPA 10, *Standard for Portable Fire Extinguishers*, for each type of fire extinguisher.

The inspection, testing and maintenance of fire extinguishers shall be performed by a duly certified company. The relevant local legislation may allow exceptions to this recommendation so that the maintenance of fire extinguishers may be performed by the main company, if its operators are certified by the manufacturer, for example in distant locations (fields) where an outsourced service is not available.

Following the guidelines of the 2010 edition of NFPA 10, Paragraph 6.1.3.7, fire extinguishers shall be protected against temperature, dust and moisture. The implementation of easy-to-fit protective sheathing (with velcro tape) is recommended. The volume of water storage and/or foam concentrate, flow rate and pressure of the water pump and the type of foam supplying system shall be specified.

NFPA 10 establishes an annual maintenance for fire extinguishers. However, in regions where the humidity and the risk of powder caking before one year are very high, it is highly recommended to perform maintenance every six months. Maintenance may be performed before schedule depending also on the visual inspection of powder performed every month.

5.12. Automotive Fire Apparatus

A fire truck is a very delicate vehicle that requires constant care and attention. Fire trucks shall be purchased when the following conditions are met:

- The facilities to be protected are very far from emergency care centers.
- The areas to be protected are very far from fixed fire protection systems, such as oil wells, ports and airports. It is assumed that hydrocarbon production and storage facilities shall have reliable fixed fire protection systems.
- Trained personnel are available for driving, safe operation and maintenance of fire trucks following the guidelines of NFPA 1911.
- Water sources for fast filling of the fire truck are easily available, thereby ensuring its continuous operation.
- There are quick access roads to the facilities to be protected.
- Adequate preventive and predictive maintenance programs for vehicles are available.

5.12.1. Replacement of Automotive Fire Apparatus

The purchase of automotive fire apparatus and their equipment shall be the direct responsibility of each company.

Field tests and the age of fire trucks will determine the operational and mechanical condition of the equipment for their replacement. According to these results, specifications shall be developed following international and national applicable regulations, and the best practices in the industry.

The useful life of fire trucks depends on the use of the equipment and the relevant maintenance program. However, it is generally considered that the useful life of a pumper may be from ten to fifteen years and/or twenty years, as detailed below:

a. Aerial ladder: Fifteen years
b. Pumpers: Twenty years
c. First-line fire apparatus: Ten years

The vehicles shall be equipped with all the tools required for fire control. NFPA standards on automotive fire apparatus include lists of equipment and appliances carried in each vehicle.

Old vehicles may be retained as a reserve fleet provided that they are in good operating and mechanical condition. However, the main vehicles shall be no more than twenty years in service.

5.12.2. Regulatory Compliance

They shall be designed to comply, as a minimum, with the requirements of the latest edition of NFPA 1901, *Standard For Automotive Fire Apparatus.* The equipment shall be UL listed and assembled by the manufacturer.

The water and/or foam concentrate storage volume, the flow rate, the water pump pressure and the type of foam proportioning system shall be specified.

The vehicles shall be listed by parts (pump, proportioner, storage tank, etc.), and the water pumps shall be listed for use in firefighting.

Fire Protection Systems in Oil and Liquid Hydrocarbons Transportation Facilities

Chapter 5: Economic and Project Aspects

1. INTRODUCTION

This Chapter of the Guidelines refers to the economic aspects that influence projects regarding fire protection systems. These aspects include a generic development of the methodology for evaluation of FPS projects, the bases for the technical and economic evaluation, a cost-benefit analysis of the FPSs investment, the risk tolerance evaluation and the cost of FPS maintenance and operation.

The theme referred to in this Chapter may be very wide and varied depending on how to address it. The purpose here is to present some aspects considered relevant that can serve as a basic aid to the readers, who will then be able to deepen their analysis as they deem necessary.

2. METHODOLOGY FOR EVALUATION OF FPS PROJECTS

In general, no profitability assessment, economic or financial evaluation is carried out on FPS projects to analyze the returns on investment of the installation of a fire protection system. These projects are rather evaluated upon consideration of the following guidelines.

Guidelines for Evaluation of FPS Projects:

- ✓ Compliance with legal regulations in force
- ✓ Compliance with related corporate rules
- ✓ Compliance with protection systems standards of widespread use in the industry and/or as recommended best practices, including recommendations of insurance companies
- ✓ Implementation of a technological model adopted as a result of the consideration of the above guidelines and of the technical-economic strategy of the company regarding fire protection systems

It is also pertinent to consider the perspective of the industrial asset or facility where new, refitting or improvement projects, and any maintenance processes involving acquisitions, extensions and/or modifications to existing fire protection systems will be carried out, and whether it is part of a larger FPS investment plan within an investment program of the company that includes the total technological upgrade or the partial or total renewal of the FPS of the asset or industrial facility at a later instance than the above-mentioned project, for which purpose a budget program is to be defined. This can mean that an intermediate project on the asset may consider the guidelines only in part, precisely because the investment program of the major plan will consider them subsequently, or because the industrial investment plan will leave the specific asset or facilities out of service in a short time, and because it is feasible and/or viable for the owner of the assets to take a risk probably greater than the adoption of all the guidelines.

The methodology presented here is generic and by way of example, as the purpose is to provide introductory basic tools. The methodologies used by different companies may be more complex or different, or may include other stages or methods. The purpose of this document is only to provide basic guidelines to establish an alternative methodology and present aspects that should not be disregarded.

2.1. Evaluation Stages

The minimum stages recommended for the evaluation of the project according to the aspects mentioned above are presented below.

2.1.1. Considerations about the Asset

This Section presents the aspects relating to the asset to be protected, based on the risk analysis, the inclusion of the asset in a larger FPS investment plan or not, and the perspective of the asset within the industrial investment plan.

2.1.2. Guidelines to Consider

Based on the previous stage, and according to the technical-economic strategy of the company regarding fire protection systems, the guidelines to be considered for the project are defined. In this definition, there will be a consideration of the risk that the company and/or the owner of the assets will set as acceptable, for the partial or total adoption of all the guidelines into consideration. The partial adoption of the guidelines in any FPS project cannot imply failing to consider the requirements of the applicable law. It is up to the company to decide whether to postpone an adopted technological model, as it involves the protection of an asset with prospects of becoming out of service in the short or medium term - according to the strategy of each company, generally between 5 and 10 years. The risk that this implies should be considered acceptable by the owner of the assets. At this stage, all the aspects and requirements of the FPS project evaluation guidelines stated in Item 2 of this Chapter shall be considered.

2.1.3. Diagnosis of Existing Facilities

This stage applies to projects that have an impact on existing industrial facilities, where the scope of the FPS project should be defined on the basis of existing equipment and systems to be expanded, renewed and/or improved.

Once the guidelines to consider have been established, a review is made of the current situation in the case of installations or upgrades that form part of an existing industrial facility. The impact of the FPS project on the fire protection systems of the industrial facility where the project will be developed shall necessarily be considered, for example, the impact on the pumping capacity and FPS water supply. This review will result in a list of items complied with and/or not complied with as regards the guidelines defined in the previous stage.

2.1.4. Definition of FPS Project Scope

The implementation of measures that correlate the diagnosis of the previous stage with the guidelines to consider shall be defined at this stage.

Feedback may arise with respect to the guidelines under consideration due to the assignment to a larger FPS investment plan, to the acceptance of a certain level of risk resulting from the perspective of the asset in the short or medium term, or to certain failures to comply with the guidelines detected in the previous stage.

It will certainly not be possible to postpone the implementation of measures provided for by the applicable laws. However, mitigation measures may be implemented if a particular requirement is not properly complied with and should be dealt with in particular with the regulatory agency and/or the competent authority.

2.2. Scheme of the Assessment

A scheme of the assessment stages of an FPS project is shown in Figure 1.

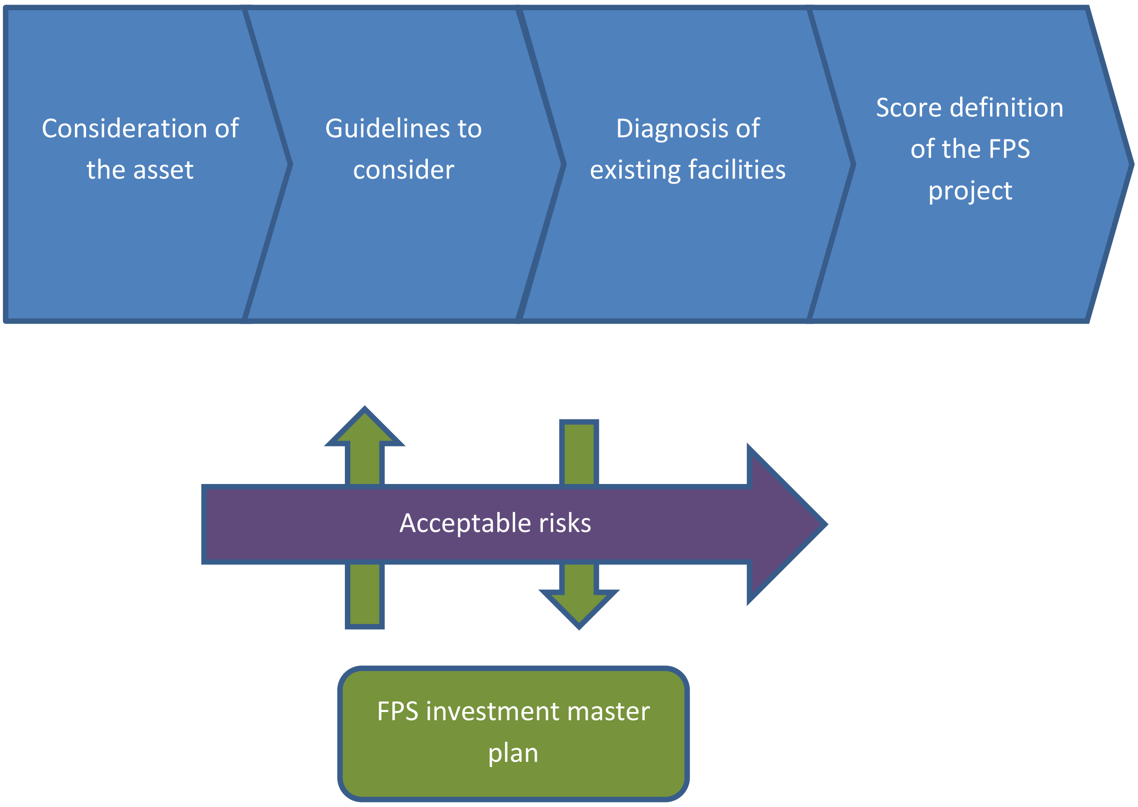


Figure 1. Scheme of the Assessment of an FPS Project

3. TECHNICAL AND ECONOMIC EVALUATION

This Section presents the methodological bases of technical and economic analysis generally used for FPS projects, when the evaluation of alternatives takes place, either for technological and/or for economic aspects. This means that the desired result from the viewpoint of performance and/or adopted as a standard of design can be obtained through more than one system, which implies a technical analysis of benefits and disadvantages of each alternative, and also an economic evaluation to select the most efficient system.

In addition to the methodological rationale, an illustrative example is provided to select between the different dosing systems of foam concentrate for a typical oil and liquid hydrocarbons storage plant. This example is stated in *italics* in this Section.

3.1. Conditioning Factors

As in any methodology of analysis, there are conditioning factors that limit the study and its scope. These refer to the particular characteristics of each project, the facilities, the typology of risks into consideration and the environmental conditions. It is necessary to list them in order to take them into account, as they will set the way to go into the analysis.

In the example, these are the conditioning factors of the analysis:

a) Type of installation to be protected: Although there are other equipment and facilities, the terminal is the facility that shows the highest risk from the viewpoint of foam demand, as it comprises a tank truck loading sector and a tank farm for finished products with cylindrical fixed-roof tanks. Due to their magnitude, the definition of the quantity and quality of foam for protection shall be based on *these tanks.*

b) *Main features of the facility - The diameter of most tanks is 40 meters (131 feet), the tanks are widely separated from each other, and each one is inside a containment dike, also of large proportions. The size of the plant is 750 meters x 500 meters (2460 ft x 1640 ft). The spacing between the tanks is a relevant factor, as it may be constitute a passive fire protection system if it is larger than a diameter, especially at the moment of evaluating the possible cooling of a tank exposed to thermal radiation generated by a nearby fire.*

c) *Stored products: Conventional hydrocarbons (gas oil, JP1, fuel oil, normal gasoline), blendings of gasoline with MTBE at a volume exceeding 10 % (ultra gasoline) and alcohols. The latter behave in a particular way, as polar solvents of water, and shall require special design considerations.*

d) *Typology of risks: The typical risks at these facilities are:*

- *Pool fires in tanks, API pools and other confined spills with thicknesses of over 25 mm (1 inch).*
- *Surface fires of not confined spills with thicknesses of less than 25 mm (1 inch)*
- *Jet fires due to pressure leaks in pump seals, flange blows, valve bonnets*
- *Spills in general, with no fire*

e) *Minimum room temperature: The temperature of the area may be below 0 °C (32 °F), though not for a long time.*

External fire-fighting resources available: As it is a typical oil and liquid hydrocarbons storage plant, there is no industrial water tender with its own foam supply system and appropriate capacity as an alternative to the fixed systems (which is the case in a refinery).

3.2. Technical Analysis

The technical analysis shall combine the constraints with the variables in the design of the project. There will be independent and dependent variables, based on the constraints and the design strategy selected. The process may even be iterative in the dependency of the variables. The analysis shall cover each variable, considering the technical feasibility in every aspect, their advantages and disadvantages.

As a result of the technical analysis, the variables that do not make the project technically feasible shall be eliminated.

In the example, the variables taken into consideration are the type of concentrate and the proportioning technologies.

Variable A: Type of Concentrate

The foam concentrate most suitable for application in the plant shall be defined, and based on this, the product design parameters determined by carrying out the performance test stated in standard UL162, and in the UL Directory shall be applied.

Selection criterion:

- *Minimum winter temperature: The plant is subjected to temperatures below 0 °C (32 °F).*
- *Type of discharge device: The nozzles required for hoses and monitors shall be nonaspirating-type nozzles suitable for water and foam, and for full jet or mist.*
- *Type of risk: The products involved are conventional hydrocarbons, blendings of gasoline with*

MTBE (ultra and premium) and alcohols (ethanol).

Based on the evaluation of the above-mentioned conditions, a decision was made to select an AR-FFFP fluoroprotein concentrate applied at 3 %, as it is an aqueous film forming foam suitable for conventional hydrocarbons and polar solvents, with very low[1] viscosity.

This product was selected due to its low viscosity, its suitability both for vacuum and non-vacuum discharge devices, and its formulation without polymers (that is typical of AR-AFFF products and makes them prone to stratify, extremely viscous, non-linear and more likely to clog pipes and small-section devices).

The work parameters arising from the UL 162 test for this product are the following:

Application in Conventional Hydrocarbons:

Foam chambers

Application rate: 4.1 L/min - m^2 (0.1 gpm / ft^2).

Minimum chamber design pressure: 5 bar (72.5 psi)

Monitors and handlines for spills

Application rate: 6.5 L/min - m^2 (0.16 gpm/ft^2)

Minimum nozzle pressure: 7 bar (101.5 psi)

Open or closed sprinklers

Application rate: 6.5 L/min - m^2 (0.16 gpm/ft^2)

Minimum discharge pressure: 1 bar (14.5 psi)

Directional sprinklers

Application rate: 6.5 L/min - m^2 (0.16 gpm/ft^2)

Minimum discharge pressure: 2 bar (29 psi)

Application in Blendings of Gasoline with MTBE and Alcohols:

Foam chambers

Application rate: 6.5 L/min - m^2 (0.16 gpm/ft^2)

Minimum chamber pressure: 5/7 bar (72.5/101.5 psi)

Monitors and handlines for spills

Application rate: 6.5 L/min - m^2 (0.16 gpm/ft^2)

[1] The product trade name is not mentioned as it is not necessary for the purposes of the example.

Minimum nozzle pressure: 7 bar (101.5 psi)

Open or closed sprinklers

Application rate: 12.5 L/min - m^2 (0.33 gpm/ft^2)

Minimum discharge pressure: 2 bar (29 psi)

Directional sprinklers

Application rate: 12.5 L/min - m^2 (0.33 gpm/ft^2)

Minimum discharge pressure: 3 bar (43.5 psi)

The following size guidelines are required for compliance with the above-mentioned design guidelines and the correct use of concentrate.

Tanks

Use of foam chambers (foam expansion ratio 5 to 7 in 1), with a rate of 4.1 L/min - m^2 (0.1 gpm/ft^2) and minimum chamber pressure of 5 bar, for conventional hydrocarbons, and with a rate of 6.5 L/min - m^2 (0.16 gpm/ft^2) and minimum chamber pressure of 5 bar (72.5 psi), for gasoline and alcohol. For floating roof tanks, the rate stated by the NFPA 11 standard is followed: 12.2 L/min - m^2 (0.3 gpm/ft^2), minimum chamber pressure of 5 bar (72.5 psi).

Minimum discharge times:

Fixed-roof tanks

Conventional hydrocarbons (flash point between 37.8 $^{\circ}$C and 60 $^{\circ}$C): 30 minutes (according to NFPA 11, Table 5.2.5.2.2)

Gasolines and alcohols: 55 minutes (according to NFPA 11, Table 5.2.5.2.2)

Floating roof tanks

Conventional hydrocarbons or gasoline and alcohols: 20 minutes (according to NFPA 11, Table 5.3.5.3.1)

Reserve supply of foam for a single tank. The amount of foam adopted as the required minimum amount shall be the largest of the following: the amount required for the fixed system and the amount necessary to flood the complex.

Enclosures

Use of monitors, hose lines with nonaspirating-type nozzles or any Type III discharge outlet (according to NFPA 11 or UL 162), with a rate of 6.5 L/min - m^2 (0.16 gpm/ft^2) and minimum discharge pressure of 7 bar (101.5 psi) (monitors and handlines), for conventional hydrocarbons, alcohols or gasoline. In groups of small tanks within a single dike, and where sprinklers are applied in the case of alcohol or gasoline, the rate shall be 12.5 L/min - m^2 (0.31 gpm/ft^2) at a minimum discharge pressure of 3 bar (43.5 psi) (upright) or (directional).

Minimum discharge times

The systems shall be dimensioned so that the foam layer covers the whole of the enclosure (including the tank surface). In order to maintain consistent ranges, the flow rates of the discharge devices shall be no less than:

Foam monitors: 1325/1893 L/min (350/500 gpm)

Handline foam nozzles: 189 L/min (50 gpm)

Upon consideration of the above, and of the type of foam concentrate to use, the foam pressures required in discharge devices in each case and the minimum discharge times, the proportioning alternatives are discussed below, evaluating their advantages and disadvantages, in order to determine the extent of their applicability to this project.

Variable B: Proportioning Systems

Venturi-type Systems: (LP)

Advantages:

- *Economical*
- *No mobile parts*
- *Refill while operating allowed (in case greater autonomy is required for a specific incident)*

Disadvantages:

- *Accurate proportioning with a fixed flow (any variation of flow generates an extremely important deviation in the proportioning percentage)*
- *Complicated calibration*
- *Loss of 35 % - 40 % of pressure with respect to the inlet pressure (this is the main disadvantage, as in the case of alcohols or blendings, it is not possible to reach the minimum chamber pressure required by the concentrate, according to UL 162)*
- *They do not allow centralizing the protection of several tanks with a single foam concentrate tank (if the lines supplied by each proportioner are very long, and the proportioner backpressure exceeds the admissible pressure, the eductor fails to generate suction). This requires a higher amount of concentrate.*
- *Only one manufacturer in the world provides UL certified eductors of only a couple of sizes (it is not possible to cover all system designs with UL certified elements).*

Applications:

- *Low risks*
- *Self-educting*
- *Portable hose lines and equipment*
- *Foam chambers, typically in batteries, PTCs, where there are few tanks, and the pressures required in chambers are low (crude)*
- *Shall not be used with sprinklers (multiple discharge devices)*
- *Shall not be used with monitors (high loss of pressure loss, which sacrifices the scope)*

Volumetric Proportioning Systems (Minosse / FireDOS)

Advantages:

- *Accurate proportioning in a wide range of flow rates*
- *Low pressure loss*
- *Requires no external power (driven by mains water)*
- *Wide range of sizes available (FireDOS)*
- *FM approved (FireDOS)*
- *Refill while operating allowed (in case greater autonomy is required for a specific incident)*
- *Does not require calibration if the concentrate viscosity is changed (volumetric)*

Disadvantages:

- *Higher investment than a Venturi-type system*
- *The system makes the foam-water solution and it shall then be distributed to the different discharge devices. If several risks (two or more tanks) are centralized, a very large-diameter piping system must be run, which makes the installation very expensive.*
- *The entire downstream piping of the equipment must be kept drained, since the premix has a short life, and also impairs the metal pipes. The pipes cannot be washed leaving clean water inside, as water cannot be discharged into foam chambers. Dry pipes are required after the proportioner. When these dry pipes are very long, precautions must be taken in the design to prevent the overspeeding of the hydraulic engines (differential pressure valves)*
- *Filtering the water that drives the hydraulic engine is required*

Applications:

- *Risks that involve variable intakes*
- *Small systems, where they represent a simple and economical solution*
- *Risks involving incidents of variable duration (requiring refill while operating)*
- *Tanker truck loading facilities*
- *Pump farms*
- *High and medium expansion systems*
- *Subsurface injection systems*
- *Closed sprinklers systems*
- *Deluge systems*
- *Do not use with poor quality water*

Bladder Tank Proportioning Systems

Advantages:

- *Accurate proportioning in a wide range of flow rates*
- *Do not require external power (only water pressure)*
- *Low pressure loss in the proportioner*

Disadvantages:

- *As the size increases, the cost grows exponentially*

- *In locations with freezing temperature, complementary protection installations are required to prevent freezing of the water film that is always present between the internal wall of the tank and the bladder, as ice breaks the bladder easily.*
- *The maximum typical operation pressure is 12 bar (175 psi).*
- *The proportioning maneuver is very complicated and slow.*
- *The rupture of the bladder is frequent, and its replacement must be performed at the installation site, therefore, the equipment is no longer UL listed.*
- *It cannot be refilled while operating (it is like a fire extinguisher, once discharged, the equipment is unavailable if the incident extends).*

Applications:

- *Risks that require high reliability and low autonomy*
- *Single risks (loading facilities, floating roof tanks, pump parks)*
- *Heliports, platforms, ships*
- *Closed sprinklers systems*
- *Deluge systems*
- *Do not install in cold areas (or take the necessary precautions)*
- *Do not use with salt water or poor quality water*

In-Line Balanced Pressure Proportioning Systems (ILBP) (with foam concentrate pump)

Advantages:

- *Accurate proportioning in a wide range of flow rates*
- *Low pressure loss in the proportioner*
- *UL listed systems available*
- *The foam concentrate reserve may be centralized for the whole plant, minimizing the product inventory and maximizing the autonomy of any discharge device (even a monitor or hydrant).*
- *The tank may be refilled while operating, or a complementary foam concentrate trailer may be connected to the auxiliary suction (for longer incidents).*
- *It is possible to convert any monitor or hydrant near the foam concentrate distribution piping to a water-foam device.*
- *These systems can be purchased in a wide range of capacities and pressures, and a variety of combinations of engines (electric, diesel, double electric, electric and diesel, with or without jockey pump).*
- *Only one pumping system is required for the whole plant, which, in addition to the above-mentioned foam concentrate savings, makes this system the most economical solution for large plants.*
- *The foam concentrate line may be extended in a very simple way to reach other points of the plant.*

Disadvantages:

- *Electric pumps require external power.*
- *It is necessary to build a line (typically Ø3") of material compatible with the concentrate product*

(AISI 304 L, bronze, PVC, GRP, HDPE, etc.)

- *A large amount of foam concentrate is required just to fill the concentrate line.*
- *It is uneconomical for small installations.*

Applications:

- *Multiple risks*
- *Large plants (refineries, storage plants)*
- *Wharves and port facilities*
- *Facilities handling large flows of foam (telecommanded monitors, large deluge systems, large cannons, etc).*

Technical Feasibility of the Proportioning System

In view of the above, for this particular project we ruled out the use of Venturi-type systems due to the deficiency in the chamber inlet pressure typical of these systems (gasoline and alcohols in the plant require high pressure in chambers). We also ruled out the use of bladder tanks, as the typical risk of fixed-roof tanks is that fires may last very long because there is no supplementary equipment (such as pumpers) in addition to the fixed systems. Moreover, as the bladder tank-based systems should feature a manifold for foam distribution, it is important to consider the size of the equipment, not only for protection of the tank, but also for the protection of the entire enclosure with foam. Due to the required availability of hardware and the foam concentrate stock in the plant, the dimensions of bladder tanks are really uneconomical.

Therefore, volumetric proportioning systems (Minosse /FireDOS), and in-line balanced pressure proportioning systems (ILBP) are selected at this technical feasibility stage.

3.3. Economic Analysis

After the technical feasibility stage, if more than one possible technical solution have been determined, an economic analysis shall be performed to state which solution is best in terms of investment, operation and maintenance. This economic analysis stage shall conclude with the determination of the most efficient system.

For the example, presented below is a differential analysis of investment costs for volumetric proportioners and in-line balanced pressure proportioners. Similar operational costs and maintenance costs are considered for both systems. The economic values are presented here only by way of reference.

ILBP System:

ITEM	DESCRIPTION	QUANTITY	UNIT COST	TOTAL COST
1	Pipe for distribution of concentrate (AISI 304 L SCH 40) 3" mounted	3170 m	USD 193	USD 611,810
2	Pipe for distribution of concentrate (AISI 304 L SCH 40) 1.5" mounted	125 m	USD 74	USD 9,250
3	Concentrate tank of 15,000 l (3963 gal) GRP	1	USD 6,500	USD 6,500
4	UL listed skid ILBP with electrical pump, diesel and jockey 120 gpm@250 psi	1	USD 240,000	USD 240,000

5	UL listed AR-FFFP foam concentrate at 3 % in pipes	15318 l (4046 gal)	USD 7	USD 107,228
6	UL listed AR-FFFP foam concentrate at 3 % in tank	13535 l (3576 gal)	USD 7	USD 94,745
7	Proportioning modules at checkpoints	19	USD 5,500	USD 104,500
8	Direct injection modules	42	USD 2,600	USD 109,200

Total: USD 1,283,233

Volumetric Proportioners:

ITEM	DESCRIPTION	QUANTITY	UNIT COST	TOTAL COST
1	FOAM CONCENTRATE TANKS	19	USD 4,000	USD 76,000
2	UL LISTED AR-FFFP foam concentrate AT 3 %	95,000 l (2,510 gal)	USD 7	USD 665,000
3	MINOSSE 121	7	USD 59,000	USD 413,000
4	MINOSSE 301	3	USD 62,000	USD 186,000
5	MINOSSE 450	5	USD 84,000	USD 420,000
6	FOAMING AGENT FOR MONITORS (2 BARRELS PER SYSTEM)	16,800 l (4,438 gal)	USD 7	USD 117,600
7	ASPIRATING NOZZLES FOR MONITOR	42	USD 1,280	USD 53,760

Total: USD 1,931,360

The conclusion is that the most convenient system from the technical, operational and economic viewpoint is the ILBP system.

Therefore, the use of an in-line balanced pressure proportioning system for the example project is justified for the following reasons:

1. *The size of the plant and the number of tanks allow the installation of a single Skid ILBP for pumping concentrate.*
2. *The centralization of the foam concentrate reserve, covering the highest risk, and even exceeding it, implies the possibility of having ALL this amount of concentrate to generate foam at ANY point of the plant.*
3. *All monitors along the concentrate distribution network can be converted to water-foam economically through direct injection modules, and the system allows discharging foam through one or several devices at a time until the existing reserve is exhausted.*
4. *If an incident in a tank lasts longer than expected (which is statistically highly likely), either due to a complication or to a wrong fire-fighting strategy, it is always possible to refill the main foam tank or bring a foam trailer and connect it to the auxiliary suction inlet. (There is no industrial water tender for additional support).*
5. *The loss of pressure in the proportioning modules is low, which allows reaching the foam chambers in the blendings tanks with the minimum pressure required for the chosen concentrate.*
6. *All components have a high degree of reliability and comply 100 % with NFPA 11 and NFPA 20 standards.*
7. *This is the most used foaming system around the world for tank farms.*

8. *As the whole amount of concentrate is in one single tank, its preservation and control are easier and safer.*

4. COST-BENEFIT ANALYSIS OF THE INVESTMENT IN FPSs

While the risk reduction approach is toward life safety and environmental protection, fire protection systems may also play a fundamental role in the reduction of the business continuity risk and the assets risk. It is also necessary to consider the efficiency of the system in this regard.

The cost-benefit analysis as a method of assessment of the risk of fire also provides an assessment of the expected risk to the lives of people, i.e., an estimate of the costs associated with a specific design of a fire protection system. These costs include investment and maintenance of the fire protection system, as well as the loss of assets as a result of a likely spread of fire on the installation. The joint evaluation of the risks to life and the costs of the fire allows the identification of cost-efficient fire designs that provide the required level of safety with the lowest cost.

This introduction to the topic is framed within standard NFPA 551 - *Guide for the Evaluation of Fire Risk Assessments*.

An option for the reduction of the risk is beneficial from the viewpoint of the costs if[2]:

$$\{ (C \times g) - (C_{op} \times g_{op}) \} \times Pr_{control} > \text{cost of implementation}$$

Where:

C = expected cost of the incident without option in place

C_{op} = expected cost of the incident with option in place

g = expected statistical frequency of the initiating event if option is not implemented

g_{op} = expected statistical frequency of the initiating event if option is implemented

$Pr_{control}$ = probability that option will perform as required.

Incident cost elements may include:

- Life safety
- Environmental damage
- Asset value
- Downtime
- Public image and reputation
- Legal repercussions
- Insurance repercussions

For mitigation measures, the simplified equation is presented, where a measure for the fire risk management is cost-effective if:

$$(C - C_{op}) \times F_i \times P_c > C_{med}$$

[2]Fire System Integrity Assurance. Report No. 6.85/304 June 2000. International Association of Oil & Gas Producers.

Where:

C = Cost of the incident without measure

C_{op} = Cost of the incident with measure

F_i = Statistical frequency of incident

P_c = Probability of control

C_{med} = Cost of measure (capital and operational)

5. EVALUATION OF RISK TOLERANCE VS IMPLEMENTATION OF A FPS

The concept, approach and applicability of the ALARP (As Low As Reasonably Practicable) is set as a recommended practice to demonstrate that the risks are being managed and controlled within the acceptable levels of tolerance.

The demonstration process of the ALARP risk level is applicable to all processes of the industry in a balanced way for process safety conditions, reputation, business of the company, damage to property, occupational safety and health.

The purpose of this instruction is to define the concept, criteria and steps to follow for the documented demonstration that the health, safety, environmental and social risks are being managed at the level as low as reasonably practicable.

5.1. Previous Requirements

The analysis of the ALARP process is carried out by a team of specialists formed by SSMS, maintenance, operations, finance and engineering staff, the competent authority in FPSs, and any other specialized staff if required. The minimum requirements for the members of this team are detailed below.

The ***HSSE Specialist*** shall have knowledge and experience in:

- Risk analysis
- Fire safety standards and regulations
- Best practices of the industry regarding HSSE
- Analysis and investigation of accidents
- Operational safety audits
- Documents on quality
- Health, safety, environmental and social management

The ***Engineering and Construction Specialist*** shall have knowledge and experience in:

- Design of processes
- Engineering standards and regulations on fire safety
- Best practices of the industry regarding engineering and construction
- Analysis and investigation of accidents

- Risk analysis

The ***Maintenance Specialist*** shall have knowledge and experience in:

- Analysis of preventive and predictive maintenance techniques
- Regulations and standards on FPS maintenance
- Best practices of the industry regarding maintenance
- Analysis and investigation of accidents
- Cause-effect failure analysis
- Metrology and units
- Hydraulics and thermodynamics of components
- Risk analysis

The ***Operational Specialist*** shall have knowledge and experience in:

- Risk analysis
- Regulations and standards on FPSs
- Best practices of the industry regarding operations
- Analysis of operational processes and programming
- Operation of refineries and pipeline transportation of hydrocarbons
- Hydraulics and simulation of transportation of hydrocarbons

The ***Financial Specialist*** shall have knowledge and experience in:

- Cost analysis
- Risk analysis

The role of the competent authority in FPSs, as defined in Chapter 3, may be assumed by the HSSE Specialist as long as he or she complies with the profile described (specific expertise) in the mentioned chapter.

5.2. Terminology

Hazard: Potential cause of losses, physical damage to health, injuries, damage to property and/or assets of the company, plant products or the environment, production losses or an increase of responsibilities, including damage to reputation.

Risk: Generally defined as the probability that an undesired event occurs at a certain moment and causes damage or effects with a particular severity. It is also defined as the combination of the probability and consequence of occurrence of a hazardous event. In contrast, risk assessment may be defined as the comprehensive process to estimate the magnitude of the risk and the decision-making process to determine if the risk is tolerable or not.

Threat: A factor or situation that could potentially cause a hazard and result in an incident.

Control Measures or Barriers: Measures of protection and guard that, if located in the right place, help to prevent hazards that could cause threats. They may be physical (valves, walls, etc.), administrative (training, procedures, etc.) or operational (operational plan).

Environmental Aspect: An element of the activities, products or services of an organization that can interact with the environment.

Significant Environmental Aspect: Any change, either adverse or beneficial, that affects the environment, and results, either wholly or in part, from the activities, products or services of an organization.

Environmental Impact: Any effect on the set of natural, social and cultural assets existing in a given space, which may be positive or negative.

ALARP: As Low as Reasonably Practicable. See the concept of ALARP in the graphical representation of Annex III.

HSE - Health, Safety and Environment

HSSE: Health, Safety, Social and Environment

HSSE Risk Management: The environmental risk management process is a very important technique for the effective implementation of a health, safety, social and environmental management system. The process ensures that the hazards, environmental aspects and potential impacts are fully evaluated (see Chapter 1).

Tolerance: Admissible level for compliance and applicability of legal and regulatory requirements, international standards, best practices and documents that identify the accepted application limits.

Risk Analysis and Assessment: The process used to define the probability and severity of the damage caused by a specific set of undesirable events, and to compare them with a risk tolerance criterion (see Chapter 1).

5.3. Operational Procedure

ALARP is an acronym for "As Low As Reasonably Practicable," which is described as the process to demonstrate that the risks are being controlled below the limit of tolerance, considering a balance of these risks versus resources (time, contingencies costs) to control the same, demonstrating that any other additional effort is disproportionate in the use of resources with the purpose of controlling the risks so that they are below the margin of tolerance.

Controlling the risks according to the ALARP concept means complying with the legal requirements, standards, regulations, procedures, instructions and best practices of the industry.

The higher the risk associated with a hazard or hazardous activity, the larger the resources or efforts (time, contingency and cost) required to control the risk.

The steps for the ALARP demonstration and for all high risks to be controlled are summarized in five steps, as follows:

Step 1:

On the basis of the explanation provided in Chapter 1 - "Risk Analysis", the specific activities are defined and the environmental hazards and aspects of each one of these activities are identified on the basis of the risk (Risk Analysis and Assessment).

If the risk of hazards or aspects are high (intolerable zone), a documented analysis of the ALARP demonstration is performed.

Step 2:

Once the high risks are identified, the measures to control the environmental hazard or aspect are registered according to the risk management procedure.

Step 3:

The definition of the level of tolerance is performed on the basis of the following criteria:

Risk Tolerance Analysis

The risk tolerance concept includes three distinct sections (see Section 5.4 - Conceptual Framework of Tolerance): Intolerable, Tolerable and Widely Accepted. It is important to emphasize that there are no delimited borders or boundaries between these sections, as the definition of the risk tolerance margin depends on the type of activity, country and/or specific requirements.

***Intolerable*Section**- The risks of activities that are located in this section are "intolerable", therefore, the activity shall be managed according to the principles of the company, adopting alternatives in order to reduce the risk or probability of occurrence of the event.

***Tolerable*Section** - The risks of activities in this section are those that people are prepared to tolerate. Some of the factors influencing people to be prepared to tolerate a risk is the degree of knowledge, control and information they have on the basis of the exposure to the risk and the benefits they obtain when exposed to the risk. Example: People who work in a pumping or compression station are more prepared to tolerate risks related to the operation than people living near the station (neighbors).

***Widely Accepted*Section** - The risks of activities in this section are “widely accepted” because people consider these risks as trivial or insignificant in their daily activities. They are described as risks of activities that are not dangerous (low risk) or activities with high risk but whose barriers are completely controlled and managed. Therefore, the effort of a measure or additional barrier in order to reduce the risk is probably disproportionate regarding any additional benefits.

The following shall be considered for definition of the limit of tolerance:

- Corporate and departmental objectives
- Goals and objectives related to operational, administrative and HSSE programs
- Standards and recommended practices of the industry for the specific activity (ANSI, ASME, NFPA, API, AGA, NEC, ISA, ISO, etc.)
- Legal requirements of the country or region where the activity is performed
- Recommended engineering designs for the industry
- Specific risk analysis for the activity or process according to the applicable methodology (HEMP, HAZOP, What If, AMFE, QRA, etc.)

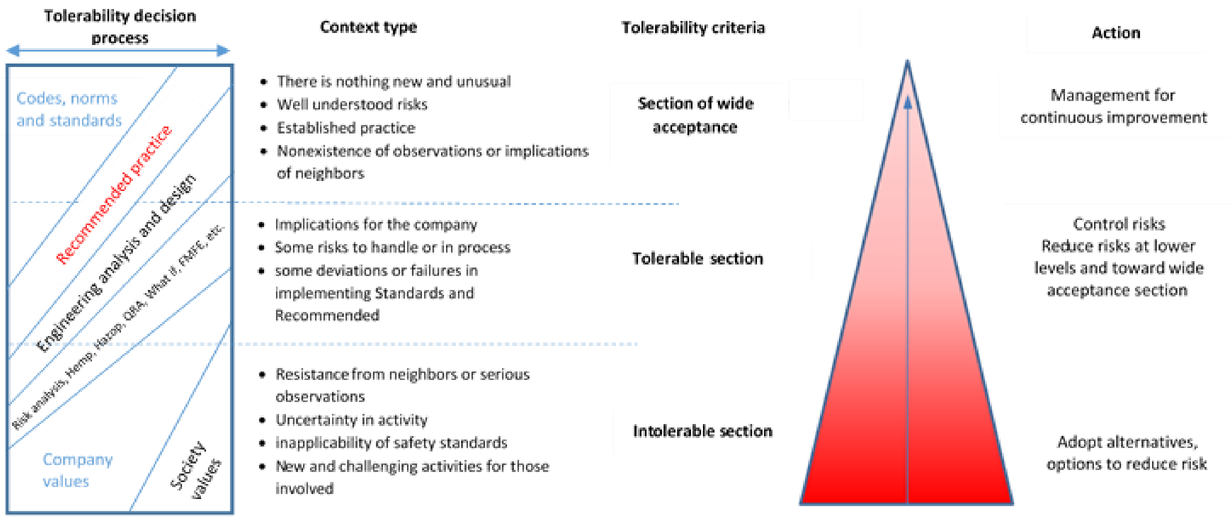
Step 4:

Using a Risk Reduction Evaluation Tool (see Section 5.5), the required control measures are prioritized according to HSSE Risk Management, based on the benefits and the resources used. After the prioritization of control measures, the ALARP group analyzes these measures and chooses those which qualitatively reduce the risk and are below the margin of tolerance. The control measures that do not significantly diminish the HSSE risk and have a high cost should not be considered as practicable. Thus, the control measures for the threats are within the limits of tolerance and are reasonably practicable, and therefore, the HSSE risk from the specific activity is the ALARP.

Step 5:

After the analysis, a document entitled HSSE Case demonstrating the ALARP principle is prepared to provide details about HSSE risk management.

5.4. Tolerance Conceptual Framework



5.5. Risk Reduction Evaluation Tool

The Risk Reduction Evaluation Tool presented here is a combination of a simple 3x3 cost vs. benefit matrix, with the level of difficulty and/or effort to implement it. It is used with the purpose of listing barriers in order of priority in order to have a transparent process of analysis and implementation. There are other tools that can also be used to this end, to the discretion of each company.

		Benefit		
		A	M	B
Cost	B	1	2	3
	M	2	4	6
	A	3	6	9

Cost Factor vs. Benefit

X

Multiplied by

Effort		
B	M	A
1	2	3

Effort Factor

=

Equals

00

Risk Reduction Index from 1 to 27

Implementation Cost

The implementation cost represents essentially the amount required to implement the barrier, assuming that it will be during a scheduled shutdown. The costs of time with no production are not included in this analysis.

The cost is expressed in US Dollars (US$), and the following are examples of the levels to consider, which may be modified according to the criterion of the Financial Advisor as required.

Implementation Cost	*Monetary Cost*
Low	< US$ 50k
Medium	US$ 50k - US$ 500k
High	> US$ 500k

There is a dependency between cost and effort, sometimes a lower effort can be offset with a higher cost.

Benefit

The benefit can be interpreted as a reduction in the probability of occurrence of the event or in the consequences - if some event occurred -, or a combination of both.

Consider the benefit for people, assets, environment and reputation. Example: A positive benefit (positive barrier) for people can mean an adverse effect on the environment. The benefit shall be expressed as High, Medium, Low, as detailed below:

Benefits	*Examples*
High (moves one or more blocks in the risk matrix)	Highest reduction in probability (the probability of failure drops from 1/10 to 1/100), the consequences are significantly reduced (from fatality to minor injury), and so are the benefits from insurance premiums, cost of accidents, and production, and there is a positive effect on reputation.
Medium	Lowest reduction in probability (from 1/10 to 1/50), the consequences are reduced, benefits in insurance premiums and penalties are achieved / and cost of accidents and production are reduced.
Low	Limited reduction in probability and consequences due to an event.

At the time of performing the feasibility analysis of studies or monitoring as important barriers, it shall be analyzed, if relevant information to make improvements to the system or process analyzed will result from the study, and if they will serve as other priority barriers in the study.

Implementation Effort

The implementation effort relates to the easiest way to implement the barrier. This may include the scope of the idea, complexity, previous analyses, specialized studies, etc. An example of interpretation of the Implementation Effort Matrix is provided below:

Implementation Effort	*Examples*
Low	Easy, quick and immediate solution and implementation, applicable to a specific installation Simple and short planning is required with the participation of the executing institution on site only, a single person or a small group will be able to implement the barrier. No plant shutdown or interruption of operations required Examples: Installing a valve, training on use of equipment, procedure upgrade, etc.
Medium	Simple solution with the involvement of operations and maintenance Implementation is complex, activity to be performed on site requires some detailed planning and a small group of people for the analysis. Plant shutdown or interruption of activity might be required Examples: replacing parts of equipment, simple redesigns of the installation by areas or schemes, development of an HSSE Risk Management Study specific for the site, hiring additional support staff to perform the analysis or jobs
High	Complex initial activity, requires comprehensive planning, involves a majority of the areas of the company, requires single planned shutdown of plant to implement the barrier. Examples: Overhaul or major repairs of equipment, withdrawal of large equipment, plant shutdown, integrity checks.

Note: When a high number of FPS barriers are presented and the level of resolution of the 3x3x3 matrix is not effective in terms of the priority, some other criteria shall be used. Example: **Remaining time of operation** - This analysis can be useful to those barriers to implement that had a major impact on the HSSE case and on the reduction to ALARP criteria. If an installation has few remaining years of useful life and it is not feasible to adapt the FPS, the analysis shall be focused on those barriers of immediate impact and a low implementation cost. In contrast, if the installation were new and with a long useful life remaining, and the contract or business sustainable, an investment shall be made or long-range barriers shall be implemented in accordance with the legal requirements and regulations of the site. It is also important to consider in this analysis the disproportionate maintenance cost of each barrier per year, the savings in the allocation of the asset or installation, the insurance premium involved, and the analysis of the practicality and benefits of the barrier per barrel or product transported, among other issues.

Consider that the ALARP process to prioritize and determine control measures in fire protection systems is a philosophy and a continuous way of conducting business at lower levels of risk.

6. FPS MAINTENANCE AND OPERATION COSTS

As stated in Section 1 of this Chapter, the evaluation of FPS projects are generally not economic-financial assessments, where operation and maintenance costs impacting on the investment return or profitability of the business shall be considered, but rather monitor guidelines for evaluation of FPS projects, such as legal regulations, corporate standards, good practices and technological models adopted.

However, these costs are likely to be considered for budgetary purposes, or for a cost-benefit analysis, as mentioned in Section 4, where it is necessary to decide if an option for the reduction of the risk is beneficial or cost-efficient, providing the required level of safety at the lowest possible cost, and also considering the initial investment (CAPEX) and the cost of operation and maintenance (OPEX).

These shall also be considered to define the technological model to adopt with regard to the FPS project evaluation guidelines. However, once the technological model has been adopted, it shall not be reviewed during the evaluation of each project. In any case, it may be revised periodically with reference to new technologies, lessons learned and recommendations of the industry.

The operating and maintenance cost of a FPS will not be conceptually very different from operation or production equipment, if the required resources and maintenance routines and the operating time in the year are known. Perhaps the latter is the conceptual distinction with respect to a production or operation equipment. The question is, then, to define the operating time of a system that is not normally activated throughout the year. Passive systems and detection systems will probably be activated at all times. Active systems will be defined by the sum of the periodic testing and inspection defined in Chapter 4, plus the necessary drills defined by each company.

Therefore, based on the inspection and testing routines defined in Chapter 4, plus those defined by the equipment manufacturer, the resources required for FPS operation and maintenance may be defined.

A situation may arise where there are no internal resources to carry out the periodic inspection and testing mentioned or the maintenance routines defined for specific equipment, so the corresponding outsourcing and associated costs shall be planned.

In summary, based on the application of Chapter 4, the recommendations of FPS manufacturers and the testing and drills defined by the company, a plan may be developed for FPS use and maintenance routines, which will be used to estimate the resources required and associated costs, with feedback from the experience of the professionals associated in the implementation of such plan.

Glossary

ACTIVE FIRE PROTECTION: Equipment, system or means whose specific role is extinguishing a fire.

ADIABATIC FRACTION: A fraction of fluid that evaporates instantaneously in sudden depressurization in adiabatic conditions, i.e. when there is no transfer of heat.

ADMINISTRATIVE AREA: Constructions used as offices and for related services.

ACUTE EXPOSURE GUIDELINE LEVELS (AEGL): Maximum concentration levels in the air established by the United States Environmental Protection Agency as a guide for managing emergencies due to acute or short time exposure to certain critical substances.

AICHE: American Institute of Chemical Engineers.

AMERICAN INDUSTRIAL HYGIENISTS ASSOCIATION (AIHA): A professional organization based in Fairfax, Virginia (USA), whose purpose is to address occupational and environmental health and safety issues, and to provide services for certified industrial hygienists.

ALARP: As Low As Reasonably Practicable.

ALCOHOL-RESISTANT FORMING FOAM (AFFF): A synthetic foaming liquid concentrate resistant to the action of polar solvents, that mixed with fresh or salt water, extinguish fires that originate on the surface of polar liquids soluble in water, avoiding their re-ignition. This type of concentrate, mixed with water in a proportion of 1 %, 3 % and 6 %, is effective for extinguishing fires in storage tanks containing flammable products or fuels that are not soluble in water.

API: American Petroleum Institute.

APPROVED: An approval issued by an agency or laboratory stating that the performance of equipment, materials and accessories is in compliance with the relevant fire protection standard to be used for fire protection.

AQUEOUS FILM FORMING FOAM (AFFF): A synthetic liquid concentrate with a special foaming formulation that mixed with fresh or salt water in a proportion of 1 %, 3 % and 6 % produces a low expansion foam that by floating on the burning surface of flammable liquids and/or fuels lighter than water, acts as a surfactant and cools the surface, spreading a high-consistency film that isolates the liquid surface from the air oxygen, thus suppressing the generation of flammable vapors.

ALARM RECEPTION FACILITY: A place where alarm or monitoring signals are received.

COMPETENT AUTHORITY: An organization, office or working group responsible for stating and approving the requirements of these Guidelines, a code or standard, or for approving equipment, materials, an installation or a procedure.

AUTOMATIC DETECTION EQUIPMENT: Equipment that automatically detects heat, flames, combustion products, flammable gases or other conditions that could result in fire or explosion and cause another automatic activation of the alarm and protection equipment.

AUTOMATIC OPERATION: Operation without human intervention.

AUTOMATIC SPRINKLER: A fire suppression or control device that operates automatically when its heat-activated element is heated to its thermal rating or above, allowing water to discharge over a specified area.

BLADDER TANK PROPORTIONER: A system that is similar to a standard pressure proportioner, except that the foam concentrate is contained inside a diaphragm bag that is contained inside a pressure vessel. It operates in the same way as the standard pressure proportioner, with the exception that, due to the separation of the foam concentrate from the water, this system can be used with all foam concentrates, regardless of the specific severity.

BLOCK VALVE: A device used to block piping circuits in private fire service main for the purpose of repairing, maintaining and directioning the water flow to a specific site during an emergency.

BOILING LIQUID EXPANDING VAPOR EXPLOSION (BLEVE/BL): A fireball produced when external heating causes a sudden and total burst of a container of gas under pressure, when the wall material loses mechanical resistance and cannot withstand the internal pressure. The mechanical or thermal expansion could affect the entire facility, with considerable damages, depending on the type of gas or product stored.

BOILING POINT: The temperature at which the vapor pressure of a liquid equals the surrounding atmospheric pressure.

BUSINESS: Any activity carried out with a general purpose (e.g.: exploration, production, transport, refining, etc.)

CAUSE: A condition that gives rise to another event, phenomenon, action or situation.

COMBINED STANDPIPE AND SPRINKLER SYSTEM: A system where the water piping services supply both 2 in. (65 mm) outlets for fire department use and outlets for automatic sprinklers.

CONTROL MEASURES OR BARRIERS: Measures of protection and guard that, if located in the right place, help to prevent hazards that could cause threats. They may be physical (valves, walls, etc.), administrative (training, procedures, etc.) or operational (operational plan).

CONTROL VALVE: A valve controlling flow to water-based fire protection systems.

CRITICAL SCENARIO: A risk that demands the greatest amount of water and/or foam in the event of a fire and is the result of a risk analysis.

DAMAGE OR IMPACT: Alteration with negative consequences on people, communities, environment, reputation and/or goods.

DEFICIENCY: A condition where the implementation of the component is not within the specified limits or specifications.

DELUGE VALVE: A water supply control valve intended to be operated by actuation of an automatic detection system that is installed in the same area as the discharge devices.

DIKE: A concrete retaining wall, built around one or more storage tanks, to contain a spill of a flammable liquid or fuel.

DIKE FIRE: Any type of fire that occurs within the containment area outside the tank. These types of fire may vary from a small spill incident to a fire covering the whole area of the dike.

DIRECTLY AFFECTED AREA: An area potentially affected by final events that originate and develop directly in the site where the loss of containment of the product occurred.

DISCHARGE DEVICE: A device designed to discharge water or foam-water solution in a predetermined, fixed or adjustable pattern.

DISPERSION (DIS): Evolution of a toxic or flammable gas cloud in the atmosphere that depending on the weather conditions extends and moves while it is being diluted.

DOUBLE CHECK VALVE ASSEMBLY: Assembly consisting of two internally loaded check valves, either spring-loaded or internally weighted, installed as a unit between two tightly closing resilient-seated shutoff valves as an assembly, and fittings with properly located resilient-seated test cocks.

EFFECT: An event, condition or action that may alter an area or element.

EFFECTIVE CONCENTRATION (EC50): A concentration of a substance that produces a response equal to half of the maximum response for the 50 % of the population.

EMERGENCY RESPONSE PLANNING GUIDES (ERPG): Roof type limits established by the AIHA as a guide for planning the response to emergencies by release of chemicals in the air. They are used for protection of almost all individuals in occupational environments.

EMISSION: A discharge of a substance or element into the air, in solid, liquid and/or gaseous state.

ENVIRONMENTAL ASPECT: An element of the activities, products or services of an organization that can interact with the environment.

ENVIRONMENTAL IMPACT: Any effect on the set of natural, social and cultural assets existing in a given space, which may be positive or negative.

ENVIRONMENTAL PROTECTION AGENCY (EPA): United States government agency responsible for establishing regulations for the protection of health and the environment and enforce them in the United States.

EVENT TREE: Logical modeling of combinations of occurrence and non-occurrence of events, used to identify sequences of accidents that lead to all the potential consequences given an initiating event.

EXPLOSION (EXP): A sudden release of high pressure gas into the atmosphere. According to their nature, explosions can be classified into physical and chemical.

EXPLOSIVE LIMITS

Lower Explosive Limit (LEL) - The lowest concentration (percentage) of a gas or vapor in air capable of producing a flash of fire in presence of an ignition source (arc, flame, heat). Below this level, the mixture is too "poor" to start the combustion.

Upper Explosive Limit (UEL) - The highest concentration (percentage) of a gas or vapor in air capable of producing a flash of fire in presence of an ignition source (arc, flame, heat). Above this level, the mixture is too "rich" to start the combustion.

FACILITY: An area or premises where a private operation is performed (e.g., a plant, a terminal, a building, a floor of a building).

FILTER: A device capable of removing from water all solids of sufficient size to obstruct the spray nozzles.

FINAL EVENT: An uncontrolled event capable of producing damage to people, an area or an element. When the damage is realized, it becomes an accident.

FIRE AND GAS DETECTION SYSTEM: A set of functions carried out by circuit initiators, fire & gas panel, and final elements of notification and control, running security features for detection and control of fire & gas. This system integrates field input and output signals and enables, in accordance with the particular specifications of each installation, monitoring, control and elimination of events and incidents in the facilities of a plant.

FIRE DEPARTMENT CONNECTION: A connection through which the Fire Department can pump supplemental water into, standpipe or other system furnishing water for fire extinguishment to supplement existing water supplies.

FIRE PROTECTION FOAM: A product consisting in a stable aggregation of bubbles formed by water and foaming concentrate, which are mixed with air to inflate the bubble. As the latter is lighter than liquid hydrocarbons, it floats on the surface, preventing the access of oxygen and avoiding its mixture with flammable vapors, as well as cooling and separating the flame from the burned surface, and therefore causing the extinguishment of the fire.

FIRE PROTECTION RING: A piping circuit intended for distribution of water for fire protection.

FIRE PROTECTION SYSTEM: A set of active and passive fire protection forms whose main function is to prevent and control fire in industrial facilities.

FIRE PUMP: A pump that is a provider of liquid flow and pressure dedicated to fire protection.

FIXED FOAM SYSTEM: A fire system where a foam solution generated in a main station is transported through a piping network to the risk site, so that foam is generated through special devices and discharged through fixed outlets. These systems require permanent pumping equipment for operation.

FIXED WATER SPRAY SYSTEM: A special fixed piping system connected to a private five service main, with nozzles for spray, discharge and distribution of water in a specific pattern over the surface to be protected.

FLAMMABLE AND COMBUSTIBLE LIQUIDS: For purposes of this document, all petroleum products fall within the groups of flammable or combustible liquids, according to the following NFPA classification:

Flammable Liquids: Class IA - Any liquid that has a flash point below 22.8 °C and a boiling point below 37.8 °C. Class IB - Any liquid that has a flash point below 22.8 °C and a boiling point at or above 37.8 °C. Class IC - Any liquid that has a flash point at or above 22.8 °C, but below 37.8 °C.

Combustible Liquids: Class II - Any liquid that has a flash point at or above 37.8 °C, but below 60 °C. Class IIIA - Any liquid that has a flash point at or above 60 °C, but below 93 °C. Class IIIB - Any liquid that has a flash point at or above 93 °C.

FLASH FIRE (FF): A progressive dissemination, low speed fire. Does not produce significant pressure waves. Usually associated with the dispersion of flammable vapors at ground level. When these vapors find a point of ignition, the front of the flame is propagated up to the point of emission, sweeping and burning the entire area occupied by the vapors in conditions of flammability.

FLASH POINT: The minimum temperature at which an oil product emits vapor sufficient to form an ignitable vapor mixture with air near its surface, producing a "flash" or soft explosion.

FLUOROPROTEIN (FP): A foam concentrate with a base of proteins and synthetic fluorinated surfactant additives that mixed with fresh or salt water excludes the air through the foam layer, also spreading a film on the surface of the liquid burned to prevent its vaporization and avoid its re-ignition.

FOAM CONCENTRATE: A liquid foaming agent as received from the manufacturer.

FOAM DISCHARGE DEVICE: Any device that, injected with a solution of foam and water, produces foam.

FOAM SYSTEM: A set of equipment, piping and appurtenances used to conduct and distribute foaming solution to the foam-making equipment for protection of facilities.

FOAM-WATER SPRAY SYSTEM: A system connected through a piping network to a source of foam concentrate and to a water supply. The system is equipped with foam-water spray nozzles to discharge the agent (foam followed by water or in reverse order) and for distribution on the protected area.

FOAM-WATER SPRINKLER SYSTEM: Piping network connected to a source of foam concentrate and to a water supply, employing appropriate devices for discharge and distribution over the protected area.

HAZARD: Potential cause of losses, physical damage to health, injuries, damage to property and/or assets of the company, plant products or the environment, production losses or an increase of responsibilities, including damage to reputation.

HAZARDOUS SUBSTANCE: Any substance that is flammable, explosive, toxic to human health and dangerous to the environment, with the features listed in Annex 1.

HOSE CONNECTION: A combination of equipment provided for connection of a hose to the standpipe system that includes a hose valve with a threaded outlet.

HOSE HOUSE: An enclosure located over or adjacent to a hydrant or other water supply designed to contain the necessary hose nozzles, hose wrenches, gaskets and spanners to be used in firefighting in conjunction with and to provide aid to the local fire department.

HOSE STATION: A combination of a hose rack, hose nozzle and hose connection.

HOSE VALVE: A valve to an individual hose connection.

HSE: Health, Safety and Environment

HSSE: Health, Safety, Social and Environment

HSSE RISK MANAGEMENT: The environmental risk management process is a very important technique for the effective implementation of a health, safety, social and environmental management system. The process ensures that the hazards, environmental aspects and potential impacts are fully evaluated (see Chapter 1).

HYDRANT: A valved connection on a water supply system having two or more outlets and that is used to supply hose and fire department pumpers with water.

HYPERSUSCEPTIBLE INDIVIDUALS: Individuals that show a reaction to the exposure to a specific level of a substance that is stronger than the response shown by the great majority of the subjects.

IEEE: Institute of Electrical and Electronics Engineers.

IMPACT DISTANCE: Length within which the vulnerable elements are likely to be impacted as a result of a final incident associated with an event.

IMPAIRMENT: A condition where a fire protection system or unit or portion thereof is out of order, and the condition can result in the fire protection system or unit not functioning in a fire event.

INDIRECTLY AFFECTED AREA: An area potentially affected by final events that originate in a spill trajectory or from stagnation or accumulation of product withdrawn from the site where the event occurred.

INITIATOR: An event that causes the loss of containment or the ignition of hydrocarbons vapors or hazardous substances, which in turn gives rise to a chain of subsequent events that trigger a final event.

IN-LINE BALANCED PRESSURE PROPORTIONER: This system is similar to the standard pressure proportioner, except that the pressure of the concentrate pumped is maintained in a preset fixed value. The compensation of the water and the liquid takes place in individual proportioners located in the system riser or in segments of multiple systems. It is recommended that this equipment have an alternate foam proportioning system.

INSPECTION: A visual examination of a system or portion thereof to verify that it appears to be in operating condition and is free of physical damage.

JET FIRE: A stationary and elongated flame (long and not wide) caused by the ignition of a turbulent jet of gas or vapor fuel.

JOCKEY PUMP: A pump intended to maintain pressure in a fire protection system when there is no water flow within the pressure limits specified for each system.

INSPECTION, TESTING AND MAINTENANCE SERVICE: Service program provided by a qualified contractor or qualified property owner's representative in which all components unique to the property's systems are inspected and tested at the required times and necessary maintenance is provided.

LEAK: An accidental release of a gas product due to loss of containment.

LEL: Lower Explosive Limit

LETHAL CONCENTRATION (LC50): A concentration of a substance to which 50 % exposed to this concentration dies.

LINE PROPORTIONER: A system that uses a Venturi pickup-type device where water passing through the unit creates a vacuum, thereby allowing foam concentrate to be picked up from an atmospheric storage container.

LISTED: Equipment, materials or services, included in a list published by an organization that is acceptable to the competent authority and concerned with the evaluation of products or services, that maintains periodic inspection of production of listed equipment or materials or periodic evaluation of services, and whose listing states that either the equipment, material or service meets appropriate designated standards or has been tested and found suitable for a specified purpose.

LOC: Loss of Containment.

LOPA: Layer of Protection Analysis.

LOWER FLAMMABILITY LIMIT (LFL/LEL): The lowest concentration of flammable gas mixed with air that could maintain the combustion of a gas.

MAIN DRAINAGE: Main drainage connection located in the system column and also used as test connection.

MAIN PUMP: A pump or set of fixed fire protection water pumps operated with an electric motor or an internal combustion diesel engine, whose nominal capacity or sum of nominal capacities meets the requirements of increased demand for water in the event of fire, at a specified pressure.

MAINTENANCE: Work performed to make equipment operable or to make repairs.

MAJOR ACCIDENT: A significant event that requires a response beyond routine, which results from an uncontrolled process during the operation of any installation, and which may exceed the boundaries of the facilities.

MANUAL OPERATION: Operation of the system or its components.

MONITOR: A device connected to the private fire service main and equipped with a nozzle that delivers a constant and adjustable direct jet, narrow and wide coverage, with mechanisms that allow rotating the position of the nozzle at least 120º in the vertical plane and 360º in the horizontal plane, and remain stable in the selected position with no need for additional fastening.

MONITOR NOZZLE: A device specifically designed with large and free water conduits to provide a far-reaching stream for protection of large quantities of combustible materials, aircraft, tank farms or any other locations where large amounts of water need to be available without the delay of laying hose lines.

NATIONAL FIRE PROTECTION ASSOCIATION (NFPA): United States agency that standardizes fire protection issues. Its standards have been adopted by numerous countries.

NET POSITIVE SUCTION HEAD (NPSH): The suction that makes a liquid flow through the suction piping toward the pump impeller.

NOZZLE: A device for use in applications requiring special water discharge patterns, directional spray or other unusual discharge characteristics.

OPERATIONAL AREA: Industrial facilities where product handling or transformation processes are carried out.

ORIFICE PLATE PROPORTIONING: This system utilizes an orifice plate(s) through which passes a specific amount of foam concentrate at a specific pressure drop across the orifice plate(s).

PASQUILL ATMOSPHERIC STABILITY: Atmospheric stability classification on a range from A (extremely unstable) to F (stable).

PASSIVE FIRE PROTECTION: A material, system or means designed to prevent or avoid the spread and facilitate the extinguishment of a fire. The specific function of a passive fire protection system is not direct and active firefighting.

PFD: Process Flow Diagram.

PHA: Preliminary Hazard Analysis.

P&ID: Piping and Instrumentation Diagram/Drawing

PLANT: A set of machines, equipment and installations conveniently arranged in appropriate places, whose function is to transport and store flammable and combustible products.

POOL FIRE (PF): A buoyant diffusion flame of a liquid fuel in a fuel bed of known dimensions (extension), which occur in an open enclosure.

PRESSURE CONTROL VALVE: A pilot-operated pressure reducing valve designed for the purpose of reducing the downstream water pressure to a specific value under both flowing (residual) and nonflowing (static) conditions.

PRESSURE REDUCING VALVE: A valve designed for the purpose of reducing the downstream water pressure under both flowing (residual) and nonflowing (static) conditions.

PRESSURE-REGULATING DEVICE: A device designed for the purpose of reducing, regulating, controlling or restricting water pressure.

PRESSURE-RESTRICTING DEVICE: A valve or device designed for the purpose of reducing the downstream water pressure under flowing (residual) conditions only.

PRESSURE VACUUM VENT: A venting device mounted on atmospheric foam concentrate storage vessels to allow concentrate expansion and contraction and tank breathing during concentrate discharge or filling.

PRIVATE FIRE SERVICE MAIN: A set of equipment and appurtenances that, arranged as rings, are used to conduct and distribute water to the facilities protection systems.

PRIVATE FIRE SERVICE MAIN: Pipe and its appurtenances on private property (1) between a source of water and the base of the system riser for water-based fire protection systems, (2) between a source of water and inlets to foam-making systems, (3) between a source of water and the base elbow of private hydrants or monitor nozzles, (4) used as fire pump suction and discharge piping, and (5) beginning at the inlet side of the check valve on a gravity or pressure tank.

QUICK-ACTING SHUT-OFF VALVE: A ball-type valve used for opening and closing the supply of water and foam; it closes in less than five seconds.

QRA: Quantitative Risk Analysis.

QUALIFIED PERSONNEL OR CONTRACTOR: Defined as indicated in Chapter 3 of these Guidelines.

RISK: Generally defined as the probability that an undesired event occurs at a certain moment and causes damage or effects with a particular severity. It is also defined as the combination of the probability and consequence of occurrence of a hazardous event. In contrast, risk assessment may be defined as the comprehensive process to estimate the magnitude of the risk and the decision-making process to determine if the risk is tolerable or not.

RISK ANALYSIS: A set of qualitative and quantitative procedures which allow the assessment of risk in an industrial plant, based on the establishment of initiating events, threatening events, identification of risk scenarios and estimation of consequences.

RISK ANALYSIS AND ASSESSMENT: Consideration of the causes and sources of risk, its consequences and the likelihood that such consequences may occur.A model by which the threat is related to the vulnerability of the exposed elements in order to determine the potential adverse social, economic and environmental effects and their probabilities. The value of damages and potential losses is estimated and compared with the safety criteria established, with the purpose of defining types of intervention and scope of risk reduction and preparedness for response and recovery.

RISK LEVEL: Quantified value of the probability of a type of damage that an event or activity may cause to a person, area or item.

ROOF FIRE: In a roof fire, the tank roof is on fire but the roof maintains its buoyancy. Flammable vapors escape through the tank vent or through any roof appurtenances or cracks.

SEAL FIRE: A fire on the seal between the tank and the roof, caused by loss of seal integrity and the consequent ignition of the vapor in the seal area. The burned area may vary from a small localized area to the whole circumference of the tank. The flammable vapor can be present in various parts of the seal, according to its design.

SEMI-FIXED FOAM SYSTEMS: In this type of fire systems, the facilities to be protected are equipped with fixed foam discharge devices connected to a piping system whose supply is located at a safe distance, which presents no operational risks. This installation does not include the foam generation devices, nor the materials needed to produce foam, which are transported to the event site and connected to the supply line after the fire has started.

SIGNIFICANT ENVIRONMENTAL ASPECT: Any significant change, either adverse or beneficial, that affects the environment, and results, either wholly or in part, from the activities, products or services of an organization.

SIL: Safety Integrity Level.

SOURCE OF SUPPLY: Any natural water body (river, lagoon, lake, spring, sea, etc.) or artificial body of water (well, municipal service, water treatment system and/or system for recovery of hydrocarbon-free effluents, among others).

SPILL: An accidental spillage of a liquid product on soil or water.

SPRINKLER SYSTEM: A fire protection system that consists of an integrated network of underground and above ground piping designed in accordance with fire protection engineering standards.

STANDARD BALANCED PRESSURE PROPORTIONER: A system that utilizes a foam concentrate pump, where foam concentrate is drawn from an atmospheric storage tank, is pressurized by the pump, and passes back through a diaphragm balancing valve to the storage tank. The water and concentrate sensing lines are brought toward the balancing valve and keep the foam liquid pressure equal to the water pressure. Both equal pressures are supplied to the proportioner and are mixed according to a preset regime. It is recommended that this equipment have an alternate foam proportioning system.

STANDARD PRESSURE PROPORTIONER: A system that uses a pressure vessel containing foam concentrate where water is supplied to the proportioner, which directs an amount of downward onto the contained concentrate, thereby pressurizing the tank. The pressurized concentrate is then forced by the water through a hole into the water jet flow. This type of system is applicable for use with foam concentrates with a specific gravity substantially higher than that of water. It is not applicable for use with concentrates with a specific gravity equal or similar to that of water. It is recommended that this equipment have an alternate foam proportioning system.

SUFFOCATING ATMOSPHERE: Type of hazardous atmosphere that occurs when a nonflammable gas nor toxic gas manages to displace or reduce the normal concentration of oxygen below the minimum required to sustain human life.

SUPERVISION: In water-based fire protection systems, a means of monitoring system status and indicating abnormal conditions.

SUPPORT PUMP: A pump or set of fixed fire protection water pumps operated exclusively with internal combustion diesel motor, with the same output and pressure as the main pump(s), to replace it/them in case of failure.

SYSTEM: Infrastructure that brings together different facilities with the same operational purpose (e.g., production field, transportation system).

TESTING: A procedure used to determine the status of a system by conducting periodic physical checks, such as water flow tests, fire pump tests, alarm tests and trip tests of dry pipe, deluge or preaction valves.

THREAT: A factor or situation that could potentially cause a hazard and result in an incident.

TOLERANCE: Admissible level for compliance and applicability of legal and regulatory requirements, international standards, best practices and documents that identify the accepted application limits.

TRENCH: Longitudinal excavation with brick and/or concrete walls and floor, which hosts one or more pipes.

UEL: Upper Explosive Limit

UVCE: Unconfined Vapor Cloud Explosion.

UPPER FLAMMABILITY LIMIT (UFL/UEL): The highest concentration (percentage) of a gas or vapor in air capable of producing a flash fire in presence of an ignition source (arc, flame, heat). Above this level, the mixture is too "rich" to start the combustion.

VULNERABILITY: An internal factor of a subject, object or system exposed to a threat, that corresponds to its inherent disposition to be damaged.

VULNERABLE ELEMENT: People, environment or goods that may suffer damage as a result of a major accident.

WATER SPRAY: Water in a form having a predetermined pattern, particle size, velocity and density discharge from specially designed nozzles or devices.

WATER SPRAY NOZZLE: An open or automatic water discharge device that, when discharging water under pressure, will distribute the water in a specific directional pattern.

WATER SUPPLY: A source of water that provides the flows (gpm - L/min) and pressures (psi - bar) required by the water-based fire protection system.

WATER TANK: A tank supplying water for water-based fire protection systems.

WHOLE SURFACE FIRE: A fire where the tank roof has lost buoyancy and the entire surface of the liquid is ignited.

BEST PRACTICES

Fire Protection Systems in Transportation and Storage Facilities

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REGIONAL ASSOCIATION OF
OIL, GAS AND BIOFUELS SECTOR COMPANIES
IN LATIN AMERICA AND THE CARIBBEAN

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