National Iranian Petrochemical Co.
HSE Directorship

2 Process Safety

Design Basis Safety Concepts For Petrochemical Plants and Projects

IN THE NAME OF GOD

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For Petrochemical Plants and Projects

2 PROCESS SAFETY

Design Basis Safety Concepts For Petrochemical Plants and Projects

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انتشارات حک

شرکت ملی صنایع پتروشیمی

پیشگفتار

تولید پایدار و ایمن همراه با توجه ویژه به مقوله سلامت کارکنان و حفظ محیط زیست جزء اولویت های اساسی در واحدهای صنعت پتروشیمی می باشد، که یکی از عوامل مهم در تحقق اهداف فوق، لحاظ نمودن اصول ایمنی فرآیند و طراحی ذاتاً ایمن این تاسیسات می باشد.

با توجه به روند توسعه صنعت پتروشیمی توسط بخش خصوصی در کشور و تنوع صاحبان لیسانس و مشاوران/ طراحان بعضاً شاهد سطوح متفاوتی از طراحی ذاتاً ایمن توسط این مجریان هستیم. از آنجائیکه شرکت ملی صنایع پتروشیمی (NPC) نقش حاکمیتی در توسعه این صنعت را بعهده دارد، لذا بمنظور اطمینان از یکپارچگی و لحاظ شدن حداقل الزامات در طرح ها و پروژه ها در طی مراحل مختلف انتخاب لیسانس، طراحی پایه و مفهومی و عملیات ساختمان و نصب، این مدیریت نسبت به گردآوری و تدوین الزامات پایه ایمنی فرآیند شامل ۱۲ عنوان مدرک به عنوان سند بالادستی در قالب مجموعه ای سه جلدی اقدام نموده است که لازم است کلیه مشاوران/ طراحان و پیمانکاران جهت ایجاد محیطی ایمن و پیشگیری از حوادث احتمالی از این الزامات پیروی نمایند.

قدرت ا... نصیری

مدیر بهداشت، ایمنی و محیط زیست

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Basic Safety Concepts for Building Blast Protection
NPC-HSE-S-05

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1. Scope and Philosophy

This document describes the fundamental assumptions and basic design criteria for establishing and specifying blast resistance requirements for new buildings that are being considered as part of processing facilities or for existing buildings in the vicinity of new processing facilities.

2. References

- API RP -752, Management of hazards associated with location of process plant Buildings
- Guidelines for evaluating process plant buildings for external explosions and fires, CCPS
- Exxon-Mobile Engineering Standards

3. Definitions

Building Spacing Category - Four Building Spacing Categories (0 through 3) are defined for the purpose of blast resistant design based on spacing from a credible VCE hazard. The higher the category number, the lower the blast resistance requirements. The construction requirements for each building category shall be prepared by Civil engineering department within each specified project. The required Building Spacing Category is a function of the distance from the building to the edge of Potential Explosion Domains, the mass of the release of Potentially Explosive Vapor and the volume of the Potential Explosion Domain. Based on conservative assumptions about the magnitude of releases of Potentially Explosive Vapor and of the volume of Potential Explosion Domains, the default Building Spacing Category as a function of distance from the edge (not the epicenter) of the nearest Potential Explosion Domain is as follows:

DISTANCE TO EDGE OF POTENTIAL EXPLOSION DOMAIN		DEFAULT BUILDING SPACING CATEGORY
ft.	m	
50-100	(15-30)	Category 0
> 100-200	(> 30-60)	Category 1
> 200-400	(> 60-120)	Category 2
> 400-700	(> 120-215)	Category 3

Critical Operations Building - A building containing equipment and/or instrumentation essential to the control and/or operation of two or more processing units or operating areas, which can operate independently of each other indefinitely. Examples of critical operations buildings include Control Houses, Substations and Remote Instrument Module (RIM's).
Explosion Epicenter - The point within an exploding vapor cloud which gives rise to the highest pressure and from which pressure shock waves are assumed to propagate out radially.

Occupied Building:

- Building housing people who are regularly assigned there and perform the majority of their job function within the building are normally classified as **"Occupied Buildings."** This includes control houses, single unit operating control rooms, office buildings, main laboratories, central maintenance workshops, gate houses and smaller offices within larger buildings such as warehouses and fire stations.
- Buildings which are only occupied for part of the working day, such as local operator shelters, change houses, locker rooms, dining rooms, meeting rooms, rooms used for issuing work permits, rooms for conducting training sessions, etc., should be classified as **"Occupied Buildings"**. Examples of buildings typically considered as **"Occupied Buildings"** include the following:
  a. Buildings having occupancy equal to or greater than 400 person-hours per week.
  b. Buildings having periodic peak occupancy of 20 or more persons at any one time.
  c. Buildings in which one or more persons spend 50% or more of their time during a typical workday.
  d. Any building in which personnel are present 50% or more of the time.
- Buildings which are seldom occupied, such as electrical substations, analyzer houses, smoking pens, unmanned storerooms, rest rooms, etc., are not normally classified as **"Occupied Buildings"** but as **"Unoccupied Buildings."**

Potential Explosion Domain - The space (onsite or offsite) immediately surrounding operating equipment, e.g., drums, exchangers, towers, pumps, loading racks, pipe racks, steelworks, etc., or other obstacles, which can potentially be engulfed and filled by a flammable fuel-air mixture, and which is sufficient in size to give rise to a vapor cloud explosion.
Potentially Explosive Vapor - Gas or vapor below its auto ignition temperature which has the potential to form an explosive mixture when mixed with ambient air and could give rise to a vapor cloud explosion. This includes:

- Flammable gases having a molecular weight greater than 21.
- Vapors arising from flashing liquids having a closed -cup flash point less than 100°F (38°C) and a volume average boiling point less than or equal to 350°F (175°C)

Process Equipment - drums, exchangers, towers, pumps, compressors, etc., which contain flammable or combustible material. Piping in pipe racks is generally not considered to be process equipment.

Source of Release - A single piece of operating equipment, such as a drum, exchanger, tower, pump, piping or valve, etc., which can release Potentially Explosive Vapor should it leak or fail catastrophically. Isolated pipe racks outside process area battery limits containing only valves, vents and drains, and which are protected adequately from overpressure, including thermal expansion, and contain no dead-legs, are not considered as a **Source of Release** for the purposes of this document. When determining whether a Source of Release can release sufficient Potentially Explosive Vapor to form a Potential Explosion Domain, only single equipment catastrophic failures should be considered.

Vapor Cloud Explosion (VCE) Scenarios - Generic scenarios used to characterize potential explosions for the purpose of establishing blast loadings for new buildings in facilities and for existing buildings affected by new process facilities. These scenarios are the basis for the blast loadings presented in **Appendix 2**. These scenarios are described below:

VCE-1 - A relatively small but strong explosion centered in a highly congested area of the unit. This event results in a blast wave with a high overpressure of short duration.

VCE-2 - A large but average strength incident that could cover an entire process block. This event yields a low overpressure, long duration blast wave.

VCE-3 - The maximum credible VCE incident involving a double explosion in a single VCE. This is an extreme event with a high overpressure and long duration.

VCE-1 and VCE-2 are vapor cloud explosion scenarios that set the design basis for slight-to-moderate building damage. It is expected that building operations will continue after such an event. VCE-3 constitutes the maximum credible event and it sets the design basis to provide for survivability of the occupants (i.e., avoiding building collapse). It is expected that the damage will require replacement of the building following a VCE-3 event. Refer to **Appendix 2** for the applicability of each of these three scenarios to the design and evaluation of buildings according to their criticality and occupancy.

Vapor Cloud Scenario No. 1 (VCE #1)

Following a leak or uncontrolled release from process equipment, a vapor cloud develops resulting in a congested/confined area of a process unit or operating area becoming enveloped in a flammable gas cloud. The volume of the flammable cloud is assumed to be 140,000 ft^3 (4000 m^3) containing LPG type material in stoichiometric proportions. This is equivalent to a 165 ft. (50 m) diameter cloud 6 ft. (2 m) high, or an overhead pipe rack, 300 ft. (90 m) long, 25 ft. (7.5 m) wide, filled with gas to a depth of 20 ft. (6 m). It is judged that this is close to the upper volume limit of the most highly congested/confined part of a typical process unit or operating area.For this first design basis VCE scenario, referred to as VCE#1, the Multi-Energy method explosion strength 7 is used because of the highly congested/confined nature of the cloud. This represents a violent explosion at the top end of the deflagrative scale.

Blast overpressure loadings arising from VCE #1 are given below as a function of the distance from the edge (not the epicenter) of the Potential Explosion Domain.

DISTANCE TO EDGE OF POTENTIAL EXPLOSION DOMAIN		BLAST OVERPRESSURE LOADING		DURATION
ft.	(m)	psi	(kPa)	ms
50	15	10	70	40
100	30	6.5	45	50
200	60	3.0	21	55
400	120	1.5	10	65
700	215	1.0	6.9	

Vapor Cloud Scenario No. 2 (VCE #2)

The second scenario, VCE #2, involves a large vapor cloud engulfing an entire process unit area. It is assumed that the flammable portion of the cloud, occupying areas filled with process equipment obstacles does not exceed a volume of 1,000,000 ft^3 (30,000 m^3) and contains LPG type material in stoichiometric proportions. For a typically sized process unit [70,000 - 100,000 ft^2 (6,500 - 9,300 m^2) plot area], this is equivalent to the flammable cloud covering the whole block to a depth of 10 - 15 ft. (3 - 5 m). It is assumed that the process area generally meets spacing specifications, and that the cloud will envelop a variety of process equipment having different degrees of congestion/confinement. Using the Multi-Energy method to model the entire cloud, based on an explosion strength scale of 1-10, it is assumed that the cloud will have overall explosion strength of 5, which is representative of an "average" strength explosion. A middle range explosion strength of 5 is chosen since there will be a great variety of process equipment which is in some cases fairly close to each other and in other cases more spaced out. Blast overpressure loadings arising from VCE #2 are given below as a function of the distance from the edge (not the epicenter) of the Potential Explosion Domain.

DISTANCE TO EDGE OF POTENTIAL EXPLOSION DOMAIN		BLAST OVERPRESSURE LOADING		DURATION
ft.	(m)	psi	(kPa)	ms
50	15	3	21	230
100	30	3	21	200
200	60	1.9	13	200
400	120	1.1	7.5	200
700	215	1.0	6.9	

Vapor Cloud Scenario No. 3 (Maximum Credible Vapor Cloud Explosion) (VCE #3)

The third scenario, referred to as the "Maximum Credible Vapor Cloud Explosion" (VCE #3), is a large flammable cloud engulfing a process unit area, which includes a central core of highly congested/confined equipment. To model this vapor cloud, it is assumed that two explosions will occur , one involving that part of the cloud occupying the "highly congested/confined" area and the other involving the "partially congested/confined" area. Those parts of the cloud which fall outside the "partially congested/confined" area, e.g., outside the plant battery limits, and which do not engulf any process equipment or obstacles, are assumed to have a negligible contribution to the overall explosion. Using the same sized vapor cloud which was used for the VCE #2, namely 1,000,000 ft^3 (30,000 m^3), containing a stoichiometric concentration of LPG type material the following breakdown is assumed. The cloud in the "highly congested/confined" area is assumed to be 170,000 ft^3 (5,000 m^3), with the remainder of the cloud, 830,000 ft^3 (25,000 m^3) occupying the "partially congested/confined" areas of the plant. The central core area representing the "highly congested/ confined" parts of the plant is once again given an explosion strength of 7. The outer part of the cloud is given strength of 5, consistent with the outer process equipment items being less congested.

Blast overpressure loadings arising from VCE #3 are given below as a function of the distance from the edge (not the epicenter) of the **Potential Explosion Domain.**

DISTANCE TO EDGE OF POTENTIAL EXPLOSION DOMAIN		BLAST OVERPRESSURE LOADING		DURATION
ft.	(m)	psi	(kPa)	ms
50	15	11	75	100
100	30	7.0	48	130
200	60	3.5	24	155
400	120	1.5	10	200
700	215	1.0	6.9	

It should be noted that VCE-1, VCE-2 and VCE-3, as described above, represent hypothetical "worst-case" scenarios that have been developed to characterize the overpressures associated with an explosion when relatively little is known about the potential magnitude of a release or the volume and degree of confinement of the flammable portion of a vapor cloud. This is often the case for facilities. As such, the blast overpressures and durations shown represent the maximum values to be used in the design of blast resistant buildings.

4. Blast Resistance and Spacing Requirements

The model is based on the premise that the building damage from vapor cloud explosions (VCE's) that have occurred has been determined by the size of a domain (space) in which there is congestion of equipment, an accumulation of a combustible vapor-air mixture originating from some source either within or outside the domain, and the distance between the damaged building and an apparent origin (epicenter) of the explosion.

The contents of this subsection include a comprehensive screening methodology for new buildings. The screening methodology is based on the following assumptions:

1. The potentially explosive vapor is assumed to be propane, which is considered medium reactivity.
2. The release occurs within a chemical plant having a degree of congestion or confinement typical of units that satisfy the spacing criteria given in NPC-HSE-S-03.
3. The postulated release rates are high enough that the Potential Explosion Domain can be assumed to be filled entirely before ignition occurs.

When more than one of these conditions deviates significantly from the above assumptions, a site specific study may be conducted, taking into account the actual reactivity of the Potentially Explosive Vapor and the actual volume and degree of confinement of the Potential Explosion.

Note: The design of buildings as "safe havens" in the event of toxic gas releases is outside the scope of this document.

All buildings which house people within a chemical plant should incorporate basic construction features intended to reduce the likelihood of their occupants becoming injured from the effects of a VCE.

In general, the only occupied buildings to be located near equipment having a potential for a VCE are those directly associated with the operation of processing units. All other buildings which house people shall be located outside areas likely to be subjected to overpressure. However, occasions arise when alternative locations do not exist or there are sound logistic and operational reasons to locate such buildings where they may be subject to overpressure. Any building likely to be so affected shall be designed to an appropriate level of blast resistance. The intent is that the buildings would not collapse even when subjected to an extreme design basis VCE (described as VCE-3 elsewhere in this section). Similarly, blast resistance shall be built into those buildings (whether or not they are occupied) which, if damaged, would result in widespread production debits, e.g., control centers, electrical substations and remote instrument modules. The intent with these types of building is to provide an assured level of blast resistance such that the buildings can continue to operate following a design basis VCE in one of the operating areas. Hence essential process control and electrical supply are maintained to non-affected units and emergency actions can be taken for the affected area.

The procedure described in this document is intended for use in determining the blast resistance requirements of new buildings that are part of facilities, and for evaluating the blast resistance of existing buildings that may be impacted by facilities when relatively little is known about the magnitude of potential releases of Potentially Explosive Vapor and about the volume and degree of confinement of the flammable portion of the resulting vapor cloud. The procedure involves determining whether or not the minimum conditions for the existence of a Potential Explosion Domain are present in a given facility. If one or more Potential Explosion Domains are identified, then it is assumed that any one of them may experience any one of the three hypothetical design basis VCE scenarios (VCE-1, VCE-2 and VCE-3). The procedure to determine blast resistance requirements for new buildings within the Scope of this document involves the following steps:

1. Establish criticality of building.
2. Establish building occupancy.
3. Establish distance from building to nearest Process Equipment in accordance with spacing standards (NPC-HSE-S-03).
4. Establish distance from building to the boundary of the nearest area of equipment that may be part of a Potential Explosion Domain.
5. Determine spacing category for building.
6. Specify building design overpressure scenarios.

Once a building category has been specified, the blast loads used to design the building will be set. The blast loadings shown in Appendix 2 represent the maximum values to be used for the design of buildings depending on their spacing category. Less conservative values may be used when supported by engineering calculations.

Step 1 - Establish Criticality of Building

A building is considered to be a critical operations building if it contains equipment and/or instrumentation essential to the control and/or operation of processing units or operating areas, which can operate independently of each other indefinitely. Buildings falling into this category would normally include Control Houses, Substations and Remote Instrument Module (RIM’s).

Step 2 - Establish Building Occupancy

The minimum distance from Occupied Buildings to the boundary of the nearest Potential Explosion Domain shall be 150 ft. (45 m). A distance of less than 150 ft. (45 m) is permitted for Substations, RIM's and other Critical Operations Buildings not classified as Occupied Buildings. It is expected that only periodic visits would be made to such buildings to carry out routine maintenance. If it is required to install manned work stations in these buildings, then a minimum spacing of 150 ft. (45 m) from the nearest Potential Explosion Domain should be used and the requirements for Occupied Buildings should be applied in addition to those for Critical Operations Buildings. Control Houses are always considered to be both Occupied Buildings and Critical Operations Buildings.

Step 3 - Establish minimum distance from building to the nearest Process Equipment

Refer to **NPC-HSE-S-03** for minimum recommended distances between buildings and process equipment. These distances are intended to limit the exposure of buildings to potential fires associated with process equipment. They do not necessarily represent the distances to the boundaries of the nearest Potential Explosion Domain (i.e., not all process areas meet the criteria for a Potential Explosion Domain).

Step 4 - Establish distance from building to the boundaries of each Potential Explosion Domain.

To determine the existence and boundaries of Potential Explosion Domains, use the following procedure:

1. Determine the mass of Potentially Explosive Vapor, Ms, which can be released from a potential Source of Release. In establishing the mass of vapor capable of being released from a potential Source of Release, only single equipment catastrophic failures should be assumed. Credit may be taken for automatic control valves or automatic shutdown systems in place, but no credit for manual intervention, such as the closing of remotely operated valves or stopping pumps, should be assumed. Where liquid streams are involved, estimates of the vapor leaked to the atmosphere should be based upon adiabatic flash calculations.
2. For areas containing a Source of Release, a Potential Explosion Domain exists when both of the following criteria are satisfied:

   a. The equipment contains a Source of Release capable of releasing to the atmosphere at least 1,100 lb. (0.5 tones) of Potentially Explosive Vapor,

   b. The plot area of operating equipment and obstacles containing the Source of Release exceeds 5,000 ft^2 (500 m^2) or the plot volume of operating equipment and obstacles containing the Source of Release exceeds 75,000 ft^3 (2,100 m^3).

3. For areas not containing a Source of Release, a Potential Explosion Domain exists when both the following criteria are satisfied:

A nearby Source of Release is capable of releasing to the atmosphere at least 1,100 lb (0.5 tones) of Potentially Explosive Vapor, and b. There is at least 5,000 ft^2 (500 m^2) of equipment and obstacle plot area or 75,000 ft^3 (2,100 m^3) of equipment and obstacle plot volume within a radius, R, of the nearby Source of Release. R should be taken as:

R = 330 ft. (100 m) for Ms $\geq$ 22,000 lb. (10 tones)

or

R = 2.2 Ms 0.5, ft. (31.6 Ms 0.5, m), for Ms < 22,000 lb. (10 tones)

An isolated pipe rack is considered to be a Potential Explosion Domain when the pipe rack has at least three levels of piping, each being at least 20 ft. (6 m) wide with no gaps between adjacent pipes exceeding 3 ft. (1 m) and has at least 53,000 ft^3 (1500 m^3) of interstitial volume within a radius, R, of the Source of Release (R is given above). The volume between the lowest level of the pipe rack and grade is only included in the estimate of interstitial volume when the height above grade of the lowest level is less than 15 ft. (5 m).

The minimum distance between a Critical Operations Building and the boundary of the nearest Potential Explosion Domain shall be 50 ft. (15 m). The minimum distance between an Occupied Building and the boundary of the nearest Potential Explosion Domain shall be 100 ft. (30 m).

It should be noted that:

1. One Potential Explosion Domain can be regarded as independent of another where there is a clear minimum separation distance of 15 ft. (5 m).

2. Pipe racks running around the periphery of processing unit areas should be included in the process area Potential Explosion Domain when the separation distance to the process equipment is less than 15 ft. (5 m) and the elevation of the lowest tier is less than 15 ft. (5 m) above grade.

3. Potential Explosion Domains which are at least 15 ft. (5 m) apart, but are linked only by a pipe rack, may be regarded as independent, provided the pipe rack itself does not qualify as a Potential Explosion Domain.

4. If a pipe rack runs from a process area in a direction towards a building, the process area Potential Explosion Domain would not include the section of pipe rack beyond the battery limit.

Step 5 - Determine Spacing Category for Building

Using the actual distance, D, from the building to the boundary of the nearest Potential Explosion Domain, specifies the Building Spacing Category in accordance with the following:

a. Occupied Buildings not considered Critical Operations Buildings

DISTANCE TO EDGE OF POTENTIAL EXPLOSION DOMAIN		Default building spacing category
ft.	(m)	psi
> 100-200	(> 30-60)	Category 1
> 200-400	(> 60-120)	Category2
> 400-700	(> 120-215)	Category 3
> 700	(>215)	Category 3

Note that occupied buildings shall be located a minimum of 100 ft. (30 m) away from the boundary of the nearest Potential Explosion Domain.

b. Critical Operations Buildings

1. If the building is also an Occupied Building, the building shall be located a minimum distance of 100 ft. (30 m) from the boundaries of the nearest Potential Explosion Domain or from the nearest process equipment.
2. If the building is an Unoccupied Building, the building shall be located a minimum distance of 50 ft. (15 m) from the boundaries of the nearest Potential Explosion Domain or from the nearest process equipment.
3. The default Building Spacing Category shall be determined as follows:

DISTANCE TO EDGE OF POTENTIAL EXPLOSION DOMAIN (D) ft. (m)	MITIGATING QUALIFIER (IF ANY)	DEFAULT BUILDING SPACING CATEGORY
> 50 - 100 (15 -30)	Unoccupied Buildings only	Category 0
> 100 - 150 (30 - 45)	None	Category 1
> 150 - 200 (45 - 60)	A ≥ 13,000 ft^2 (1200 m^2) and Ms ≥ 2,200 lb. (1 tone)	Category 1
> 150 - 200 (45 - 60)	A < 13,000 ft^2 (1200 m^2) or Ms < 2,200 lb. (1 tone)	See Note 1
> 200 - 275 (60 - 85)	None	Category 2
> 275 - 400 (85 - 120)	A ≥ 13,000 ft^2 (1200 m^2) and Ms ≥ 2,200 lb. (1 tone)	Category 2
> 285 - 400 (85 - 120)	A < 13,000 ft^2 (1200 m^2) or Ms < 2,200 lb. (1 tone)	See Note 2
> 400 - 700 (120 - 215)	None	Category 3

Where: D = Distance to the edge (not the epicenter) of the Potential Explosion Domain, ft. (m)
Ms = Mass of potentially explosive vapor released, lb (tones)
A = Plot area of potential explosion domain, ft^2 (m^2)

Note 1: For D ≤ 130 + 0.02 Ms, ft. (40 + 15 Ms, m), specify Category 1. Otherwise, specify Category 2.

Note 2: For D ≤ 210 + 0.06 Ms, ft. (65 + 45 Ms, m), specify Category 2. Otherwise, specify Category 3.

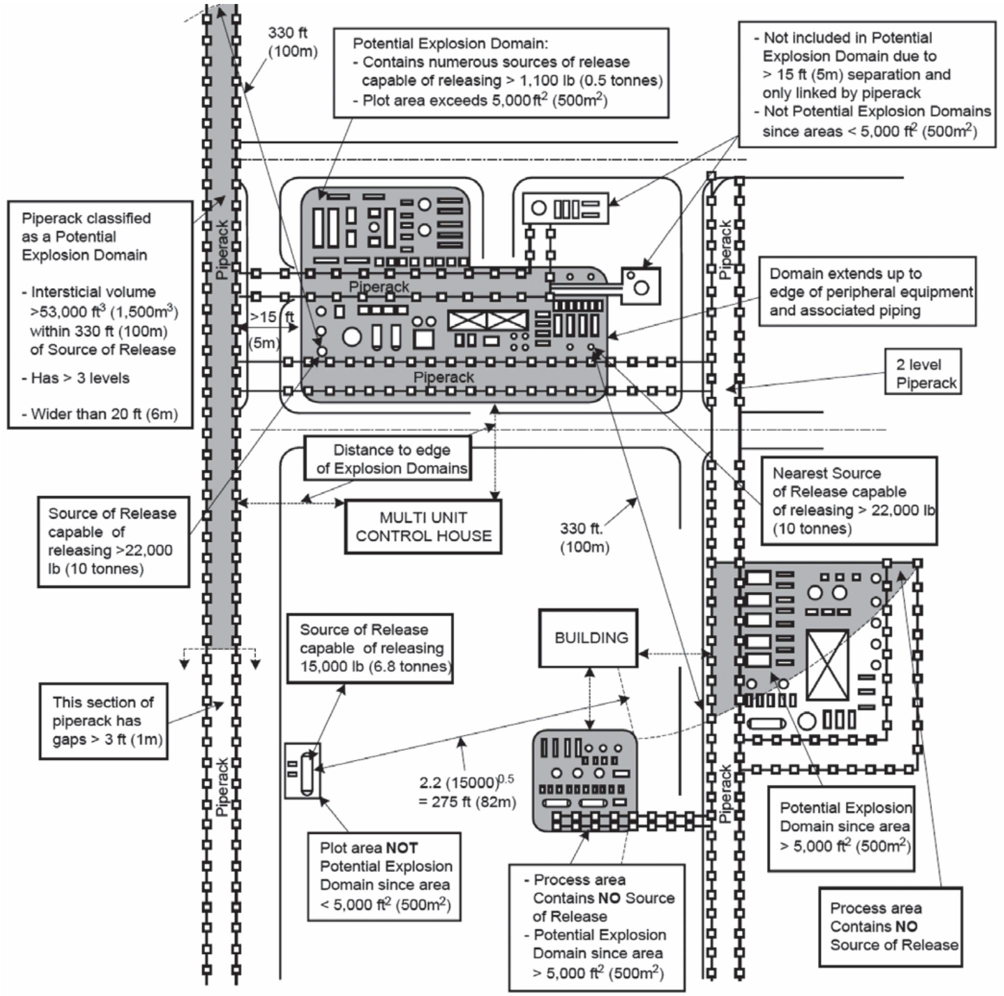
Step 6 - Specify the Building Design Overpressure Scenarios

Appendix 2 is a summary of the default design overpressures for various building types and Spacing Categories. It should be noted that the design blast loadings presented in Appendix 2 are based on extreme events, specifically, the design basis VCE scenarios (VCE-1, VCE-2 and VCE-3). These should be considered the maximum blast loads for design purposes. These overpressures and durations were developed using a Potential Explosion Domain plot area of 70,000 ft^2 (6,500 m^2) and a total release (before dispersion) of 22,000 lb. (10 tones) of Potentially Explosive Vapor.

The blast loadings presented in Appendix 2 are representative of those that would result from an explosion involving propane or similar gases, and a degree of confinement typical of that found in chemical plants that follow the equipment spacing NPC-HSE-S-03. For situations involving other vapors with higher reactivity (such as ethylene) and equipment layouts that differ from the NPC-HSE-S-03. a site specific study shall be conducted.

Note: When determining the blast resistance requirements for new buildings, consideration should be given to overpressures arising from potential explosion scenarios which may occur at facilities outside the property line. Similarly, the siting of new processing facilities on Company property should consider the impact of potential explosion scenarios on buildings and other structures located outside the property boundary.

Appendix 1
Potential Explosion Domains Example Plot Layout



Appendix 2
Summary of VCE Scenarios, Blast Loading and Building Category

Building Spacing Category	Design Basis VCE Scenario(1)	Blast Loading and Duration (3) Overpressure in psi (kpa), Duration in ms		
		Building Type		
		Occupied Critical Operations Buildings Example: Control House	**Unoccupied Critical Operations Buildings** Example: Substation or RIM	**Occupied Non-Critical Operations Buildings** Example: Werehouse, office, locker room
Category 0	VCE # 1 VCE # 2	(2)	10(70), 40 3(21), 230	(2)
Category 1	VCE # 1 VCE # 2 VCE # 3	6.5(45), 50 3(21), 200 7(48), 130	6.5(45), 50 3(21), 200 -	- - 7(48),130
Category 2	VCE # 1 VCE # 2 VCE # 3	3.0 (21), 55 1.9(13), 200 3.5(24), 155	3(21), 55 1.9(13), 200 -	- - 3.5(24), 155
Category 3	VCE # 1 VCE # 2 VCE # 3	1.5(10), 65 1.1(7.5), 200 1.5(10), 200	1.5(10), 65 1.1(7.5), 200 -	- - 1.5(10), 200

Notes:
(1) Loads from VCE #1 and VCE #2 are used to design for "slight-moderate" damage; loads from VCE #3 are used to design for "survival without collapse."
(2) Only unoccupied buildings may be located between 50 ft. (15 m) and 100 ft. (30 m) from a Potential Explosion Domain.
(3) For blast loads 1 psi (6.9 kPa) and less, in some cases it may be justified, based on little incremental cost, to specify Category 3 construction as a minimum for new Multi-Unit, Control Houses shall have protective film applied to the inside of windows or use laminated glass or polycarbonate.

Basic Safety Concepts for Fire & Gas Detection System
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1. Scope

This document describes the basic design requirements of detection systems for flammable or toxic gas releases and for fires in process plants and tankage areas.

Note: *building's detection systems requirement is out of this document's scope and it shall be referred to NFPA 101*

2. References

- NFPA 72, National Fire Alarm Code.

3. General

The risk from flammable or toxic gas releases or fires can be reduced by early detection and subsequent mitigating actions. The risk from a flammable or toxic material release is the combination of the probability of a leak occurring and the potential consequences should the leak occur. In determining the probability of a leak, the type of operation, the operating conditions, and the equipment involved are all considered. In determining the consequences, the material contained the size of the leak, the proximity of the leak to other equipment or the fence line and speed with which the leak might be detected without instruments are all considerations.

All releases occur as a result of some failure. These failures can generally be classified as follows:

- *Human errors (e.g., failure to close a drain valve, incorrect valve opened).*
- *Active equipment failures (e.g., pump seal or bearing failure).*
- *Passive equipment failures (e.g., pipe gasket failure or pipe rupture).*

In addition to this general classification, data on typical chemical plant indicate certain areas which have historically caused release problems. Areas of higher probability include:

- *Open sampling or drain points.*
- *Equipment opened for maintenance.*
- *Seals on rotating equipment, i.e., pumps and compressors.*
- *Atmospheric seals on sulfur units.*
- *Flange gaskets.*
- *Tanks, due to overfilling.*
- *Small lines in vibrating service.*
- *Lines in corrosive/erosive service.*
- *Plate and frame heat exchangers.*

When a leak does occur the consequences may range from inconsequential effect to personnel health effects, fire, or vapor cloud explosion. The severity of the consequences depends on the following factors:

- *Toxicity or Flammability of the material leaked.*
- *Leakage mass rate which are a function of the material vapor pressure, the operating temperature and pressure, and the cross-sectional area of the opening.*
- *Proximity of the leak to in-plant personnel, ignition sources, and the property line.*
- *The ability to detect the leak and stop or reduce the rate.*
- *Atmospheric conditions, especially wind velocity and direction.*

Toxic gas, flammable gas, and fire detectors can reduce the risk of a release by reducing the severity because faster response is possible. The response may be carried out by the operator or through an automated response. Automated responses include stopping and/or isolating equipment and automated foam, water spray, or deluge systems.

4. Toxic Gas Detection

Toxic gas often is present in chemical plant streams. Hydrogen sulfide (H_2S), hydrogen fluoride (HF), chlorine (CI_2), carbon monoxide (CO), anhydrous hydrogen chloride (HCI), bromine (Br_2), and ammonia (NH_3) may be present at a site. Small releases of toxic gas are a threat to personnel working directly where the leak occurs. Medium releases may affect other personnel working on the unit but not directly at the release source. Large releases may produce toxic concentrations outside the unit or even outside the plant fence line.

Toxic releases may be generally classified by the cause of the release as follows:

- Releases resulting from venting or draining equipment, typically for sampling or as part of maintenance. Toxics are not intentionally vented but equipment may not be properly gas freed or the toxic concentration may not be properly identified.
- Releases from "active" equipment includes: pump and compressor seals, sulfur plant seals, and H_2S incinerators which have lost flame.
- Releases from "passive," higher integrity equipment, such as pipe flanges and pipe/vessel wall ruptures. These are lower probability release points than for active equipment. Unlike active equipment, the amount of passive equipment is very large and the most likely release points are not easily identified. Different detection methods are employed for each type of release.

Releases from higher potential, active equipment shall be monitored with toxic gas detectors. Toxic gas detectors available for use in chemical plants are based on a wide range of technologies including electrochemical sensors, solid state sensors, ion mobility sensors, and FTIR and laser diode open path systems. Detectors shall be located close to the potential leak source and signal the problem to those in the general area or those who might enter the area.

Releases from higher integrity, passive equipment generally do not require monitoring Because of the lower likelihood of a release and the very large area covered by passive equipment complete monitoring is not possible. Note that Manifolds (such as Battery limits or metering stations) with a large number of valves and flanges, representing a concentration of leak sources, and shall be monitored by detection systems.

4.1. H_2S Detection

Three hazard levels are defined for H_2S operation: high, medium, and low.

High potential hazard areas contain both a potential release source and high H_2S concentrations. Examples of potential release sources include floating roof tank seals, pump and compressor seals, sulfur plant seal legs, H_2S incinerators, vents, drains and sampling connections. High H_2S concentrations are defined as those where the H_2S concentration in the vapor phase of the contained stream is above %2 volume. If H_2S is dissolved in a liquid, and an isenthalpic flash of the liquid at atmospheric pressure produces a vapor with more than 2% volume H_2S, the stream would also be considered high concentration. Typical sources with higher release potential and high H_2S concentrations include, but are not limited to:

- Amine regenerator overhead pumps.
- Sour water stripper overhead pumps.
- Compressors for H_2S rich gas.
- Atmospheric seals.
- Burners of H_2S combustors and incinerators.
- Water seals on flare drums which often have a high H_2S concentration.

Medium potential hazard areas require both a potential release source and contained H_2S concentrations between a minimum of:
a) 250 volume ppm, if potential exposure involves possible direct exposure to the vessel vapor space, such as sampling or opening vessels, or b) 500 volume ppm, for dispersed process exposure not involving possible direct exposure to the vessel vapor space and a maximum of 2.0 % volume. Typical examples for such areas include:

- Sour water draw off facilities.
- Sour hydrocarbon tanks and slop tanks.
- Heavy fuel oil tanks.

Low potential hazard areas contain either a potential release source with H_2S concentrations of between a minimum of 10 vppm and a maximum of:
a) 250 volume ppm, if potential exposure involves possible direct exposure to the vessel vapor space, such as sampling or opening vessels, or b) 500 volume ppm, for dispersed process exposure not involving possible direct exposure to the vessel vapor space, or high H_2S concentrations within passive, high integrity equipment. High H_2S concentrations are defined as those where the H_2S concentration in the vapor phase of the contained stream is above 2% volume. If H_2S is dissolved in a liquid, and an isenthalpic flash of the liquid at atmospheric pressure produces a vapor with more than 2% volume H_2S, the stream would also be considered high concentration. Examples of passive, high integrity equipment include process vessels, piping, flanges, and other static equipment (no moving parts).Typical examples of Low Potential Hazard areas include:

- Light ends pumps handling fluids with low H_2S concentrations (e.g., untreated propane).
- Sour fuel gas at fired boilers as long as the gas contains less than 500 vppm H_2S.
- Heavy fuel loading.
- Acid gas transfer lines (typically high H_2S concentration but no potential release source).

Fixed H_2S detectors shall be considered within high and medium potential hazard areas. The detection points should be located at each potential release point. Ideally, the detectors should be located within 5 ft. (1.5 m) of the leak point, and between the centerline and 2 ft. (60 cm) below. Access may require some adjustment to the location. The detector shall alarm between 10 and 20 ppm. When multiple sources are located together, e.g., pumps, one detector can service two sources, provided the sources are located within 10 ft. (3 m) of each other. Other protective measures may be specified by the local SOP's. The area may be marked, personal H_2S detectors may be required, and/or authorization before entering the area might be required. In the low hazard area, it is unlikely that a person will be exposed to dangerous concentrations as a result of a leak. The alarm system for high and medium potential hazard areas shall allow for rapid identification of the leak source.for this purpose,the following alarm systems shall be considered:

1. Locate all detector outputs in the control room on a panel or distributed control computer display. The panel/display should indicate all detectors in alarm, and the first detector which went into alarm. A local common alarm shall sound in the process area. It's recommended to provide specific sound alarm distinguished especially for toxic detectors.

2. Locate a panel with all alarms in the fire station control room. The panel should indicate all detectors in alarm and the first detector which went into alarm. A local common alarm should sound in the process area.

3. Provide each detection point with a flashing light which would indicate an alarm.

An H_2S detector shall also be placed in the air intake duct for normally occupied buildings as unit operating control rooms, office buildings, laboratories, and central maintenance workshops in close proximity to high potential hazard H_2S areas.

The local Safety specialists will determine whether areas occupied for part of the day such as local operator shelters or change houses are classified as "normally occupied". Close proximity will be determined by the size and scope of potential releases. Where release scenarios and dispersion modeling have already been carried out, the results will indicate which buildings can be subject to high concentrations. When dispersion results are not available, nominally occupied buildings within 200 ft. (60 m) should include a detector. Normally H_2S detectors in air inlets shall alarm at 10 ppm H_2S. When the building is a control house or designated safe haven, the air system should also shut down upon alarm. The shut down concentration may be higher than 10 ppm, provided there is an alarm at 10 ppm. Higher shut down levels should be based on discussion with the local Safety specialist. In addition to locating fixed detectors at potential leak sources, other toxic gas detectors may be used for additional protection of personnel from H_2S leaks in high potential hazard areas.

5. Flammable Gas Detectors

The detection of flammable vapors is similar to that for toxic vapors. The most likely release points are similar, as is the behavior of the vapor as it disperses. The concentration of flammables required for ignition is generally much higher than the concentration of toxic gas required for an acute health threat. However, the use of liquefied hydrocarbons above their normal boiling points can lead to much larger leaks and higher concentrations. Although detection is similar, the consequences of flammable hydrocarbon and toxic releases can be quite different. Since detectors are installed to assist in mitigation of releases, the different consequences of flammable gas and toxic gas releases can result in different deployment strategies.

There are three distinct types of flammable gas detectors for use in plants: catalytic point detector, short path infrared point detector, and infrared open path detector. There are advantages and disadvantages for each.

All types **of flammable gas detectors are calibrated for one composition** and their response to other compositions may vary. For example, a catalytic detector calibrated to the LEL of methane will read 65% of the LEL when propane is present at its LEL. Many gases do not exhibit as pronounced a difference in sensitivity. IR detectors will have similar sensitivity issues. Where multiple gases are present, the calibration standard should be selected to allow sufficient detection for as many other potential gases as possible.

5.1. Locating Flammable gas Detectors

Several factors must be considered when determining the need for flammable gas detectors. They include the potential for vapor cloud formation upon release, the potential for equipment to develop a leak, and the proximity of the potential leak point to ignition sources. Contained materials with higher potential for vapor cloud formation upon release include:

- Liquid with an atmospheric boiling point below ambient temperature, (C_4 and lighter).
- Liquid which is contained at a temperature above its atmospheric boiling point such that 25% or more vaporizes upon release to the atmosphere.
- Gas at high pressure.

When equipment contains higher risk materials, i.e. materials with a higher potential for vapor cloud formation, and the equipment has a higher potential for leaks, fixed detectors are recommended.

For **pumps**, a detector shall be located at each seal. One detector may be used between two seals provided the detector is within 5 ft. (1.5 m) of each seal. The detector should ideally be located at or below the centerline of the pump and at least 18 in. above the ground. Some changes to location may be necessary for accessibility.

For **compressors**, a detector shall be located as close as possible to each seal, at or below the centerline for heavier than air gases and above the centerline for lighter than air gases.

Manifolds (such as Battery limits or metering stations) with a large number of valves and flanges, representing a concentration of leak sources, and shall be monitored by detection systems.

There are other **lower probability sources** of hydrocarbon leaks. The leak point from these sources is not as localized as with pump and compressor seals. Generally hydrocarbon detectors are not deployed. However, when they are in close proximity to ignition sources and contain the higher risk materials described above, detectors may be considered. Lower probability sources include:

- Small pipes and connections subject to failure due to vibration.
- Pipes subject to external corrosion (i.e., cooling tower overspray).
- Drain and sample points.
- Control valves operating above 200 psig (14 barg).

Detectors shall be considered if these potential leak points are within 100 ft. (30 m) of ignition sources such as:

- Furnaces.
- Hot, uninsulated metal surfaces above 600°F (315°C).
- Vehicle traffic.
- Other internal combustion engines.
- Electrical substations.
- Railroads.
- Areas with high levels of construction or maintenance.
- Designated smoking areas.

Flammable gas detectors shall also be used to **monitor the air of enclosures** to prevent the buildup of an explosive atmosphere. These detectors may also be coupled with an automated shutdown system to prevent a possible confined space explosion. Air monitoring of the following items shall be considered:

- Air intake to control rooms and “safe haven” buildings.
- Gas turbine acoustic enclosures.
- Hydrocarbon process analyzer buildings.
- Cooling tower exhaust, monitoring for presence of hydrocarbons from a cooling water exchanger tube leak.
- Compressor shelters, which do not provide free ventilation.

Detectors shall also be considered for monitoring of **offsite pressurized storage**. The offsite location results in reduced surveillance by process operators and leaks are less likely to be detected. If the storage area is diked, one detector may be placed within the dike along each wall. This will take advantage of the wall which will tend to contain the hydrocarbon vapors Open-path detectors may also be used to monitor the perimeter, especially when there is no dike. Flammable gas detectors may be set between 20 and 60% of the LEL. A setting of 40% is nominal. Alarm announcement system as described in the toxic gas section, shall be used also for Flammable gas detectors.

6. Fire Detectors

Flammable gas detectors may not be appropriate for all types of hydrocarbon releases. In operations where gases may occasionally be present at 10% of LEL or more as part of normal operation, detectors could result in numerous false alarms. In other cases, the release may readily ignite, e.g., material above its auto ignition point, or high concentrations of hydrogen. In these cases, fire detection systems may be used. Early detection of fire will provide the best chance for control.

Fire detectors may also be used even if hydrocarbon or alternative leak detection is already in use, when it is desirable to further reduce risk. The combination of fire detection with automated actuation of a water deluge or spray will mitigate the effect of a fire and reduce risk. Pump retrofits which might require deviation to spacing standards may be able to offset the increased risk of reduced spacing with an automatic deluge system. There are also fires which do not develop from flammable vapors which may also benefit from the use of fire detection as follows:

1. Electrical equipment fires.
2. Mechanical equipment fires as a result of failures and increased friction and heat.
3. Fires from flammable dusts or solids, as in exhaust ducts or filter bag houses.

7. Smoke Detectors

Smoke detectors are usually employed only in **confined spaces such as control house buildings or electrical substations**. There have been numerous fires in electrical substations, despite proper electrical design. All new substations should have smoke detection, tied to a control house alarm. Smoke detection should also be considered for retrofit of any existing substations. The large amount of electrical equipment in control house buildings is a potential source of fire too. Smoke detection is not employed in outdoor process areas because wind currents make detection unreliable. Ionization and Photoelectric are two types of smoke detectors. Ionization detectors are preferred for electrical or high energy, flaming fires which generate small smoke particles. Photoelectric detectors are usually preferred for low energy, smoldering fires. Additional detail on smoke detectors is available in NFPA 72.

8. Heat Detectors

Heat sensing detectors should be employed when the **potential source of the fire is well known.** Temperature sensitive devices should be placed near each fire source.

There are three types of heat detectors: temperature sensing point detector, rate-of-rise point detector, and temperature sensing line detector. Temperature sensing point detectors use a fusible link or plug which melts at a pre-determined temperature to detect a fire. Rate-of-rise detectors respond to a sudden increase in temperature, typically 12-15°F/min (6-8°C/min). The rate of rise is typically detected by the rapid expansion of gas within one or more detecting heads. **Line detectors** depend on localized heating of a temperature sensitive line.

Point detectors can be applied to specific locations where the likelihood of fire is higher. Pumps with flammable liquids or liquids operating above their auto ignition points and exchangers operating above the process material auto ignition point are possible locations. In certain cases air-pressurized, long-lasting, UV-resistant plastic tubes may be used as alternatives to traditional fire-sensing devices. This type of fire-sensing devices may be used, for example, in remote or congested areas, in pumps with liquids above their auto ignition temperature, or in pumps utilizing dual sealing systems and meeting the criteria for possible monitoring due to fire potential per the Pump Sealing Technology. While heat sensing point detectors are typically not used outdoors, the process pressure and flammability of liquids and vapors in plants often make for intense fires which can be easily sensed. Temperature sensing detectors are more often employed than rate of rise detectors.

Line detectors may be useful for equipment which covers a large area and in which a fire is likely to develop anywhere in the area with equal probability. Equipment such as long conveyor belts and switch gear are possible locations for line detectors.

Because temperature sensing point detectors monitor a small local area and have been demonstrated to have low false alarm rates, they have been coupled with automatic actuation of a deluge system. Two systems which have been used are:

- Pilot heads with a fusible plug are typically located 4-6 ft. (1.2-1.8 m) from possible fire sources such as higher risk pumps or exchangers. The fusible plug can be selected to melt from 135 to 580°F (57 to 304°C). The pilot heads are part of a piping system, which contains pressurized air so that the melted plug releases the air, which actuates the deluge valve.
- A similar system replaces the pilot heads with nylon tubing. The tubing, instead of a fusible plug, melts and actuates the emergency response. This is similar to the plastic tubing described above for point detectors.

9. Flame Detectors

Flame detectors shall be used when there are multiple fire sources in an area. Flame detectors also respond faster than heat sensing or smoke detectors. When rapid spread of the fire is expected, and automated response is required, the flame detector will provide faster response than the heat sensing device. There are two types of flame detectors, UV and IR. UV detectors monitor radiant energy from about 0.18 to 0.27 microns. All flames emit radiation in this region. At these wavelengths, radiation from sunlight is absorbed by the atmosphere so that there is no background solar radiation, and the detector is not affected by the sun. IR detectors monitor radiant energy from about 4.1 to 4.6 microns. All hydrocarbon flames produce CO_2 which has an emission spike at this band, see **Figure 1**. The amount of CO_2 determines the intensity of the radiation. Radiation from the sun is partially absorbed by the atmosphere in this region, see **Figure 2**.

9.1. Dual Sensor Fire Detectors

IR-IR detectors monitor a second narrow band typically near 3.9 microns. Hydrocarbon fires produce less radiation here than at the CO_2 peak. The two bands are compared to increase the rejection of false signals due to flickering radiation from flashing lights, reflected sunlight or heated equipment with flickering.

UV-IR detectors combine standard single band UV and IR sensors. Fire must be sensed by each device to provide an alarm. Generally dual sensors type detectors are preferred as they do reduce the number of false alarms.

9.2. Design Consideration for Fire Detectors

The need for flame or heat sensing detectors is determined by reviewing the potential hazards, risk exposure, and appropriate response to fire. The following conditions would support the installation of fire detectors:

- High fire risk facility; quick response is needed to avoid rapid escalation and endangerment of personnel or equipment.
- Sufficient personnel not available for regular surveillance.
- Early warning by other means not feasible: gas detectors, seal leak detectors, protective equipment systems, process instrumentation, etc.
- Capability exists for prompt response to alarm: shutdown, isolation, and fire suppression.
- Ongoing maintenance support available in the case of UV and IR detectors.

Detectors have also been applied in a limited way for special situations in the plant. Equipment containing hydrocarbons above their auto ignition point, which historically was subject to periodic leaks and fires, have been placed under surveillance. In this case, the detectors serve an alarm function only. Heat sensing devices in combination with deluge systems have been successfully used with low maintenance costs and essentially zero false alarms both onsite and offsite.When a fire detection system is needed, the following guidelines should be followed to ensure acceptable performance:

- Review possible fire scenarios: what fuels are involved, where the fire might start, how fast it might spread.
- Where the rapid spread of the fire is likely, automatic actuation of protective systems should be specified.
- When a flame detector is used, a dual sensor IR-IR or UV-IR flame detector is preferred to reduce the potential for false alarm and is required when the detector will automatically activate a suppression system.
- IR flame detectors are preferred for hydrocarbons. When the fuel contains little or no carbon, a single UV detector or heat detector is preferred. Heat sensing devices are viable alternatives in either case provided the potential flame location is well known and the sensing device can be located nearby.
- Flame detectors should be located no greater than 35 ft. (10 m) from possible fire sources. At 35 ft. (10 m), the detector should respond in ten seconds to a 1 ft^2 (0.1 m^2) pan fire of the expected material on fire.
- Flame detectors should be positioned to see the base of the fire not just the flames above it.
- Enough flame detectors must be deployed to avoid blind spots and to account for loss in sensitivity away from the detector's central axis.
- To avoid false alarms from sources outside the risk area, flame detectors should not have a view of the horizon.

FIGURE 1
RADIATION SPECTRA FROM A HYDROCARBON FUEL FIRE

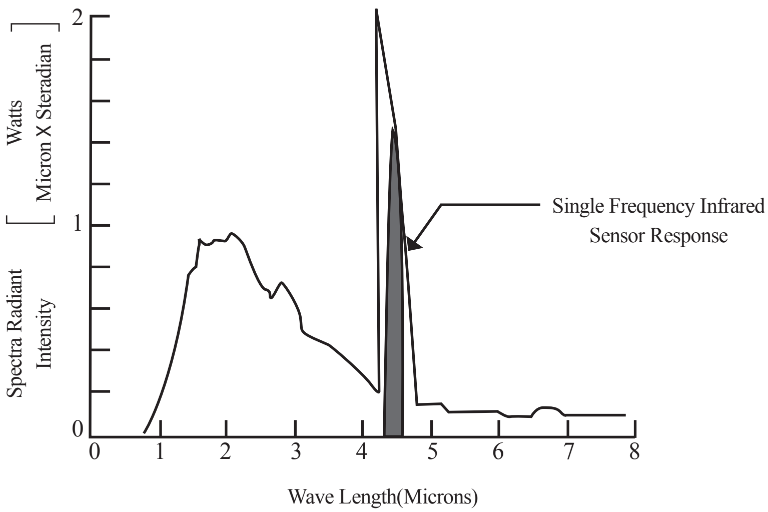
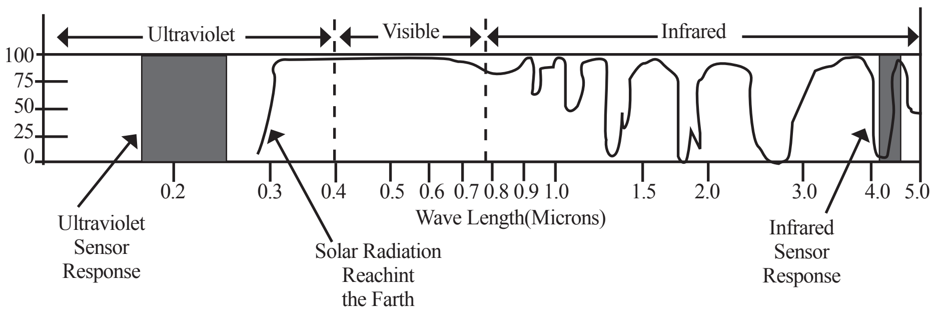


FIGURE 2
FLAME DETECTOR VS SUNLIGHT TRANSMISSION



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1. Scope

This document covers the conceptual design of active and passive fire protection for process unit, tank farm area, loading facilities, and also relevant industrial building in each area. The fire fighting specifications for each plant shall be based on design philosophy that is defined in this document. The second section describes minimum requirements for fire proofing critical equipment and supporting structures as part of passive fire protection.

Note: non-industrial building's fire protection systems requirement is out of this document's scope and it shall be referred to NFPA 101

2. References

- *NFPA 11 , Standard for Low Expansion Foam*
- *NFPA 13, Standard for the Installation of Sprinkler Systems*
- *NFPA 15, Standard for Water Fixed Sprays for Fire Protection*
- *NFPA 2001, Clean Agent Fire Extinguishing Systems*
- *NFPA 20, Stationary pump for Fire Protection*
- *NFPA 22, Standard for Fire Water Tanks*
- *NFPA 101, Life Safety Code*
- *API-RP 2001, Fire Protection in Refineries*
- *API 2218, Fire Proofing practices in petroleum and petrochemical processing plants.*
- *HSE-322-02, guidelines for structural fire proofing, Safety and Fire Fighting Guidelines in Petrochemical Industries, NIPC*

3. Definitions

High Flash Tankage - Tanks containing liquids with a closed-cup flash point of 100°F (38°C) or higher when handled at a temperature not higher than their flash point minus 15°F (8°C).

Low-Flash Tankage - Tanks containing liquid having a closed-cup flash point below 100°F (38°C) and any other (high flash) stocks if handled at temperatures above, or within 15°F (8°C) below, their flash point. For example, a stock with a closed-cup flash point of 150°F (65°C) at a temperature of 135°F (57°C) or higher is treated as a low-flash stock.

Incipient Stage - That stage of a fire immediately after ignition and before it is fully established, when persons already at the scene should be able to bring it under control and extinguish it by use of hand held fire extinguishers, wheeled extinguisher (if immediately available) or a fixed hose reel.

First Phase Fire Fighting - The "First Phase" of a fire in process and related facilities is that period after the incipient stage and prior to the arrival, set-up and initiation of secondary fire fighting by the fire brigade and its mobile units. Operators, maintenance personnel and other field personnel carry this out using fixed firefighting equipment. Effective fire fighting during this stage (typically 5 to 10 minutes) is considered crucial in limiting the degree of fire spread and overall damage.

Single Fire Concept-The extent and capacity of the firefighting equipment provided in a chemical plant or associated facilities are based on the assumption that only one major fire will occur at any one time. Thus, the requirements of the largest single fire contingency determine the design of the major fire fighting facilities. However, the sizing of the fire fighting system components may not be set by the same single fire contingency, since different fire fighting techniques are required on the various plant and offsite facilities. For example, foam production requirements are usually determined by tank extinguishing demands, whereas firewater capacity is usually a function of process unit requirements.

4. General Considerations

During incipient stage some fires may be small enough to be controlled by the immediate application of a fire extinguisher or hose reel. First-phase fire fighting is the effort expended by plant personnel in the early stages of a fire beyond the incipient stage, prior to the arrival of the fire brigade and the deployment of mobile equipment. Optimum control of fires and limitation of damage can be achieved if other equipment in the fire area can be immediately protected against flame impingement and heat radiation. First-phase fire fighting systems comprise equipment suitable for effective operator-initiated fighting of a fire during the initial stages prior to the deployment of mobile equipment.

In a process area, firewater application is the most effective fire fighting method for reducing plant damage while the source of fuel is being isolated from fire. Water is applied to exposed structures and equipment for cooling to prevent further failures and minimize damage until the fire is extinguished. In some instances (e.g., spill fires) foam can be effectively used; but this is usually of secondary importance, as far as design capacity is concerned. Judicious use of the principles of plant layout per NPC-HSE-S-03 will further minimize the impact of fire.

In particular, plant layout must incorporate adequate access ways for firefighting. Loading racks and marine terminals that handle flammable or combustible materials require both cooling water and foam protection, since hydrocarbon liquid spill fires can be expected for which foam is the most effective means of extinguishment. Water is the primary mean of protection for facilities that handle LPG or similar volatile materials.

Fires in tankage and pressurized storage areas are of particular concern, because of the large inventories of flammable liquids, vapors and gases involved. Foam is normally the most effective method of extinguishing a tank fire, in conjunction with water cooling of adjacent tanks. For pressurized or refrigerated LPG storage, water is the prime agent for preventing fire spread by cooling exposed facilities until the fuel supply can be isolated.

In designing and specifying firefighting equipment, three important factors must be kept in mind.

- *Any delay in cooling surrounding equipment increases damage and enhances the potential for the spread of fire.*
- *Traditionally, the proper and effective use of almost all the fire fighting facilities described in this section requires the direct involvement of personnel.*
- *There is a continuing trend of making the most efficient and effective use of personnel available to respond to the demands for first phase fire fighting.*

5. Design Procedures

5.1. Fire Zone

All areas of the Plant shall be subdivided into fire zones and sub zones as appropriate.
Each process unit enclosed main roads shall be considered as one fire zone. If a block will be separated from adjoining blocks by at least 15 meters, the block will be a sub zone. This separation includes major pipe racks, roadways or vacant space.
Single storage tank shall be considered as a fire zone.
Single building shall be considered as a fire zone. Each building will be divided into Sub-fire zones for fire detection purpose.

5.2. Water Demand

Single fire concept philosophy that there is one major fire at a time in the Plant shall be applied in the fire water demand calculation. Scenario of fire fighting system operation in each unit shall be considered as below:

5.2.1. Water Demand in Process Unit

Typically each process unit will be split into a number of Sub Zones for the purpose of establishing the maximum extent of any single fire and thus the fire water capacity requirement of that area. Each subdivision is separated from all others by a minimum of 50 ft. (15 m) clear space. This spacing acts as a fire break and as a means of fire fighting access. A pipe band may be routed within a separation area providing at least 20 ft. (6 m) is left clear for firefighting access. (See **NPC-HSE-S-03** for other considerations in providing firefighting access). The fire water demand for each sub Zone division will be based upon an application rate varying between 0.1 and 0.3gpm per $ft.^2$ [0.25 and (0.75 m^3/h) xm^2)] of area depending on equipment density. Compact and multi-story units with a high density of stacked equipment (exchangers, drums etc.) or units containing an unusual amount of high-risk equipment (e.g. pumps handling flammable liquid above 600°F / 316°C or above auto-ignition temperature) will require the higher rates. Similarly, consideration of the likely provision of first phase firefighting equipment (monitors, deluge systems and hose reels) may be a useful cross check on capacity requirements.

For calculating water demand in process units Simultaneous operation of both a) and b) below for each fire zone shall be considered.

a) Spray system in sub-fire zone or fire zone
b) One(1) monitor + four(4) hydrants

The minimum fire water supply for any unit shall be 3000 USgpm (682 m^3/h). If maximum water demand will exceed 1440 m^3/hr, applied fire zone or sub-fire zone shall be divided into small units.

5.2.2. Water Demand in Tank Yard

Water requirements for foam generation and cooling are based on the assumption of a fire on any single tank. As a minimum, 2000 gpm should be available in tankage areas. For calculating water demand in Tankage area the following concept shall be applied:

- Atmospheric Tank

Simultaneous operation of below a), b), c) and d) shall be considered.

a) Foam on a burning tank
b) Water spray for adjacent tanks,
c) Water spray for cooling burning Tank
d) One(1) monitor + four(4) hydrants

Some details for calculating items a, b, c (above) are as follow:

1. Pontoon or Double Deck Floating Roof Tanks - A seal fire is the design fire scenario for the purposes of determining firewater capacity and installation of fixed equipment. A floating roof tank requires a minimum of 1500 to 2000gpm (341 to 454 m^3/h) for foam generation and external cooling of its shell.

Although experience indicates that installation of fixed facilities to fight sunken floating roof full surface tank fires is not justified, these fires can occur and viable emergency plans should be available to cover these contingencies. The main thrust of these plans should be to establish the resources required and strategy for containment and extinguishment and how they might be realistically employed through mutual aid arrangements with outside industrial and municipal fire departments. One of the major difficulties is to supply adequate water to produce sufficient foam to obtain extinguishment.

Supplemental water supplies (e.g. by use of large diameter hose and portable pumps) will need to be established with mutual aid partners, together with other support equipment and personnel. Where mutual aid cannot provide the required capacity, the facility shall give consideration to the eventuality of a full surface fire in its largest floating roof tank and develop a risk based strategy for addressing it, including in it the possibility of increasing the amount and capacity of fixed equipment.

2. Cone-Roof Tanks - Experience indicates that the only effective means of fighting fires within these tanks is by means of fixed equipment. Generally the events leading to a surface fire result in only partial removal of the roof. In such circumstances it is impractical to direct portable foam streams inside the tank on the fire area from any reasonably safe location. Fixed foam systems shall be designed to handle a full surface fire is provided for such tanks. Sub-surface foam systems should not be used as a prime form of protection.

Total water to be supplied to an area should be the sum of the appropriate numbers from the following three columns:

TANK DIAMETER ft. (m)	WATER FOR FOAM PRODUCTION gpm (m^3/h)	WATER FOR COOLING OF BURNING TANK(3) gpm (m^3/h)	WATER FOR COOLING ADJACENT TANKS(1) gpm (m^3/h) per EXPOSED TANK
Up to 20 (6)	0	750 (170)	250 (57)
20 to 56 (6 to 19)	500 (114)	750 (170)	250 (57)
56 to 80 (19 - 24)	500 (114)	1000 (227)	500 (114)
80 to 110 (24 - 33)	1000 (227)	1250 (284)	750 (170)
110 to 130 (33 to 40)	1500 (341)	1500 (341)	750 (170)
130 to 140 (40 - 43)	2000 (454)	1750 (397)	1000 (227)
140 to 150 (43 - 46) (max)(2)	2000 (454)	2000 (454)	1000 (227)

Notes:
(1) Consider a downwind quadrant concentric with the burning tank and of radius 2D, where D is the diameter of the burning tank. If any part of an adjacent tank is located within this quadrant, it is considered to require cooling. Water for this purpose should be available at a rate according to its diameter, as indicated in the last column.
(2) Cone roof tanks (or fixed-roof tanks with internal floating covers) larger than 150 ft. diameter should not be used in low-flash service because of the uncertainty of being able to extinguish fires in these larger size tanks.
(3) Water for cooling the shell of a burning tank is beneficial to help in extinguishment while applying foam. There is questionable value in applying water to the walls of a burning tank unless a sustained foam attack is planned.

3. Internal Floating Roof Tanks - The problems of fighting fires within Internal Floating Roof (IFR) tanks in Low Flash service are similar to those noted for Cone Roof tanks in Low Flash service. Thus these tanks must be supplied with fixed equipment. Although the total fire record of fires in IFR tanks is good, approximately 50% of fires that did occur involved sunken floating roofs. Accordingly these foam and fire water capacity requirements shall be as per Low Flash Cone Roof Tanks, above. The cooling water requirements for the involved tank and adjacent tanks shall be as per Low Flash Cone Roof Tanks, above. Consideration can be given to the need for providing foam protection when an IFR tank is in a service where it is constantly maintained under an inert atmosphere (by means of a secure supply of inert gas e.g. by nitrogen, not fuel gas), for process purposes. Sub-surface foam systems shall not be used for internal floating roof tanks. Fire experience indicates that a sunken roof further impedes its effectiveness.

- **Pressurized and Refrigerated Storage Tank:**

Firewater requirements are based on supplying the deluge system of any one vessel which is assumed to be on fire, plus the deluge systems of adjacent exposed vessels, plus consumption from monitors and hose streams for cooling surfaces not covered by the deluges.

5.3. Water Source

The plant shall provide a firewater storage system. This storage must be large enough to provide full design flow for a minimum of 6 hours without shutting down the process or other water-using operations in the plant. Also, the water-source must be capable of supplying one-half the maximum water demand on a continuous basis after the storage capacity has been used. The continuous supply at one-half the maximum demand rate can be based on taking credit for shutting down non-critical process facilities by the end of the 6-hour period, if this is feasible. Treatment facilities shall be provided for systems having brackish or saltwater as a supply source. Water supplies shall not contain agents that could affect the quality of fire fighting foam production. The water supply must be oil-free and must not be obtained from skim ponds, ballast water tanks, etc., as slight traces of oil act as a defoaming agent. Process cooling water or other process water streams shall not be used if emulsion-breaking or anti-foam compounds are used in the water treatment process.

6. Pumps and Drivers

The firewater pumps must have a total rated capacity at least equal to the largest single demand. Normally pumps with a rated capacity no greater than 3000 gpm (682 m^3/h) should be specified. Total pump capacity requirements shall be provided in the form of at least two pumps, having different types of drive. At least one pump should be electric motor driven and at least one pump should have a diesel engine drive. Where more than two pumps are required they should be of equal capacity and an appropriate selection of drivers should be specified to give maximum reliability. Where two electric driven pumps are to be utilized, they shall be fed from separate power supplies that shall be arranged such that the failure of one supply will not cause an interruption of the other source. Spare firewater pumps shall be provided for at 100% of maximum water demand. The firewater main shall be designed to operate continuously at 144 psig (1000 kPag) at the pump discharge manifold as minimum. An adjustable set point pressure controller shall bypass excess flow from the pump discharge back to the source of supply.

A return line with a flow-measuring device shall be provided for periodic testing of firewater pumps. The flow-measuring device shall be sized for at least 175 percent flow of the largest firewater pump. Isolation valves shall be provided to permit isolation and maintenance of an individual pump while the other pumps remain in service.

A small pressurizing pump (commonly called a jockey pump) manifolded in parallel with the main firewater pumps, pressurizes the system when the latter are not in use. Rated capacity is normally 300 to 500 gpm (68 m^3/h to 114 m^3/h) at 125 psig (860 kPag). This quantity is not included in the total firewater pump capacity.

A low-pressure cut-in with alarm shall be installed on the pump discharge manifold, set at 100 psig (690 kPag), to actuate an automatic starting device on the electric motor driven firewater pump. Remote start control of this pump shall also be provided at a continuously attended control room or at the fire station. Where more than two firewater pumps are provided further pressure drop shall automatically start secondary fire water pumps to meet at least 100% of the total required pumping capacity, with a 5 - 10 second timed delay. The remaining diesel or electric driven firewater pumps may be manually started from a constantly attended location or can be automatically started as the firewater demand continues to increase. As a backup to the main firewater pumps, multiple hose connections should be installed at the Marine Terminal at two separate berths so that fire boats or tankers can pump into the plant main. Firewater pumps must be located in areas not subject to fire exposure. Therefore, a minimum of 150 ft. ,(45m) spacing to most types of operating equipment containing hydrocarbons is specified, in accordance with NPC-HSE-S-03.

7. Fire Water Distribution System

A grid or looped piping distribution system along the four sides of area block shall be used, capable of supplying water, on a single fire basis, to any part of the plant at the design rate determined for that specific area. The design is based on water flow through all loops and mains of the grid system, and the lines are sized to provide 80 psig (552 kPag) minimum hydrant (residual) pressures at full design flow rate. Piping should be sized conservatively to account for fouling and increased roughness caused by aging. Firewater networks are typically designed using the Hardy Cross method of analysis. PC based software is available to optimize pipe sizes in order to obtain a reliable and economic design. The following combination of the Hardy-Cross, and Hazen and Williams's methods may be used for sizing the pipe:

$$Q = 0.0368\, c\, d^{2.63}\, p^{0.54}$$

Where: Q = Flow rate, gpm

c = Hazen-Williams Coefficient, dimensionless - see below

d = Inside diameter, in.

p = Pressure drop, psi per 100 ft. of pipe

The Hazen-Williams coefficient, c, is a type of roughness factor. It is recommended that a value of c=100 be used, except where reinforced plastic (RTRP Grades) or Fiberglass TM Reinforced Plastic (FRP) are to be used and a value of c = 120 is more appropriate. Generally the minimum sizing will be NPS 8 for fire water mains and NPS 6 laterals. Although the water speed inside the main pipes shall not exceed 3m/s in any point.

The fire main grid shall be designed with isolation valves, which permit sections to be taken out of service for repair while still retaining half the design capacity to each area.

Fire mains shall be fireproofed at any location where they cross drainage ditches into which liquid hydrocarbons may be discharged. Elevated supports located 20 ft. (6 m) or less beyond the edge of the drainage ditch shall be fireproofed.

- **HYDRANTS**

A sufficient number of hydrants must be provided to supply the required water rate in each area. A normal flow of 750 gpm (170 m^3/h) can be assumed from each hydrant when using three 2 1/2 in. (63 mm) hose lines. This increases to 1000 to 1200 gpm (227 to 272 m^3/h) when a pumper is connected to take suction from a hydrant.

Hydrants should be located within 250 ft. (75 m) of any point where water will be required. Maximum spacing between hydrants shall be 150 ft. (45 m) in onsite areas and 300 ft. (90 m) in offsite areas containing equipment. The locations should be arranged to permit equipment to be reached from at least two opposite directions, so that manual hose line approaches can be made from the upwind side. Where appropriate, hydrants shall be positioned so that they may also be used to protect equipment in adjacent units or areas. Hydrant connections should be compatible with local community and mutual aid mobile firefighting equipment that may be used in a major incident.

- **HOSE REELS**

Hose reels fitted with 100 ft. (30 m) of 1 1/4 in. (32 mm) or 1 1/2 in. (38 mm) firm type hose and combination straight stream / fog nozzles are provided in all operating areas as a means of quickly applying water to fires in the incipient stage.

They should be located in onsite and some offsite areas to provide coverage for equipment which is likely to be a source of hydrocarbon release, i.e., major pump areas, loading racks, pier manifolds, etc. In process and utility areas, complete ground level coverage is necessary except for equipment handling non-flammable or low-risk materials. While overlapping coverage by adjacent hose reels is not necessary (generally they will be located on 200 ft. (60 m) center spacing), they should be located such that one is accessible from each side of a unit. The minimum number of hose reels in a process unit shall be two, located at opposite sides of the unit. Hose reels, supplied from a fire main riser, and should also be provided at all main platforms of major elevated structures in units.

Note - Connections must not be made into the fire main to supply regular process or utility requirements or for recurring line flushing or product displacement purposes.

8. First-Phase Fire Fighting Systems / Equipment

8.1. General

Upon discovery of a fire within a unit, operating personnel are immediately faced with a number of vital tasks that must be addressed simultaneously, including ensuring safety of personnel, isolating affected equipment and/or shutting down the unit, and fighting the fire. This latter task is referred to as **first-phase fire fighting**. To maximize the benefit that first-phase fire fighting offers to a facility it should both provide an effective response until the fire brigade arrive and are properly deployed, and minimize the time required of operating personnel to activate or supervise it. First phase firefighting equipment must meet the following criteria:

1. Equipment must permit quick and easy initiation of operation.
2. Equipment must require only intermittent attendance.
3. Equipment must be highly effective.
4. Equipment must be positioned to cover the most critical parts of the protected area.
5. Equipment must not be complicated (i.e. it must not have a high maintenance requirement and Must have a high availability).

Critical Parts of the Area - In assessing the criticality of equipment in a unit or process area thought has to be given to the consequences of that equipment being unprotected and exposed to a sustained fire, both in direct terms (i.e. the loss of that piece of equipment) and indirectly in terms of potential spread of the fire upon failure, and extended production downtimes. Examples of equipment considered critical in this context:

- Vessels with large inventories of flammable materials, particularly those with un-wetted internal surfaces. Examples include large vapor filled reactors and internally insulated vessels, as they are potentially subject to early failure due to the lack of any cooling effect from contained liquids.
- Equipment containing flammable materials that may be released due to failure of components such as gaskets or pump seals exposed to radiant heat or direct flame impingement. Two classes of material of particular concern upon release are those being processed above their auto-ignition temperature and flammable liquids such as light ends which may form vapor clouds that could explode if subject to a delayed ignition.
- High value equipment. This may be equipment with a high intrinsic cost such as large centrifugal compressors. It may also be equipment which is designated as critical by virtue of its importance to the continued operation of a particular unit either because the unit is vital and any down time has a large cost impact or the loss would result in a protracted downtime.

8.2. Types of Equipment

- **MONITORS**

Monitors with combination straight stream / fog nozzles shall be provided as the means of applying large volumes of cooling water onto process equipment and facilities. They may be operated very effectively and require very little training or physical effort.

Monitors shall be capable of delivering not less than 500 gpm (114 m^3/h) and shall have an assumed effective straight stream nozzle range of 100 - 120 ft. (30 - 36 m) for process units and 180 ft. (60m) for Takage area at 80 psig (550 kPag) residual pressure in still air as minimum requirement. The influence of cross or opposing winds should be recognized as, typically a 5 mph opposing wind can reduce the effective range as much as 50%. Generally all monitors are left in a preset fog pattern to obtain maximum cooling when they are operated. Fog streams are effective at much shorter distances, e.g. 60 ft. (18 m) maximum range with a 30 degree cone setting. Monitors used in chemical plants and associated facilities are classified as fixed, elevated and trailer-mounted.

Fixed (ground level) monitors are located a minimum of 50 ft. (15 m) spacing from the equipment being protected in order to allow access during fires. Where monitors have to be located less than 50 ft. (15 m) from equipment in order to provide coverage, the monitor's operating valves should be remotely located at 50 ft. (15 m) so as to be accessible during a fire. In this situation each monitor would be set to concentrate its water flow on a particular set of equipment, and more monitors may have to be added to ensure overall coverage of critical equipment. Consequently these are less efficient users of fire water.

Elevated monitors, remotely operable from grade, are appropriate where coverage of a close grouping of elevated equipment (such as drums, exchangers and towers) is required or where obstructions exist near grade that would prevent adequate coverage of critical equipment by manually attended fixed monitors at grade. Typically these units would be activated by means of a grade level valve and would be set to concentrate their water flow on a particular set of equipment, as the advantage of operator attendance / control is lost. Elevated monitors may be provided with remote controls, such that they can be directed to protect various pieces of equipment, but this approach should be considered only in situations where use of mobile equipment is not feasible. The complexity of these controls and the relatively high maintenance demand render such units generally unacceptable for first phase fire fighting in most refinery and chemical plant applications.

Trailer-mounted monitors can be used where effective coverage is difficult to achieve due to obstruction by pipe bands and equipment. Trailer mounted units should be located adjacent to access ways to facilitate maneuverability during a fire. Each unit is normally stationed at a hydrant or pipe outlet and connected to it with 100 ft. (30 m) of 2 ½ in.

(63 mm) hose. Trailer mounted monitors have the advantage of flexibility, since they can be moved into position for maximum effectiveness, but this advantage is at the expense of a time delay in the application of firewater and increased demands on operating personnel. Because of these limitations, trailer mounted units are not generally the first choice for providing first phase fire fighting.

- **Stand Pipe system**

in elevated structures, wet riser pipe shall be considered on each floor .They will consist of 2 ½" landing valve with female instantaneous coupling according to BS 336. For hose connection they will be installed at strategic point & near exit stair ways at elevation of app. 90 cm above the floor.

- **Foam Hose Reels**

In purpose of control and suppression of small fire in early stage and to prevent of fire spreading to other equipment with high flammable inventory, 1" foam hose reels shall be considered in process unit & tank farm area. They will be located at ground floor of process unit in strategic points and adjacent to pumps that handling flammable liquid . Also in tank farm area they will be installed in adjacent to pump stations.

- **Fixed Water Spray and Deluge Systems**

Fixed water spray / deluge systems are utilized as first phase firefighting equipment for either exposure cooling of vessels and equipment likely to be exposed to fire or fire intensity control on equipment that may be a source of fire (typically pumps and compressors in flammable service). In process areas open head dry-pipe systems, manually activated by a valve located a minimum of 50 ft. (15 m) from the equipment being protected and easily accessible to operators, are used. These systems shall be designed in accordance with NFPA15 or equivalent. Application rates can vary from 0.15 gpm per $ft.^2$ (($0.37\ m^3/h)\times m^2$) for cooling of spheres and spheroids to 1.3 gpm per $ft.^2$ (($3.1\ m^3/h)\times m^2$) for the internal firewater spray system for regenerative air pre-heaters (see Step 6 of the selection procedure and Table 2).

Spray heads may be upright type or pendant type, depending on local preference and shall have a minimum orifice opening of 3/8 in. (10 mm) to minimize the risk of plugging. Fixed water spray system piping downstream of the system strainers shall be copper-nickel or galvanized.

While fixed water spray / deluge systems can provide excellent fire protection and are more efficient than monitors in providing protection of specific pieces of equipment.

Effort shall be considered to provide operable systems capable of many years of reliable service by a combination of sound design, robust construction and a commitment by the client organization to an ongoing and rigorous testing and maintenance program.

8.3. Equipment Selection

Based upon the criteria given above for determining equipment as suitable for first phase fire fighting and upon experience within facilities the preferred order for selecting equipment is as follows:
1. Fixed monitors capable of local manual operation and control
2. Fixed or elevated monitors capable of remote / manual operation.
3. Fixed water sprays / deluge systems capable of remote / manual operation
4. Trailer mounted monitors.
5. Elevated monitors capable of remote / manual operation and remote manual manipulative control.

Table 1 determines the minimum coverage requirements of equipment that may be considered critical. It will be noted that in specific circumstances the preferred method of application may differ from the general ranking given above.

The procedure to follow in selecting first phase firefighting equipment is as follows:
1. Determine the equipment to be designated as critical per the criteria given in Critical Parts of the Area, above.
2. Review Table 1 for the preferred form of coverage for the identified critical equipment.
3. Fixed monitors to be located around the perimeter of the unit and should be positioned to achieve the maximum coverage of critical equipment and facilitate operator access.
4. Where **Table 1** indicates alternate forms of coverage, provide accordingly.
5. Provide appropriate protection for equipment not provided with coverage per steps (3) or (4) in making that selection consideration needs to be given to the following:
   - Availability of personnel
   - Realistic response times
   - Operator access
   - Prevailing winds
   - The quality of firewater (fresh, salt, brackish etc.)
   - Commitment and capability of client organization to necessary testing and maintenance
   - Availability and capability of fire brigade to provide a secondary fire fighting response
   - Adherence of layout and spacing to requirements of **NPC-HSE-S-03** (see **Table 1**)
   - Provisions for unit/equipment shutdown/isolation/Depressuring and relevant emergency response philosophy (see **Table 1**, Note 1).

6. Where fixed water sprays are used, guidance on the firewater application rate to be used in designing systems for protecting specific equipment is to be found in **Table 2**. Where no guidance is given, rates should be no less than 0.2 gpm per $ft.^2$ ($(0.48 m^3/h) \times m^2$) or as per

NFPA 15, whichever is greater. Sprinkler systems designed and installed as per NFPA 13 or equivalent are required for high-risk indoor facilities, A reputable sprinkler company should carry out detailed design.

Fire equipment cabinets containing fire hose, nozzles and fittings shall be provided in areas where there is a significant time delay in obtaining these items from the equipment truck.

Note: ***for Cooling Towers, Parts of cooling towers constructed of combustible materials are vulnerable to fire where drying out occurs, such as the top deck above the cooling water distributor or any part of the tower when not in service. Firewater coverage is, therefore, required as follows:***

- ***In accordance with Table 1 for Monitors.***
- ***In addition to the above, cooling towers constructed of combustible materials should be provided with sufficient hose reels on the fan deck to give total deck area coverage.***

Table 1: Application of First Phase Firefighting Equipment for Process plant equipment (not limited to the table)

Critical Equipment/ Unit	First Phase Firefighting Equipment (as minimum requirement)				
	Monitor	Hose reel	Deluge	Fixed water spray	Explanation
Process Unit Towers	√		√		
Process Vessels	√		√		For suitability of water use for special vessels, consult with safety engineers.
Process Unit Pumps and Compressors	√	√	√		Ensure coverage of motors and seal areas plus lube oil console for compressors
Heat Exchanger Banks	√				
Process Unit Heaters	√				Only for exposed return bends and crossovers (1).
Process Unit Air Coolers			√		
Offsite Pumps	√	√	√		
Partially Confined Areas	√	√		√	
Cooling Towers	√				For those constructed of combustible material provide coverage for all sides and top deck
Pressurized (horizontal) Storage Vessels	√		√		Coverage of areas containing nozzles or valves etc. Entire coverage of single or two vessels within 50 ft. (15m) of each other, when not fireproofed.
Ammonia Tanks	√		√		Deluge system for entire vessel.
Pumps and Compressors in Congested Areas	√	√	√		
Spheres and Spheroids in Pressurized and Refrigerated Storage Service	√		√		The upper hemisphere shall be provided with a top mounted, mushroom head type deluge system. Monitors or fixed sprays shall be provided for the lower hemisphere.
Dome Roof Tanks(Top, Side)	√	√		√	
Dome Roof Tanks in Refrigerated Storage Service	√		√		A top mounted mushroom head type deluge system shall be provided. In addition, spray rings will be provided where required.
Regenerative (Rotary) Air Preheaters	√			√	A fixed internal spray system shall be provided
Spot Loading Rail Tank Cars Tank Truck Loading Racks	√	√	√		Coverage of loading facilities where a centralized loading point is provided. Coverage is required for plant and other major racks.
Multi layer Pipe Racks in Congested Areas	√				Where multi layer pipe racks are surrounded by congested process equipment and there is the possibility of any spillage from damaged piping to accumulate under the rack, then elevated monitors shall be provided.

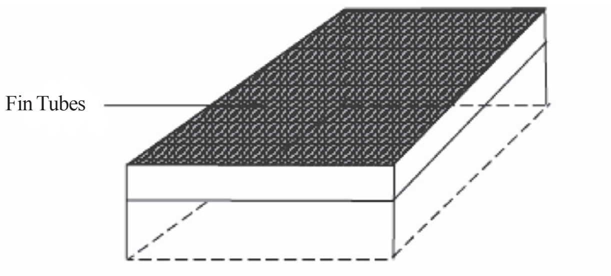
Notes:
(1) Monitor coverage is not normally required for process heaters as exposure to fire is not likely to result in immediate damage or loss of containment. The primary vulnerability of heaters to damage relates to split tubes. Where this could result in significant spillage and drainage capability is limited then monitor coverage may be justified as a means of washing the spill away from the vicinity of the process heater to a less hazardous location.

Table 2
Water Spray Minimum Design Densities (1),
[For use in designing Fixed Water Spray Systems]

Equipment	Projected Area Basis gpm/ft.^{2}(m^3/h)xm^2	For Actual Surface Area gpm/ft.^{2}(m^3/h)xm^2
Air Cooled Exchangers(2)	0.25 (0.6)(3)	NA
Sphere / Spheroid	NA	0.15 (0.37)
Pumps, Compressors, Turbines, and Motors(1)	0.6 (1.5)(4)	NA
Dome Roof Tanks - Top	NA	0.15 (0.37)
Dome Roof - Side	NA	0.15 (0.37)
Vessels / Exchangers (1)	NA	0.25 (0.6)
Fired Heaters - Exposed Bends(1)	NA	0.25 (0.6)
Regenerative (Rotary) Air Preheater (Vertical)	NA	1.3 (3.1)(5)
Regenerative (Rotary) Air Preheater (Horizontal)	NA	1.3 (3.1)(6)

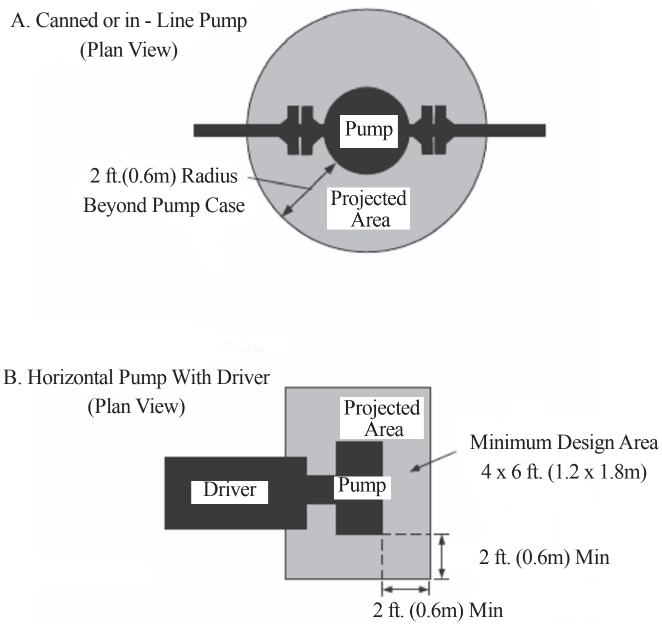
Notes:
(1) Where spacing is less than required per NPC-HSE-S-03, or in areas of higher congestion, increased water spray rates must be used.
(2) Monitors are preferred protection for this equipment - see Table 1.
(3) See Figure 1.
(4) Projected area extends 2 ft. (0.6 m) in all directions from pump - see Figure 2.
(5) Upper faces only

Figure 1
Water Spray Projected Area for Air Fin Coolers



Projected area (of fin tubes) for calculation of required water spray densities at 0.25 gpm/ft^2 (0.6 m^3/hr)×m^2
Direct sprays on underside. If forced draft, install nozzles in plenum between fan and fin tubes.

Figure 2
Water Spray Projected Area for Pumps



8.4. Automation / Remote Operation

The approach to first phase firefighting equipment may be summarized as being to keep it simple, robust, and distributed, with reliance on operator manual / local action. Experience has demonstrated the validity of this approach as this equipment has proven to be highly reliable and available, sometimes with only the minimum of basic maintenance. The key to this effectiveness of response has been the availability and presence of operating personnel. With the trend for reducing the field presence of operators, the assumption that there will always be the necessary personnel available to respond within the vital first few minutes may not always be valid.

Where the plant organization does not have the resources to guarantee the type of response required for the effective use of a traditional first-phase firefighting equipment, additional means of maximizing the utilization of available resources must be considered. This could be as simple as manifolding the operating valves for all deluge systems for each side of a unit to a single location closest to the Control House, or it could involve use of automatically activated fire fighting systems.

When considering the use of automatically activated first phase firefighting equipment the caveats contained in **NPC-HSE-S-06** regarding use of fire detectors should be noted. Before committing to the use of automatically activated equipment the following items should be reviewed individually and in combination for their applicability to the situation at hand and an assessment made of the viability, effectiveness and benefits offered by automatic activation.

- **Degree of risk:** The equipment to be protected should be higher risk either due to the fluids being handled (e.g. liquids above their auto-ignition temperature) or location (e.g. the potential for rapid escalation and significant threat to life or equipment). The potential for escalation is greater for facilities that do not meet the spacing requirements of **NPC-HSE-S-03**.
- **Availability of Personnel:** The plant organization cannot guarantee manual fire detection and/or an effective response for first phase fire fighting within the first five minutes.
- **Congested Equipment:** This may heighten the degree of risk associated with the equipment and/or be such that it severely impedes the possibility of visual detection of a fire.
- **Degree of Device Complexity:** The detection and initiation equipment, while appropriate for the risk being protected against, should be of proven and robust design, with preference given to established “Low Technology” approaches.

8.5. Foam Systems

A foam system shall be provided for fighting storage tank fires and typical oil spill fires at tankage areas, marine terminals, loading racks and process units. A system relying on fixed discharge devices and foam proportioning shall be used for maximum flexibility and effectiveness, with fixed application facilities in certain cases.

A 3% vol. foam solution in water is used, which is expanded to 6 to 8 times its volume by air aspiration, where water-miscible liquids such as alcohol and ethers (MTBE). Such materials require a special foam compound and application technique.

In the semi-fixed system, a foam proportioning truck mixes foam concentrates into the water stream and pumps the resulting foam solution to the foam making device. The foam maker aspirates air into the solution forming stable foam.

The contingency of fire on the largest low-flash cone roof tank normally sets the required generating capacity of the foam proportioning equipment. This is based on a foam solution rate of 0.1 gpm per ft^2 ((0.25 m^3/h)×m^2) of tank liquid surface for tanks up to 100 ft. (30 m) diameter, and 0.11 gpm per ft^2 ((0.28 m^3/h)×m^2) for tanks over 100 ft. (30 m) diameter. For larger tank diameters, a second foam proportioning truck must supplement capacity. Where mutual aid is not available, sparing the foam proportioning truck should be considered.

Semi-fixed foam facilities are also required for floating roof tanks. In some cases these requirements may determine the capacity of the foam generating equipment if there are no cone roof tanks requiring foam facilities.

Monitors providing coverage for large offsite pump stations may be provided with combination foam / water monitors and foam solution. In locating such monitors, this resulting loss of range needs to be taken into account.

Unattended truck loading racks shall be provided with an automatically activated foam water spray system. Attended T/T loading racks should be provided with a remotely operated foam-water spray system. If the installation does not include low-flash cone roof tanks or floating roof tanks with fixed foam systems, a foam proportioning truck is still required for use with hose lines for extinguishing loading rack fires and spill fires in general.

The total plant stock of foam concentrate held in the proportioning truck (or trucks), tank truck and in storage should be sufficient to cover the largest single fire demand for 90 minutes, but no less than 1500 gallons. In isolated areas where replacement supplies are not readily available through local mutual aid arrangements, a larger supply should be maintained. An additional allowance for training purposes should also be made. Foam stocks should be stored in a sheltered area or building to avoid extremes of temperature and tested as per manufacturer recommendations. A minimum of 30°F is necessary to maintain reasonable fluidity, and a maximum temperature of 100°F minimizes deterioration of the foam concentrate. Except for the quantity kept in the fire vehicles, foam concentrate should be stored in its original shipping containers to minimize contact with air, which also causes deterioration and sludging. If the concentrate is to be stored in large drums to aid in rapidly refilling the trucks, the drum should be covered with a sun shade.

8.6. Fire Extinguishers

Portable fire extinguishers shall be provided to enable operating personnel to quickly attack small fires. They should be located at process areas, berths, loading racks, pump areas, and similar facilities. Travel distance from the protected equipment to an extinguisher should not exceed 50 ft. Extinguishers are located at grade and on major operating platforms such as in compressor houses, on mountings which are well marked and clear of the ground or platform.

Three basic types of extinguishers are used:

- **Dry chemical extinguishers** are provided for general use. They are suitable for flammable vapors and liquids and can be safely used on electrical equipment.
- **Carbon dioxide extinguishers** are recommended for electrical fires but can also be used on small flammable liquid fires. this type of extinguisher normally is used in areas such as laboratories and electrical substations.
- **Pressurized or carbon dioxide-expelled water** extinguishers are primarily used in offices and warehouses where wood and paper fires may occur. In addition to small extinguishers which can be handled by one person, 125 lb. (57 kg) wheeled dry chemical extinguishers shall be provided at loading racks and high risk process areas (normally one per process unit).

9. Inert Gas Extinguishing System

The method of operation in fire suppression is considered to discharge a sufficient amount of the inert gas agent into an enclosure to create an extinguishing atmosphere throughout the enclosed area and other word "Total Flooding".

In this system high-pressure agent bottles to be located outside the protected room in the allocated area. Agent gas to be leaded by piping network from cylinders bank to protected area. Then agent to be discharged through nozzles designed and located to develop a uniform concentration of agent in all parts of an enclosure.

9.1. Design Basis

The system design shall be performed based up on NFPA-2001. The purpose of inert gas in this specification shall be limited to one of agents IG-01 (99.9% Argon), IG-55 (50% Argon & 50% Nitrogen) & IG-541 (52% Nitrogen, 40% Argon & 8% Carbon Dioxide) as per NFPA-2001.

The type of hazard to be taken into account is dry electrical hazard. In calculating the quantity of agent a minimum concentration of 40% volume of the room shall be considered. The discharge time to reach above concentration shall be maximum One minute for fast fire knock down. The minimum design concentration shall be sum of extinguishing concentration plus a minimum 20% safety factor. In addition of the concentration specified, some of agent shall be computed and added to quantity of agent to compensate for leakage from openings, if is available.

The design concentration of inert gas agent shall not be exceeding of 43 percent for use in normally occupied area. For multi room inert gas system, design shall be based upon a philosophy whereby the maximum number of agent cylinders is determined by the capacity requirements of the largest single protected room in the system. The concentration of agent release in any case shall be adequate for extinguishing. The inert gas extinguishing systems for required buildings shall independently be considered for each protected building.

9.2. Technical Description

The inert gas systems shall be operated at two modes of automatic/manual by a selector switch on control panel. At automatic position, system shall be automatically activated by confirmed coincidence operation of fire detectors in the protected area. At this state the system can also be triggered via manual release push buttons, and they will override the auto function. At manual position, system activation shall only be limited to manual push buttons allocated for this purpose.

Manual activation shall be achieved from three points, the remote central monitoring station, cylinder bank, and from the main entrance / exit of the protected area by break glass push button. The manual activation on cylinder bank shall be non-electrical.

At all entrances of the protected area, warning notices shall be posted that the area is inert gas protected and the system may be discharged. The inert gas control panels shall be located at the control room or suitable air-conditioned rooms at near the gas cylinder room in non-occupied buildings. The control panel must be able to relay signals to central fire alarm panel in control building.

9.2.1. Detection System

In fire zones that protected with inert gas system the fire detection acts as cross-zone fire detection to minimize fault alarm risk. For these spaces, when a single detector is activated, it shall initiate a pre alarm with following sequence:

- Local audio and visual alarm, on control panel with identification of the area involved in fire hazard.
- Audio and visual display table (e.g. “IMMEDIATE EXIT” caution board) located inside the protected room, to indicate that the room shall be evacuated (for rooms accessible to people).

The actuation of the system shall be carried out after the second detector has been activated and the agent will be released automatically with delay time of the 10 to 15 seconds. The following sequences shall be carried out:

- Initiate the same sequence as that described above. This sequence and that previously described shall be characterized by distinct signalization (e.g. intermittent light and sound for the first sequence, continuous light and sound for this sequence).
- Stop the ventilation system and close relevant ventilation dampers if available
- Switch on a visual display table (e.g. “ENTRY FORBIDDEN” caution board) located outside the involved area, near the door, to prevent people from entering the room where agent discharge is nearly to happen.
- Agent discharge in the area, after a pre-set time lag.
- Indication of signal that discharge has been performed.
- Provision for remote alarm for indication of inert gas system actuation on central fire alarm panel.

Remote indications for system operation shall be envisaged for annunciation of following:

- Fire zone status (for each protected zone)
- Gas released status (for each protected zone)
- Auto/Manual mode (for each protected zone)
- Main/Reserve armed (common for protected zones)
- Fire zone status (common for non protected zones)
- Normal operation (common for all zones)
- System fault (common for all zones)

9.2.2. Extinguishing System

The agent shall be stored in high-pressure cylinder and preferably at a pressure of 200 bars, 80 liter capacity. The installation of inert gas bottles shall incorporate 100% spare installed cylinders, connected to main manifold. The operation of the main/reserve cylinders shall be carried out by a selector switch mounted on the control panel. A suitable arrangement with necessary clearances shall be allocated for the location of cylinders, to provide easy access for maintenance or replacement of the cylinders. Containers shall be designed, fabricated, inspected, certified and stamped in accordance with section VIII of the ASME Boiler & Pressure Vessel code or European Standards En84-525-EWG. Each container shall be complete with the following accessories:

- Siphon tube
- Discharge valve
- Pressure indicator
- Check valve
- Flexible pipe for connection to discharge manifold
- Safety device
- Bottle support
- All other required accessories for good performance

Each agent container shall have a permanent name plate or other permanent marking that indicates the agent name, pressurization level of container, and nominal agent volume.

The design pressure shall be suitable for the maximum pressure developed at the maximum controlled temperature limit. Cylinders shall not be directly exposed to sunlight and therefore shall be placed inside fire resistance GRP cabinets or cylinder storage room. Each container shall be equipped with a pressure gauge for indication of any agent quantity loss from cylinder.

The container valves should be of such type as to ensure safe functioning under normal conditions and shall be leak resistant in order to minimize extinguishant gas losses. The valves should have a simple means of filling their respective containers with extinguishant. The actuators shall activate immediately, without any delay, and with its rated power output. The internal material especially o-rings inside valve & actuators shall be resistant & compatible to agent.

The material of valves, actuators, and other components allocated outdoor installation shall be provided for tropical marine and sand storm weather conditions.

All electrically energized actuators shall be capable of being monitored from the control panel. Manual actuators shall be secured by appropriate means to prevent accidental actuation (safety pins, etc.).

All prefabricated piping and manifolds shall be hydrostatically tested and its certificate to be submitted by supplier.

The piping etc. should not impinge on the routing required for HVAC ducting, beams and ribs. For flooding of multi protected area in a building, supplier shall be predicted directional or selector valves on gas manifold for directing to appropriate section, where the fire is spreading.

The actuation of selector valves may be accomplished as the electrical, pneumatically, or mechanical by vendor. In any case a manual means for actuation of the selector valves shall be provided for security reasons. This means shall be easily activated by manpower and accessible.

The overall apparatus for installation in battery rooms shall be flame proof and suitable for zone 1, group IIC, class T1 (per IEC).

The enclosure protection of electrical devices allocated for outdoor installation shall be IP55 as minimum requirement.

All manual operating devices shall be identified as to the hazard they protect.

Discharge nozzles should be listed or approved for the appropriate discharge characteristics. The material used to manufacture the nozzles shall be of corrosion resistant metal. Pressure relief valves shall be installed in the pipe-work, in compliance with NFPA rules. They must be fitted between sections of pipe where are closed. All pressure relief devices shall be designed and located so that the discharge from the device will not injure personnel or pose a hazard.

In systems using pressure operated container valves, means shall be provided to vent any container leakage that could build up pressure venting shall be arranged so as not to prevent reliable operation of the container valve. Discharge orifices, and discharge orifice plates and inserts, shall be of a material that is corrosion resistant to the agent used and the atmosphere in the intended application.

9.3. System Components

- **Control Panel**

The control panels shall be located in air-conditioned and accessible room of protected buildings. They shall be fed from UPS power supply 110 V/50 HZ existing in plant and be included with battery backup & charger.

Automatic gas release shall be possible via command from control panel and energizing of solenoid valve on pilot cylinder with time delay 10 to 15 sec. The control panel shall be equipped with following accessories and status indications for protected zones:

- Manual Release Push Button
- Main / Reserve Switch
- Normal Operation Status
- Fire Zone Status
- Reserve / Main Armed Status
- Auto / Manual Switch
- Auto/Manual Status

- Gas Released Status
- System Fault
- Silence Alarm Switch
- Reset Switch
- Lamp Test Switch

The status indication shall be the following:

- Normal Status
- Fault Status
- Fire Status
- Silence Alarm Switch
- Reset Switch
- Lamp Test Switch

The panel shall be supplied with adequate space for 24 VDC secondary sealed batteries and battery charger .The batteries to be sized for 24 hours quiescent load and 10 min. alarm load. The panel will be provided as top cable entry and along with cable glands and earthing facilities.

The cabinet shall be surface wall mounting and be made from min 1.2 mm mild steel sheet. The exterior finish color will be in accordance with RAL 7032 (pebble gray).

- **Smoke Detector**

The smoke detectors shall be optical light scattering type and suitable for conventional system which give one of two output states to the controller relating to “Normal or Fire Alarm ” condition. They shall be equipped with an indication LED on it so that the one in alarm can be identified when a zone is being searched during a fire. For the cases, detectors are installed in void spaces, a remote indication device in addition of integral LED shall be provided to alert personnel. The detectors and remote indication device shall be surface mounted with flame retardant base and case. The type of detectors for classified area shall be provided as intrinsically safe.

- **Heat Detector**

The heat detectors shall be pre-determined fixed temperature type and suitable for conventional system. These detectors can be used in areas where smoke sensors are unsuitable due to environmental conditions such as smoke, dust, humidity & etc. All detectors are equipped with an LED optical alarm display, which lights up in the event of an alarm, thus making it easy to locate the activated detector quickly. For the cases, detectors are installed in void spaces, a remote indication device in addition of integral LED shall be provided to alert personnel. The detectors and remote indication device shall be surface mounted with flame retardant base and case. The type of detectors for classified area shall be provided as intrinsically safe.

• **Audible Alarm**

The audible alarms shall be provided as exposed wall mounted for indoor and outdoor installation. The minimum ingress protection for outdoor and indoor units shall be in order to IP-55 & IP-44. The power supply will be 24VDC. A minimum sound level of either 65 dB or 5 dB above any other noise likely to persist for a period longer than 30 S, whichever is the greater. The outdoor units shall be suitable for harsh environmental and will be installed nearby main entrances. The type of units for classified area shall be flame proof and be suitable for relevant gas group.

• **Visual Alarm**

The visual alarms shall be provided as supplementary for indoor and outdoor installation. The minimum ingress protection for outdoor and indoor units shall be in order to IP-55 & IP-44. The power supply will be 24 VDC. The intensity of the light should be sufficient to draw the attention of people in the vicinity. The indoor units shall be lettered with caution words such as "Immediate Exit" or "Evacuation Immediate". The outdoor units shall be lettered with warning words such as "No Entry" or "Entrance Forbidden". The outdoor units shall be suitable for harsh environmental and will be installed nearby main entrances. The type of units for classified area shall be flame proof and be suitable for relevant gas group.

• **Manual Alarm Call Point**

Any developing fire can be normally recognized earlier by means of human detection than by an automatic fire detector when people are in the supervised areas during working hours. For this purpose manual call point is considered for buildings.

They shall be operated by the single action of breaking a frangible element. The activated device shall remain in its alarm initiating state until the frangible element is replaced. They should be so located that, to give the alarm, no person in the premises need travel more than 30 m.

It may be better call points allocated for a building to be considered separately from detectors circuit to prevent misleading indication of fire position.

The unit shall be suitable for harsh environmental and will be installed in entrance, corridor & strategic points in building as surface mounting at a height of 1.4 m above the floor. Each unit shall be provided with red color finish, marking, and data.

• **Manual / Auto Switch**

This selector switch in normal condition shall be positioned in "Automatic" mode. In this state, system will be actuated via command of fire detection system.

In fault event at auto mode or abnormal conditions as example when personnel entry to protected area for maintenance activity the switch must manually be changed over to "Manual" position. In this case, system will be actuated via manual release push buttons.

This selector switch will be located on extinguishing control panel in quantity of one per each protected area. The unit shall be supplied with red color finish and be marked relevant protected area name on duty label.

- **Manual Release Push Button**

The manual release push button is intended for when fire is observed by personnel prior of automatic detection or fault on Auto mode.

Manual actuation of system in place shall be performed by break glass push button.The manual release advice shall be located so as to be conveniently and easily accessible at all times including at the time of the fire occurring.The type of manual release device shall be double action, for a more deliberate action and prevention of accidental operation. It consists a transparent hinged lift flap and breaking glass element.

The unit shall be suitable for installation in severe weather conditions and will be installed on outside wall in adjacent of main entrance door to protected area as surface mounting. Each unit shall be supplied with yellow color finish and be marked relevant protected area name on duty label.

10. Fire Protection in industrial Building

Classification of Fire

The fire classes are as given below based on NFPA-10:

- Class A fires involving solid materials usually of organic nature in which combustion normally takes place with the formation of glowing embers. Wood, cloth, paper, rubber, and plastic, etc. These materials are commonly used in overall building furniture's and appliances.Fire extinguishing media for this fire class are considered as water and dry chemical.
- Class B fires involving combustible liquids or liquefiable solids, oils, greases, tars, paint, lacquers, and flammable gases.These fires can occur in laboratory, analyzer, kitchen, diesel generator, workshop, and buildings. Suitable agent for this class is dry chemical and carbon dioxide.
- Class C fires involving energized electrical equipment so the extinguishing media must be nonconductive. After the equipment is denergized, extinguishers for class A or class B hazards can be used. This fire class exists in elec. substation and control buildings. Suitable agents for suppression are dry chemical and carbon dioxide. Application of carbon dioxide as clean agent is preferred on elec. panels, instrument apparatus, and other electronic devices.
- Class D fires involving combustible metals, Lithium, Sodium, Magnesium, Titanium, Zirconium, etc. This fire class is not anticipated in plant buildings.

Classification of Hazards

Hazards are divided into three classes, in NFPA 10, as follows:

Light or low hazard, occupancies where the total amount of class A combustible, including furnishings, decorations, and contents, is of minor quantity. These could be office, etc. small amounts of class B flammable are included if kept in closed safety cans and if safely stored.

Ordinary or moderate hazard, these occupancies have total amounts of class A, B, materials present in greater amounts than light hazard occupancies. These could be laboratory, and class I and class II commodity warehouses.

Extra or high hazard, these occupancies have total amounts of class A, B, materials present over-and-above those expected in ordinary hazard occupancies. These occupancies include warehousing of other than class I, II commodities.

Utilization of Fire Fighting Equipment

The fire extinguishers shall be provided for the protection of both the building structure, if combustible, and the occupancy hazards contained therein.

It is necessary to select extinguishers that fulfill both the distribution and travel distance requirement for a particular occupancy classification. Minimum extinguishers ratings to be determined by occupancy classification for particular hazard. Maximum travel distances for application of extinguishers for class A hazards in all occupancies are 23 meters, and for class B regarding to type of hazard classification and extinguisher ratings shall not exceed 9 and 15 meters.Travel distance is not merely a simple circle radius matter, but is the actual distance the user of the extinguisher will need to walk.

The best locations for fire extinguisher installation should be selected with the following considerations:

a) Provide uniform distribution
b) Provide easy accessibility
c) Be relatively free from blocking by equipment
d) Be near normal paths of travel
e) Be near entrance and exit doors
f) Be free from the potential of physical damage
g) Be readily visible
h) Be installed on a floor by floor basis

Extinguishers shall be suitable for installation location temperature and they shall be of a type approved and listed for the temperature.

In class B fires, substituting two or more extinguishers (with CO_2 or dry chemical agent) of lower rating for the minimum ratings given in NFPA 10 shall be avoided. Extinguishers shall be installed on the hangers or in the brackets supplied unless the extinguishers are of the wheeled type.The extinguisher should be placed on building column or walls with top 90 to 150 cm above the floor, and a sign should be posted on direct attention to the extinguisher. Wheeled extinguishers with additional agent and range are applicable for high hazard areas and have added importance when a limited number of people are available. They are seen for areas where additional protection is needed. Wheeled extinguishers should be distributed according to the 15m travel distance rule, though longer travel distances may be authorized by the proper a uthorities.

In addition of extinguishers, water hose reels as supplementary to be located in entrances and corridors of buildings for suppression of class A fires. The number of stand pipes and hose reels in each building and each section of a building divided by fire walls shall be such that all portions of each story of the building are within 34m for 1 ½ " hose with 25m length .

Where personnel are not available, the hazard should be protected by fixed systems. The primary use of CO_2 extinguishing system is considered for protection of electrical apparatus or items that may be damaged by the application of water.

Portable Dry Chemical Extinguisher

Portable dry chemical extinguishers are 12 kg capacity. They shall be provided with extinguishing agent suitable for class A, B, C, fires and as nonconductive.

The discharging time of agent shall be 8 to 20 seconds and 8 meter approx. stream range. The extinguisher shall be designed and manufactured in accordance with EN-3, BS-5423, DIN -14406 or Iranian Standards. Test pressure of the dry powder extinguisher shall be 25 bars and cartridge shall be tested at 250 bars.

It also shall be equipped with flexible hose, nozzle, squeeze control valve, siphon tube, safety spring valve, and wall mounting bracket.

The external surface of extinguisher shall be painted with an anti corrosion primer plus epoxy coat. Colors of finish shall be fire red and also fire classes and operating instructions shall be marked on body surface.

Wheeled Dry Chemical Extinguisher

Wheeled dry chemical extinguishers are 50 kg capacity and suitable for class A, B, C, fires and as non conductive. The discharging time of agent shall be 30 to 60 seconds and stream range minimum 9m. The material of the cylinder shall be of steel 4.5 mm minimum thickness.

The extinguisher shall be designed and manufactured in accordance with DIN-17100, EN, or Iranian Standards. Working pressure of extinguisher body is 15 bar and cylinder shall be tested at 28 bar. The extinguisher shall be operated with external pressure cartridge containing of Carbon Dioxide or Nitrogen propellant gas. High pressure cartridge shall be tested at 250 bar.

The extinguisher should be equipped with 10 meters of 19mm diameter braded hose, extinguishing pistol with flow controller, solid tires, handle to facilitate manual carriage, safety spring valve, siphon tube and others.

The external surface of extinguisher shall be painted with an anti corrosion primer plus epoxy coat. Color of finish shall be fire red and also fire classes and operating instructions shall be marked on body surface.

Portable Carbon Dioxide Extinguisher

Portable CO_2 extinguishers are 6 kg capacity and suitable for class B, C, fires. The discharging time of agent shall be 8 to 30 seconds, and stream range minimum 1 meter. The material of the cylinder shall be steel with suitable thickness. The working pressure shall be 50 bar and test pressure 200 bar.

The extinguisher shall be designed and manufactured in accordance with BS-5423, EN 3, DIN-14406 or Iranian Standard.

The extinguisher operating is as self expelling and shall be equipped with flexible hose, lever valve, discharge horn, siphon tube, safety bursting disc and wall mounting bracket.

Discharge horn shall not be metal material. The external surface of extinguisher shall be painted with an anti corrosion primer plus epoxy coat. Color of finish shall be fire red and also fire classes and operating instructions shall be marked on body surface.

Wheeled Carbon Dioxide Extinguisher

Wheeled carbon dioxide extinguishers are 20kg capacity and suitable for class B, C, fires. The discharging time of agent shall be 10 to 30 seconds, and stream range minimum 1 meter. The material of the cylinder shall be steel alloy with suitable thickness. The working pressure shall be 50 bar and test pressure 200 bar.

The extinguishers shall be designed and manufactured in accordance with BS, DIN, EN or Iranian Standard.

The extinguisher operating is as self expelling and shall be equipped with 2.5 m flexible hose, control valve, discharge horn, siphon tube, safety bursting disc, trolley with 2 solid rubber wheels, handle to facilitate manual carriage and others.

Discharge horn should not be metal material.

The external surface of extinguisher shall be painted with an anti corrosion primer plus epoxy coating. Color of finish shall be fire red and also fire classes and operating instructions shall be marked on body surface.

Water Hose Reels

Water hose reels are suitable for class A fires. They shall be considered as wall mounted and recessed type , including of support frame , swinging reel , cabinet with hinged door & handle ,1½" flexible hose 25m length, with standard 1½" fixed water nozzle (fog/jet/close stream) , and 1 ½" isolating valve . The isolating valve shall be globe valve, and angle type from gunmetal material. The valve outlet to hose connection can be storz coupling to minimize cabinet dimensions. Test pressure shall be made at minimum 28 bar. Hose reel and cabinet shall be made of min. 16 SWG (1.5 mm thickness) steel. Also surface to be finished with primer and red stove enamel topcoat. The cabinet door shall be equipped with handle. It also shall be lettered “FIRE HOSE REEL” with white color on red background.

Inert Gas Extinguishing Systems

Inert gas extinguishing system is an Auto/Manual actuation system which is used as total flooding. That is considered as primary means for spaces where need to clean agent for prevention of damage to electric or electronic equipment. Inert gas system shall be designed in accordance with section 11 of this document and NFPA-2001 by supplier.

Table 3: Application of Firefighting Facilities in Buildings

Area	Type of Protection
Control Building	- Inert Gas System -12 kg Dry Chemical Extinguisher(s) - 6 kg CO_2 Extinguisher(s) - 20kg wheeled CO_2 extinguishers
Diesel rooms	- Inert Gas System -20 kg CO_2 Extinguisher(s) -50 kg Dry Chemical Extinguisher(s) -12 kg Dry Chemical Extinguisher(s) - 6 kg CO_2 Extinguisher(s) - 20kg wheeled CO_2 extinguishers
Substation	- Inert Gas System -50 kg Dry Chemical Extinguisher(s) - 12 kg Dry Chemical Extinguisher(s) - 6 kg CO_2 Extinguisher(s) - 20kg wheeled CO_2 extinguishers
Laboratory	- 1½" Water Hose Reel(s) -12 kg Dry Chemical Extinguisher(s) - 6 kg CO_2 Extinguisher(s)
Analyzer Room(s)	- 12 kg Dry Chemical Extinguisher(s) - 6 kg CO_2 Extinguisher(s)
General buildings, admin, gate houses, Locker, Fire station	- 12 kg Dry Chemical Extinguisher(s) - 6 kg CO_2 Extinguisher(s) - 1½" Water Hose Reel(s)

11. Fire Proofing

Fire proofing of certain critical equipment and supporting structures enables a degree of fire exposure to be tolerated while a fire is being brought under control and extinguished, without major collapse or further failures.

Fireproofing should be considered in conjunction with other emergency and fire protection facilities, i.e., emergency shutdowns, isolation valves and blow downs, equipment spacing and layout, fixed water spray systems, and firefighting equipment.

Fireproofing requirements defined in Design standards and Global Practices must always be complied with as a minimum, but protection in excess of these standards may be justified in high-risk locations, as described in NPC-HSE-S-01. Also Requirements for HSE-322-02 (NIPC Fire Proofing Guideline) shall be complied.

- **Equipment to be Fire Proofed**

1.Equipment constructed of low melting point materials (e.g., aluminum), and located in a potential fire area.

2.Onsite vessels containing large inventories of flammable liquids [over 5000 gallons (19 m^3)] and located in congested **areas**.

3.Offsite pressure storage drums.

4.Supports for onsite and offsite vessels, furnaces, air-cooled heat exchangers and compressors, according to criteria of contents, size and adjacent fire risks.

5.Structural steel and pipe supports.

6.The installation of electrical cables and wiring, instrument pneumatic tubing, and instrument and thermocouple wiring should be designed to minimize the risk of failure arising from fire exposure. Routing of these systems shall be considered regarding to this point in cabling rout design. Underground installation of cables and tubing is preferred, particularly for major instrument or cable bundles leading to a blast-resistant central control house or a critical electrical substation. Where critical wiring does not meet the recommended minimum spacing from high fire risk equipment, fireproofing is required.

7.All components of Type D EBV systems intended for emergency isolation of equipment in case of fire, within 25 ft. (7.5 m) horizontally of the equipment being isolated (or further if the equipment fire hazardous area demands), must be capable of functioning through 15 minutes of fire exposure by the use of suitable materials for fireproofing (see **NPC-HSE-S-10**).

8.Fire mains, where they cross drainage ditches, into which oil may be discharged, per NPC-**HSE-S-07**.

9.Critical dock services which must be protected against fire exposure include the following: fire mains, dry pipe foam headers, systems associated with the control and actuation of emergency block valves, quick-release hooks or other emergency facilities, and any other instrumentation or communications systems which are essential during an emergency. As far as possible, the layout of the above systems should provide at least 100 ft. (30 m) spacing from the berth manifolds to avoid fire exposure from three dimensional fires at these locations. Sections unavoidably extending within the 100 ft. (30 m) distance should be fireproofed. The critical systems must also be protected against spill fires burning on the water surface below the dock structure, by routing from above the deck or by fireproofing. An alternative method for the fire main is to install a remote operated dump valve at each extremity to establish flow in the event of fire.

10. Additional fireproofing, beyond the requirements of Global Practices, should be considered for critical equipment in high fire-risk areas, based on factors such as deviations from minimum spacing standards, or restrictions on fire water application caused by high equipment density, stacking, platform arrangement, etc. Fixed water spray systems may be an alternative to fireproofing in some of these cases.

- **Materials and Methods of Fire Proofing**

Fireproofing may be achieved by the application of concrete or gunite, or by hot or cold service insulation which meets certain criteria of flame exposure resistance, insulating properties, external jacketing, and resistance to fire hose stream impingement.

NPC-HSE-S-09 covers the calculation of safety valve relieving rates for vessels exposed to fire. Credit may be taken for reduced heat input resulting from fireproofing and insulation of vessels, provided that they remain effective under fire exposure. API RP 521 defines the relevant criteria for insulation systems which must be met.

Basic Safety Concepts for Bonding, Grounding and Lighting Protection
NPC-HSE-S-08

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1. Scope

This document presents the minimum requirements for prevention of hydrocarbon ignition due to static electricity, lightning, and stray currents in the petrochemical plants. This document does not address electrostatic hazards relating to solids handling.

2. References

- API-RP 2003, Protection Against Ignitions Arising Out of Static, Lightning, and Stray Currents
- NFPA 70,National Electric Code
- NFPA 77,Static Electricity
- NFPA 780,Standard for the Installation of Lightning Protection Systems,
- IPS-E-EL-100, Engineering Standard for Electrical System Design,

3. Definitions

Arc: A low-voltage, high-current electrical discharge that occurs at the instant two points, through which a large current is flowing, are separated. Technically, electrostatic discharges are always sparks, not arcs.

Bonding: The practice of providing electrical connections between isolated conductive parts of a system to preclude voltage differences between the parts.

Closed connection: A connection in which contact is made before flow starts and is broken after flow is completed (e.g., in bottom loading of tank trucks).

Combustible liquid: A liquid with a flash point at or above 38°C (100°F).

Conductivity (s): The capability of a substance to transmit electrostatic charges, normally expressed in PicoSiemens per meter (pS/m) for petroleum products.

Flammable liquid: Liquid having a flash point below 38°C (100°F) and having a Reid vapor pressure not exceeding 276 kPa (40 psia).

Grounding: The practice of providing electrical continuity between a hydrocarbon handling system and ground or earth to ensure that the handling system is at zero potential.

High vapor pressure products: Liquids with a Reid vapor pressure above 4.5 psia (31 kPa).

Intermediate vapor pressure products: Flammable liquids with a Reid vapor pressure below 4.5 psia (31 kPa) and a closed-cup flash point of less than 38°C (100°F). These can form flammable vapors at ambient operating temperatures.

Low vapor pressure products: Liquids with closed cup flash points above 38°C (100°F).

Relaxation time constant: The time for a charge to dissipate to e-1 (approximately 37%) of the original value.

Residence time: The length of time that a product remains in a grounded conductive delivery system from the point at which a charge is generated to the point of delivery, e.g., from the outlet of a micro filter to the inlet of a tank truck.

Spark: A spark results from the sudden breakdown of the insulating strength of a dielectric (such as air) that separates two electrodes of different potentials.

Splash filling: The practice of allowing fuel to free fall or to impinge at high velocity on a tank wall, tank bottom, or liquid surface while loading.

Spray deflector: A plate above the vessel inlet opening that prevents upward spraying of product and minimizes the generation of a charged mist.

Static accumulators: a liquid with a conductivity less than 50 pS/m.

Switch loading: The practice of loading a low vapor pressure product into a tank which previously contained a high or intermediate vapor pressure product, resulting in a flammable atmosphere while loading the low vapor pressure product.

Waiting period: The elapsed time between the completion of product dispensing into storage or transportation containers (i.e., storage tanks, tank trucks, and tank cars) and sampling or gauging activities.

Incentive Discharge: A discharge that has enough energy to cause ignition is considered incentive. Both brush discharges and spark discharges can ignite common hydrocarbon/air mixtures.

4. Static Electricity/ General Considerations

The generation of electric charges, their accumulation on material, and the process of dissipating these accumulated charges cause static electricity hazards. Sparks from static electricity are a significant source of ignition.

Movement of petroleum and chemical products in itself generates a static charge within the product. It involves the separation or pulling apart of surfaces that are in contact with each other. Some common examples of separation or frictional generation of static electricity are:

a. Separation of liquid or gas from a hose, nozzle, faucet, or pouring spout.

b. The movement of liquids, gases or solid particles relative to other materials, such as occurs commonly in operations involving flow through pipes, mixing, pouring, pumping, filtering, agitating, or other types of fluids handling.

c. Turbulent contact of dissimilar fluids, such as water or gas flowing through a liquid hydrocarbon.

d. Air, gas, or vapors containing solid particles (e.g., dust, rust, etc.) or droplets being dis charged from a pipe or jet. Discharge of carbon dioxide extinguishers, sand blasting, steam lances, and pneumatic transportation of solids are examples.

e. Nonconductive drive belts and conveyor belts moving across or separating from rollers or pulleys.

Ignition hazards from static sparks can be eliminated by controlling the generation or accumulation of static charges or discharge of static charges.

Table1: Conductivity And Relaxation Time Constant Of Typical Liquids

Product	Conductivity(pS/m)	Relaxation Time Constant(Seconds)
Benzene	0.005	>>100
Xylene	0.1	210
Toluene	1	21
Gasoline	10-3000	1.8 - 0.006
Jet Fuel	<50	> 0.36
Diesel	0.5-50	36 - 0.36
Gas Oil	<50	> 0.36
Lube Oil(Base)	0.1-1000	180 - 0.018
Lube Oil(Blended)	50-1000	0.36 - 0.018
Fuel Oil	50-1000	0.36 - 0.018
Asphalt	>1000	< 0.018
Crude Oil	>1000	< 0.018

Ref: SCE no.8984

4.1. Charge Accumulation

Electrostatic charges continually leak away from a charged body. This mechanism, dissipation, starts as soon as a charge is generated and can continue after generation has stopped. Electrostatic charges accumulate when they are generated at a higher rate than they dissipate. The ability of a charge to dissipate from a liquid is a function of the following:

a. The conductivity of the product being handled.
b. The conductivity of the container.
c. The ability of the container to bleed a charge to ground.

Charges can also accumulate regardless of the conductivity of the fluid if the container being filled is made of low conductivity (nonconductive) material (e.g., a plastic bucket), or if the container is conductive but is inadequately grounded.

As electrostatic charge accumulates, the electric fields and voltages increase. When the electric field exceeds the insulating properties of the atmosphere, a static discharge can occur. Two types of static discharges are of primary concern in the plant: spark and brush discharges.

- ***Spark Discharge:*** *Spark discharges occur between conductive objects that are at different voltages. Usually, one of the objects is not adequately grounded.*
- ***Brush Discharge:*** *Brush discharges can occur between a grounded conductive object and a charged low conductivity material.*

4.2. Spark Promoters

A spark promoter is a grounded or ungrounded conductive object that provides the necessary spark gap for a spark to occur. Spark promoters greatly increase the probability of an incentive discharge. An important class of spark promoters is conductive objects near the surface of the charged liquid. The following are some examples of spark promoters:

a. Loose floating conductive objects or debris inside the container.
b. Conductive downspout which does not reach the bottom of the tank.
c. Gauge rods or side wall probes which are not connected to the bottom.
d. Gauge tapes, sample containers or thermometers which are lowered into the tank vapor space.
e. Ungrounded couplings on hoses in the tank.

4.3. Earthing grid

For the earthing of electrical system, equipment and structures, each installation shall have one common earth grid connected to at least two groups of earth electrodes. The resistance of this grid to general mass of earth shall not be less than the value specified by proper design standards and international practices when one group of electrodes is disconnected for the purpose of measuring or inspection. The earth grid shall extend throughout the plant in form of a plant ring with branch interconnections to the equipment and structures to be earthed and shall from part of a single earth grid for whole site.

4.4. Bonding

Sparking between two conducting bodies can be prevented by means of an electrical bond attached to both bodies. This bond prevents a difference in potential across the gap because it provides a conductive path through which the static charges can recombine. Therefore, no spark can occur. Static bond wires are usually comparatively large because of mechanical considerations; bond wire resistances are therefore low. Bolted connections within the bond wire or at the bond wire terminals shall be adequate for static dissipation.

4.5. Grounding

The earth may be used as part of the bonding system. Where the only gaps over which hazardous static sparks can occur are between an insulated object and a grounded object, such as between electrically insulated vessels and grounded piping, the electrical insulation can be bypassed by grounding the vessel. This will prevent the accumulation of a static charge on the vessel. However, grounding of a container or tank cannot prevent the accumulation of charges in a low conductivity liquid in the container.

4.6. Reducing Static Generation

The voltage on anybody receiving a charge is related to both the rate of static generation and the rate of static dissipation. This voltage can be prevented from reaching the sparking potential by restricting or reducing the rate of static generation. In the case of liquid hydrocarbon products, the rate of generation can be reduced by decreasing or eliminating the conditions or activities that produce static Thus, reducing agitation by avoiding air or vapor bubbling, reducing flow velocity, reducing jet and propeller blending, and avoiding free falling or dropping of liquid through the surface of stored product will decrease or eliminate the generation of static. Electrostatic charging is also reduced by preventing droplets of water or other particulate matter from settling through the body of the liquid.

4.7. Increasing Static Dissipation

A charge on the liquid will dissipate over time at a rate that is a function of the liquid's conductivity. Charge accumulation can be reduced by increasing the liquid conductivity through the use of anti-static additives (to a conductivity not less than 50 pS/m, but for practical purposes, 100 pS/m); or by retaining the liquid in an enclosed pipe or relaxation tank at low turbulence to provide more time for the charge to dissipate. When anti-static additives are used, it is preferred that the additive be introduced at the beginning of the distribution train. Introducing the anti-static additive at the final distribution point (such as at a loading rack) alleviates the dilution/ absorption concerns. Regardless of where in the distribution system the additive is introduced, if this is considered part of the static protection system, it is incumbent on the operator to verify that an adequate amount of additive is present in the final product. Hence, the operator must have systems in place (instrumentation, analyzers, testing, etc.) at all the critical points in the system to ensure that an adequate increased conductivity is achieved.

4.8. Equipment Grounding

All electrical and non-electrical equipment and parts of them which are liable to contact with live conductor or accumulate static charges shall be in effective contact with earth. Two earthing connections shall be taken from the vessel to main plant earthing grid. This is not necessary done for the vessel which is mounted directly on the steelwork with well conducting to the earth. Where the vessel is too remote from the plant as to make connection to the main earthing system impractical, two connections shall be taken from the vessel to separate earth electrodes.

4.9. Earthing and protective conductor

Protective conductor shall be suitably protected against mechanical damage, chemical or electrochemical deterioration, electrodynamics forces and thermodynamic forces.

Buried earthing and protective conductors should normally be bare copper cable or tapes. However, if there is a likelihood of corrosion PVC sheathed, colored yellow / green type shall be used. Joints in protective conductors should be avoided.

The following metal parts are not permitted for use as protective conductor or as protective bonding conductors:

- Metallic water pipes - Pipes containing flammable gases or liquids - Constructional parts subjected to mechanical stress in normal service - Flexible metal parts - Support wires

Protective conductors may consist of one or more of following:

a) A conductor in multicore cables

b) Insulated or bare conductor in a common enclosure with live conductors

c) Fixed installed bare or insulated conductor

d) Metallic cable sheath, cable screen, cable armor, wire braid concentric conductor, metallic conduit subject to the conditions stated in API-RP 2003.

Where the installation contains equipment having metal enclosures such a low voltage switchgear and control gear assemblies or busbar trunking system, the metal enclosures or frames may be used as protective conductors if they simultaneously satisfy the following three requirements:

a) Their electrical continuity shall be assured by construction or by suitable connection so as to ensure protection against mechanical, chemical or electrochemical deterioration.

b) They comply with the requirement of protective conductor sizing and jointing.

c) They shall permit the connection of other protective conductors at every predetermined tap off point.

4.10. Earthing where cathodic protection is applied

Bonding between catholically protected equipments and any earthing system can reduce the efficiency of an impressed current cathodic protection system by diverting the flow of impressed current. The cathodically protected sections of pipeline shall be isolated from unprotected sections and from any earthing system. Where plant is catholically protected, either by sacrificial anodes or by an impressed current system, the design of earthing system shall be agreed with the suppliers and designers of the cathodic protection system.

5. Electrical System

One point of every system shall be earthed primarily in order to preserve the security of the system by ensuring that potential on each conductor is restricted to such a value as is consistent with the level of insulation applied. From the point of safety view, it is equally important that earthing should ensure efficient and fast operation of protective gear in the case of earth faults. The system earth resistance must be such that when any fault occurs against which earthing is designed to give protection; the protective gear will operate to make the faulty feeder or equipment harmless. In most cases such operation involves isolation of the faulty feeder or equipment by circuit breakers or fuses. The common classifications of earthing in this standard are as follows:

a) Solidly earthed
b) Resistance earthed

5.1. M.V and H.V system earthing

M.V and H.V system neutrals shall be earthed TNS at each source of supply.
M.V and H.V Transformer neutral with secondary voltage less than 36kV shall be resistance earthed. The rating of each resistor shall be such that to limit the earth fault current approximately equal to the rated full load current of the transformer secondary.

In situation where generators are to be directly connected to the main H.V switchboard, each generator should be earthed via its own earthing resistor. This however, is subject to verification that the zero sequence, triple harmonic current (3rd, 9th, 15th, etc.) that could circulate through the resistors under various loading conditions of the generators would not be damaging to the resistors.

The rating of each resistor should be such as to limit the magnitude of earth fault current to the rated full load current or manufacturer recommended value of the generator to which is connected . These resistors should be solid type and shall be rated to withstand the respective E/F current for duration of not less than 10 seconds.

Note: In any case the earthing current shall not exceed 630 A.

In situations where generators of dissimilar rating characteristics or, Loadings are to be operated in parallel such as to give rise to circulating currents resulting from triple harmonics then the system shall be earthed via one earthing resistor only. Each generator shall then be provided with a suitable switching device to facilitate connection of any machine to the single earthing resistor.

For grid in feed system voltages above 36 kV, the neutral point of transformers should be solidly earthed. In these situations high earth fault current flows in the general mass of earth in the vicinity of the substation so earthing arrangement must be designed such that these currents do not results dangerous step and touch potential. Detailed guidance is given in IEEE standard 80.

5.2. L.V system

L.V electrical system neutral at each source of supply shall be solidly earthed by means of dedicated earth electrodes which have a direct, low impedance connection to the plant main earth grid.

The earthing system shall be designed in accordance with design standards and international practices For fixed L.V equipment, each loop impedances shall be such as to effect circuit disconnection in a time not exceeding 1 s under solid (negligible impedance) earth fault condition.

The impedance between the earth electrode or earthing terminal and any point on the earth continuity conductor should not exceed 1 ohm at frequency of the supply.

5.3. Electrical equipment earthing

A bar of high conductivity hard drawn copper shall be fixed inside the trench or cable gallery of the substation to which the earth bars of all switchboards and the metallic enclosures of all low voltage ancillary equipment shall be connected.

All main switchboards shall be connected to substation earthing system at two separate points. The tank of each main transformer shall be connected directly to the plant main earth grid.

The armouring and metallic sheath (if provided) of all multi core cables shall be bonded to the switchboard earth bar via termination or the gland. Where single core cables are used they shall be bonded to earth at one end only. The earthed end should be at hazardous end (if any).

The enclosures of all high and medium voltage motors shall be connected directly to the plant main earth grid or to local earth electrodes. A common earth electrode may be used for several motors in the same area. The enclosure of low voltage equipment shall be bonded to the plant main earth grid.

6. Electronic and instrumentation System

Special attention shall be paid to electronic and instrumentation system earthing, if required for computer and control system. These equipments shall be separately earthed from the electrical earth system. This separate earth system called “clean earth” or ”instrument earth” or ”computer earth” (less than 1 Ohm) as relevant, can be one or a number of separate and independent earth system depending on manufacturer’s requirement.

The clean earth electrode(s) shall be located outside of resistance zone of power earthing electrode(s).

The earth conductor between instrument clean earth bar in the auxiliary room and the clamp type earth bar in the instrument clean earth pit shall be braided or armoured. This braiding or armoring shall be bonded to the electrical earthing system to shield this earth conductor from surface stray earth currents which may cause unwanted interference.

Where interconnection between instrument clean earth and electrical earthing system may be subjected the effect of electrical storms, or high voltage induced, the interconnecting lines or cables shall be equipped with suitable surge diverters to prevent damage to instrument equipment.

Note: Instrument earthing such as intrinsically safe, non-intrinsically shall be considered and installed as stated in proper instrument standards.

7. Truck Loading Grounding System

7.1. General considerations

The following four primary electrostatic charge generation mechanisms are related to tank truck filling operations:

a. Product flow through filters and screens. Flow-through filters and screens can produce a high electrostatic charge. The degree of hazard depends on the size of the openings within the filter or screen. In general, when product conductivity is less than 50 pS/m an adequate residence time should be provided downstream of the filter or screen to permit sufficient charge relaxation.

b. Product flow through piping. The flow of liquid through piping generates static charge. Flow rates and velocities that meet this limit are shown in Table 2 for selected pipe sizes. In addition, linear flow velocity should never exceed 7 meters per second (23 feet per second). The 0.5 limit does not ensure that static ignition will not occur, but it greatly reduces the probability of ignition.

c. Splash loading. In this instance, the electrostatic charge is generated in the liquid by turbulence and by the generation of a charged mist. Splash filling should be avoided to minimize turbulence and mist generation.

d. Multiphase flow generates electrostatic charge as a result of both flow-through piping and also when the different phases settle in the tank compartment. Therefore, whenever the fluid is a static accumulator and contains a dispersed phase, such as entrained water droplets, the inlet flow velocity should be restricted to 1 meter per second (3 feet per second) throughout the filling operation. In addition, a suitable waiting period should be employed to allow for product charge relaxation before any object such as temperature gauge or sample container is lowered into the tank compartment.

When risk factors are close to their safety limits, the chance of an ignition is greater than average. The following specific risk factors can be identified:

a. Fluid conductivity less than 2 pS/m.

b. Flow velocity at or close to the maximum allowed.

c. Residence time after filters/screens at or slightly below the minimum recommended.

d. Presence of a significant turbulence generator that is close to the compartment inlet (i.e., partly open block valves, etc.).

If more than two or more these conditions are expected at a facility where intermediate vapor pressure products are loaded or switch loading is performed, consideration should be given to preventive measures that exceed those outlined in this document and Additional measures shall be provided as per proper standards such as API-RP 2003.

Table 2: Velocities and Flow Rates for Schedule 40 Pipe

Normal Pipe Size (Inches)	Inside Diameter		Flow Velocity		*vd* Constant (Square Meters Per Second)	Flow Rate	
	Inches	Milimeters	Feet Per Second	Meters Per Second		(Gallons Per Minute)	Liters Per Minute
1 ½	1.610	40.9	3.28 22.97	1.00 7.00	- 0.286	21 146	79.5 553
2	2.067	52.5	3.28 22.97	1.00 7.00	- 0.386	34 240	129 908
3	3.068	77.9	3.28 21.05 22.97	1.00 6.41 7.00	- 0.5 0.54	76 485 529	288 1836 2002
4	4.026	102.3	3.28 16.04 22.97	1.00 4.89 7.00	- 0.5 0.72	130 637 911	492 2411 3448
5	5.047	128.2	3.28 12.79 20.5	1.00 3.90 6.2	- 0.5 0.8	205 798 1277	776 3020 4833
6	6.065	154.1	3.28 10.64 17.00	1.00 3.24 5.20	- 0.5 0.8	295 959 1539	1117 3630 5825
8	7.981	202.7	3.28 8.09 12.95	1.00 2.47 3.90	- 0.5 0.8	512 1260 2018	1938 4769 7638
10	10.020	254.5	3.28 6.44 10.31	1.00 1.96 3.14	- 0.5 0.8	806 1580 2536	3051 5980 9599
12	11.983	303.2	3.28 5.41 8.66	1.00 1.65 2.64	- 0.5 0.8	1140 1890 3020	4315 7154 11431

7.2. Bonding and Grounding

Top-loaded tank trucks shall be electrically bonded to the downspout, piping, or steel loading rack. If bonding is to the rack, the piping, rack, and downspout must be electrically interconnected. Bonding is usually achieved by means of a bond wire. The bond connection should be made before the dome cover is opened, and it should remain connected until the dome cover has been securely closed after loading is complete. Grounding of metallic loading rack components, however, may be necessary for electrical safety.

Bond circuit resistance should generally be less than 10 ohms. Bond or ground indication instruments shall be available for installation at truck loading racks to continuously monitor the bond connection. These instruments shall be operated in conjunction with signal lights and electrically interlocked with the control circuits to prevent the loading pumps from being started when a good bond is not present.

A tank gauging rod, high-level sensor, or other conductive device that projects into the cargo space of a tank truck should be bonded securely to the bottom of the tank by a conductive cable or rod to eliminate a spark gap, or placed in a gauging well that is bonded to the compartment.

Inserting a nonconductive hose equipped with a metal coupling on its outlet must be avoided unless the coupling is bonded to the fill line and to the compartment being filled so as to form a continuous conductive path.

7.3. Bottom Loading

Bottom loading minimizes the possibility of electrostatic hazards that could result from improper bonding or positioning of the downspout in top loading. However, in the initial stages of bottom loading, upward spraying of the product can increase charge generation and should be prevented by reducing the filling velocity and using a spray deflector or other similar device. If bottom-loading inlets in tanks are not designed to avoid spraying, low vapor pressure products can form an ignitable mist. The initial velocity in the fill line and discharge point should be limited to about 1 meter per second (3 feet per second) until the fill line outlet and deflector (when provided) is submerged by at least two fill line diameters.

7.4. Vapor-Balanced Tank Trucks and Vapor Recovery

During loading of vapor-balanced compartments, the same precautions taken during loading of compartments vented to the atmosphere should be observed. In addition, it is not safe to assume that the presence of a vapor recovery system will ensure a safe atmosphere within the tank truck compartments. When different vapor pressure products are being loaded using a common vapor recovery system, a flammable atmosphere may be introduced into the compartments. Such systems should be carefully reviewed to determine whether this hazard is significant at the particular facility. Isolated conductive sections should be avoided in vapor recovery lines. All conductive parts of the vapor connection on the tank vehicle should be in electrical contact with the cargo tank. Liquid cascading from one compartment to another as a result of overfilling through the common overhead system can create electrostatic and other hazards.

7.5. Unloading

Unloading system of tank trucks through open domes by means of suction pipes or closed system unloading from fixed top or bottom outlets require protection against static sparks.

Note: The handling of petroleum products in marine operations presents the potential for fire and explosion hazards due to static electricity. While the principles in this document apply to marine operations as well as onshore operations, the OCIMF International Safety Guide for Oil Tankers and Terminals, provides specific guidance related to static hazards in all facets of marine operations (including loading, unloading, sampling, gauging, tank cleaning, etc.) and should be followed.

8. Storage Tanks

8.1. Control of Electrostatic Charge Generation

The possibility of a static discharge between the liquid surface and the tank shell, roof supports, or other appurtenances is related to the static-generating qualities of the liquid in the tank. The generation rate is also influenced by the degree of turbulence in the liquid and by the settling of minute quantities of finely divided materials, such as water droplets, particles of iron scale, and sediment. The possibility of a spark is greater in the presence of a spark promoter.

Hydrocarbon products that tend to retain static charges can introduce a greater risk of static ignition unless they are handled properly. When the vapor space in a storage tank is likely to contain flammable or switch loading, the following protective measures should be used:

a. Avoid splash filling and upward spraying. The fill-pipe outlet should discharge near the bottom of the tank, with minimum agitation of the water and sediment on the tank bottom. Where the outlet of the fill line is attached to a downcomer, the siphon breakers that permit air or vapor to enter the downcomer should not be used. Avoid discharging the product from a nozzle that is elevated above the liquid level.

b. Limit the fill line and discharge velocity of the incoming liquid stream to 1 meter per second (3 feet per second) until the fill pipe is submerged either two pipe diameters or 61 cm (2 ft.), whichever is less. In the case of a floating-roof (internal or open-top) tank, observe the 1-meter-per-second (3-feet per-second) velocity limitation until the roof becomes buoyant. During the initial stages of tank filling, more opportunity exists for the incoming stream to produce agitation or turbulence, hence, the need to limit the inlet velocity. However, the product's flow rate should be kept close to 1 meter per second (3 feet per second) during this period, since lower velocities can result in settling out of water at low points of piping. Subsequent re-entrainment when the velocity is increased could significantly raise the product's charging tendency.

c. Where the material is a static accumulator and contains a dispersed phase, such as entrained water droplets, the inlet flow velocity should be restricted to 1 meter per second (3 feet per second) throughout the filling operation.

d. Provide a minimum 30-second residence time downstream of micropore filters.

e. Check for ungrounded loose or floating objects in the tank and remove them. (i.e., loose gauge floats and sample cans).

f. Avoid pumping substantial amounts of air or other entrained gas into the tank through the liquid. In particular, the practice of clearing fill lines by air-blowing should be prohibited when the material is a flammable liquid or a combustible liquid heated to within 8.5°C (15°F) of its flash point.

g. A maximum fill rate between 7 meters per second and 10 meters per second (23 feet per second *and 33 feet per second) is commonly used. If the vapor space in a tank is at or above the lower flammable limit because of the previously stored product and the tank is to be filled with a low vapor pressure static accumulating liquid, the precautions outlined above should be followed.*

Care must be taken, however, to ensure that floating roofs are in metallic contact with the shell. Following the recommendations described for lightning protection will also provide static protection. Some types of floating covers, though non-conducting, are constructed with isolated metallic clips, which if not bonded, can become charge accumulators and spark promoters.

8.2. Grounding

Tanks up to 30 m diameter shall be provided with two, and tanks over 30 m diameter shall be provided with three equally spaced earthing bosses. For group of tanks earth electrodes common to the group may be installed provided that each tank has, as minimum two paths to earth.

On floating roof tanks, multiple shunt connections shall be provided between the floating roof and the tubing shoe at adequate intervals around the roof periphery. The addition of grounding rods and similar grounding systems may be required for electrical safety (see NFPA 70) or lightning protection.

8.3. Spark Promoters

unbonded conductive objects, within a storage tank such as tank gauging rod, high-level sensor or other conductive device that projects downward into the vapor space of a tank shall be bonded securely to the bottom of the tank by a conductive cable or rod (to eliminate a spark gap) or placed in a gauging well that is bonded to the tank. Periodic inspection should be conducted to ensure that bonding cables do not become detached. Devices that are mounted to the interior sidewall of the tank (i.e., level switches, temperature probes), and which project a short distance into the tank but have no downward projection should be evaluated on an individual basis as point of electrostatic hazard.

8.4. Sampling and Gauging

Sampling and gauging operations (including temperature measurement) can introduce spark promoters into a storage tank, increasing the likelihood for a static discharge. During tank filling operations an electrostatic charge can accumulate on the product because of various charge mechanisms. Where possible, a conductive gauge well is recommended for all manual sampling and gauging. To be effective, the gauge well needs to be attached to the top and bottom of the tank so as to prevent the development of a large voltage on the surface of the product within the well.

Sampling and gauging devices should be either completely conductive or completely nonconductive. Conductive sampling and gauging devices (including the sampling container and lowering device) should be properly bonded to the tank. Freely-floating un-bonded floats can act as spark promoters and should be avoided.

8.5. Floating-Roof Tanks

Tanks with conductive floating roofs in contact with the product are inherently safe from static charge accumulation provided that the roof is bonded to the shell. If the roof is landed, charge accumulation in the surface of the liquid may occur and appropriate precautions need to be taken.

8.5.1. Open Floating-Roof Tanks

Open floating-roof tanks require bonding shunts between the floating roof or cover and the tank's wall. The shunts are primarily required for lightning protection but they also provide protection from electrostatic charges that may be generated.

8.5.2. Internal Floating-Roof Tanks

Internal floating-roof tanks require some form of bonding, either by the use of shunts or a metal cable between the floating roof or cover and the tank roof or shell. This will sufficiently remove any electrostatic charges on the floating roof or cover that may result from product movements.

8.6. Nonconductive Tanks and Linings

It is not recommended to store flammable liquids in nonconductive (e.g., plastic, fiberglass) aboveground tanks. A plastic tank may be equipped with a metallic manhole and fluid openings.

When nonconductive tanks are used for hydrocarbon storage or storage of materials that may be contaminated with flammable products, significant electrostatic concerns are introduced. The major concerns are as follows:

a. The electrostatic field is not confined to the interior of the compartment (such that discharges could be induced externally to the tank or in an adjacent compartment); and

b. There is no efficient means for charge dissipation from the fluid (such that the probability of internal discharge is increased).

To ensure the safe dissipation of charge and prevent discharges, the following features should be incorporated in the tank if the atmosphere could be flammable:

a. All conductive components (e.g., a metal rim and hatch cover), should be bonded together and grounded.

b. When used to store low-conductivity products (less than 50 pS/m), the following additional features should be provided:

1. An enclosing grounded conductive shield to prevent external discharges. This shield may be in the form of a wire mesh buried in the tank wall, as long as it is grounded, and the shield should include all external surfaces.

2. The tank should have a metal plate with a surface area no less than 194 cm^2 per 379 liters (30 $in.^2$ per 100 gallons) located at the tank bottom, and bonded to an external ground. This plate provides an electrical path between the liquid contents and ground through which the charge can dissipate.

c. When used to store high-conductivity products, either provide a grounded fill line extending to the bottom of the tank or an internal grounding cable extending from the top to the bottom of the tank and connected to an external ground.

Note: For Buried Tanks (Underground Storage Tanks) the same precautions that are applied to above ground storage tanks are recommended.

9. Miscellaneous Electrostatic Hazards

9.1. Drive Belts and Pulleys

Belts made of rubber, leather, or other insulating materials, running at moderate or high speeds, can generate significant quantities of static electricity. If the pulley is made of conducting material, the charge will normally dissipate through the shaft and bearing to ground and will not present an ignition hazard. If the machinery frame is insulated or the bearings are composed of insulating materials, such as nylon, then bonding and grounding is required.

9.2. Filters and Relaxation Chambers

Charge generation greatly increases (from 10 to 200 times) if a filter is placed in a piping system. In some cases, wire screens can also enhance charge generation. If, after filtration, the liquid is discharged from the pipe into a container where the possibility of a flammable mixture exists, specific precautions may need to be taken.

When screen size is less than 150 microns (more than 100 mesh per inch) a hazardous charge level is likely to be generated, particularly if the filter or screen is partially plugged. In this situation, a residence time of at least 30 seconds shall be provided between the filter or screen and the point of discharge. With screen sizes between 300 microns (50 mesh) and 150 microns (100 mesh), safe operations may be possible based on the results of a risk assessment of the facility, which considers such factors as the materials being handled and the operating procedures in place. A provision of at least 30 seconds residence time after filtering is recommended for all new equipment, regardless of the product or service.

Note: The use Nonconductive Surfaces such as of sheet plastic should be avoided where flammable vapor might be present.

9.3. Internal Coatings and Linings

Metal containers with internal coatings or linings up to 2 mm thickness may be treated as an uncoated metal container. Storage tanks, tank truck or tank car compartments, piping and other metallic equipment with nonconductive linings (e.g., FRP linings for corrosion prevention) thicker than 2 mm shall be treated as nonconductive equipment. Regardless of the lining thickness, the metal container shall be bonded to the filling system. Lined piping and fittings may contribute to charge generation. Flow-through lined piping and delivery system components should not be considered in determining the residence time.

9.4. Mists

When the gas contains suspended solid particles or liquid droplets, (i.e., an aerosol or mist), a hazardous electrostatic charge concentration may develop. An electrostatic charge in an aerosol or mist can be generated during the atomization process as a result of flow through piping and equipment or as a result of contact with other charged objects. Because the suspended solids or droplets are not in electrical continuity with each other, the electrostatic charging mechanism does not depend on the conducting properties of the solid or liquid involved and charged aerosols/mists are possible with conductive as well as nonconductive materials. In addition, because the charge relaxation process requires settling of the mist, the required waiting period may be as long as five hours. The hazard associated with aerosols and mists are threefold:

a. The possibility exists of generating a charge concentration (such as during tank cleaning with liquid jets) high enough that an incentive brush discharge can be generated between the charged aerosol or mist and grounded conductors present.

b. The charged aerosol/mist can contribute a significant charge to the liquid, foam generated on a liquid surface, and isolated conductors that may be present within the enclosure or compartment.

c. The aerosol or mist itself may produce a flammable mixture in situations where the atmosphere would not normally be in the flammable range.

In situations where an aerosol or mist formation cannot be avoided or is intentional, it is recommended that the operation be carried out under an inert atmosphere. In addition, insulated conductors should be avoided/removed and all facilities (such as spraying nozzles) should be bonded and grounded.

10. Lightning Protection

Direct-stroke lightning can severely damage objects in its path as a result of heat energy and associated mechanical forces, as well as by direct ignition of flammable materials. The electric current and energy deposited by a lightning stroke can be sufficiently high to melt thin metallic components and destroy electronic components if they are not designed to propagate to ground or divert the energy.

In addition to direct-stroke lightning, the abrupt change in the electrical Field caused by a lightning stroke can cause secondary sparking at equipment that is relatively remote from the direct stroke. These induced charges or sparks usually occur when an insulated metallic body is present. The metallic body initially becomes charged by means of induction at a harmlessly slow rate through its high resistance to ground. When lightning strikes nearby, this induced charge is suddenly released in a discharge to ground, which can ignite a flammable mixture.

10.1. General Considerations

Lightning protection system shall be designed and installed in accordance with IEC 61024 or BS 6651. The connection to earth should be as short and straight as possible.

Where the plant is located in proximity to the process area substation, the lightning earthing system shall be connected to the power earthing system at two points.

In all areas classified as hazardous, steelwork such as stairways, cable racks, handrails, etc., which is mounted on or attached to non-metallic structures shall be bonded to the general earthing system either directly or via other earthed metal at intervals not exceeding 30 m.

Non-metallic structure less than 9 m in height does not generally require lightning protection. If greater than 18 m in height, lightning protection shall be provided.

The need for lightning protection on non-metallic structures between 9 m and 18 m in height shall be determined taking into account the heights of other adjacent structures, the nearness of flammables materials, consequences of damage, etc.

Metallic guy ropes used for supporting metallic or non-metallic stacks or other structure shall be bonded at their upper ends to the stack or structure if metallic, or to the lightning protective system in the case of non-metallic stacks or structures. The lower end of each guy rope shall be directly earthed.

10.2. Inherent Grounding

Metallic tanks, equipment, and structures that are in direct contact with the ground (i.e., no non-conducting membranes) have proved to be sufficiently well grounded to provide for safe propagation to ground of lightning strokes. Supplemental grounding is necessary, however, where direct grounding is not provided.

Metallic equipment that does not rest directly on the ground but is connected to a grounded piping system is usually safe for propagation to ground of lightning strokes. Such equipment may require supplemental grounding to prevent foundation damage.

Metallic tanks, equipment, and structures that are insulated from ground shall be adequately grounded and bonded.

Structures made of insulating materials such as wood, plastic, brick, tile, or non-reinforced concrete are typically not inherently grounded for lightning protection. They can be protected from direct-stroke lightning by means of properly designed lightning protection systems according to proper standards such as NFPA 70 and 780.

10.3. Protection against Direct-Stroke Lightning

In order to protect against a direct lightning stroke, the tallest structure on the plant shall be directly grounded as close to the base as possible with a minimum of two electrodes (less than 5 Ohm) and interconnected with main plant earthing grid.

In areas where the frequency and intensity of lightning is high and normal grounding measures are deemed insufficient, some form of lightning protection measures beyond those outlined in this document should be considered.

Direct stroke lightning protection systems available include the following:

a. Conventional air terminal lightning protection system to intercept the lightning stroke. Air terminal lightning protection systems do not protect against indirect lightning currents or induced voltages.

b. Charge transfer system to deflect the path of an incoming lightning stroke. The number of sharp conductors needed in the array to provide adequate protection and the construction details of the array are proprietary to the companies that have developed these systems.

c. Early streamer emission air terminal lightning protection system to attract an incoming lightning stroke to the system and propagate to ground the energy.

According to the vendors, the major difference between these devices and conventional air terminals is that the triggering device increases the probability of discharge initiation. Such devices offer lightning protection to objects and structures that fall within a protected zone adjacent to and beneath the highest point of the air terminal. Construction details of the triggering device are proprietary to the companies that have developed these systems. Early streamer emission air terminal lightning protection systems do not protect against indirect lightning currents or induced voltages.

Selection and installation of any lightning protection system should be based on a thorough analysis that considers the probability of lightning strikes at the site, the likelihood of success for the proposed protection system, and the potential consequences should the protection system fail to function as desired.

10.4. Atmospheric Storage Tanks

10.4.1 Fixed-Roof and Horizontal Tanks

Metal tanks with Fixed metal roofs and horizontal metal tanks that are maintained in good condition are generally protected from damage by direct-stroke lightning and ignition of its contents, if all metal components are in electrical contact (i.e., bonded). Most tank explosions that have occurred as a result of lightning strikes have been attributed to the following:

a. Roof openings, such as gauge hatches, that have been left open.
b. Vents that have not been protected by flashback devices, such as pressure vacuum vent valves.
c. Corrosion holes or thinned areas of tank roofs.

Pressure vacuum valves or back flash protection shall be provided in all vents. Pressure vacuum vents on tank openings prevent propagation of flame into a tank if escaping vapor ignites. Pressure vacuum vent valves, without flame arrestors shall be proved to satisfactorily stop a flame from propagating into the tank.

Metallic tanks with Fixed non-conducting roofs cannot be considered protected from direct-stroke lightning. However, these tanks can be provided with a metal covering, of adequate thickness (not less than 5 mm (3/16 in.) per NFPA 780), that is in contact with the shell or provided with a lightning protection system.

Fully nonconductive tanks are inherently not capable of withstanding direct-stroke lightning. As a minimum, any conductive appurtenances need to be grounded for lightning protection. These tanks shall be protected by a lightning protection system or replaced by a metal tank.

10.4.2 Open Floating-Roof Tanks

Mostly, Fires occur in the seal space of open floating-roof tanks as a result of lightning-caused discharges.

The most effective defense against ignition by lightning is a tight seal and properly designed shunts. Shunts are metallic straps placed at intervals of not more than 3 meters (10 feet) on the circumference of the roof that bond the floating roof to the shell and permit any lightning related current to propagate to ground without generating a spark in an area likely to ignite vapor.

For floating-roof tanks with pentagraph-type fabric primary seals, shunts should be installed above the primary seal. Regardless of the type of primary seal, where weather shields are present above the seal or where wax scrapers or secondary seals are provided, the space between the two seals may contain a flammable vapor air mixture. In these cases, shunts shall be placed so they contact directly with the tank shell above the secondary seal. In all cases, the design must ensure that good shunt-to-shell contact is maintained at the highest possible roof height (e.g., provide 51 mm [2 in.] of clearance above the shunts at the maximum Filling height).

Shunts could also be placed below the liquid, but this design is not recommended because of the difficulty of inspection.

10.4.3 Internal Floating-Roof Tanks

Internal floating-roof tanks with conductive steel roofs are inherently protected against internal ignitions from lightning induced sparking by the Faraday-cage effect. As a result, the internal floating roof does not require bonding to the shell or tank wall for lightning protection. However, the floating roof or cover still requires bonding to the shell for protection against electrostatic charges due to product flow.

10.4.4. Pressure Storage

Metallic tanks, vessels, and process equipment that are designed to contain flammable liquids or gas under pressure do not normally require lightning protection. Equipment of this type is usually well grounded and is thick enough (not less than 5 mm (3/16 in.) per NFPA 780) not to be punctured by a direct strike.

10.4.5. Atmospheric Process Vents

Flashback protection or other means of prevention of flame propagation should be considered (based on a risk assessment) for atmospheric process vents where the potential exists for a flammable vapor release and ignition during a lightning storm. Weather covers over the vents need to be electrically continuous with the vent pipe.

11. Protection of Specific Operations against Stray Currents

11.1. Pipelines

If a gas or light oil pipeline, which handles heavy stray currents, is severed, arcing may occur at the point of separation, creating an ignition hazard. Where stray currents are known or suspected, a short, heavy-gauge bond wire or jumper shall be connected across the point where the line is to be separated. The procedures to be employed when a line is opened are identical to those required when a valve or spool is removed or inserted. The bond must have a low electrical resistance (typically less than 2 ohms). The wire must be attached to the pipe in a way that provides minimal electrical resistance.

11.2. Spur Tracks

As a result of stray currents, pipelines that serve tank car loading and unloading spots located on spur tracks may be at a different potential from that of the rails. Stray currents may flow in the pipelines or in the rails. The usual protection against stray current arcs is to bond at least one rail to the pipelines that serve loading or unloading facilities. Spur tracks may connect with electrified main lines, cross electric railway tracks, and in some instances, be equipped with rail-circuit signal systems. In all such circumstances, insulating couplings should be placed in the rail joints of the spur track so that the track will be completely insulated from the source of any return rail currents. The insulating joints should not be bridged by rail equipment during the transfer of flammable liquids.

11.3. Wharf Lines

If stray currents are present in wharf piping, connecting and disconnecting a ship's hose may produce arcs because the resistance of the ship's hull to ground (water) is exceedingly low. In such circumstances, the stray currents in the ship's hose can be reduced in magnitude by providing a low resistance ground for the wharf piping. However, where cathodic-protection facilities are operating to prevent corrosion of the Wharf structure or the ship's hull, pipe grounding can increase the stray currents in the ship's hose. Insulating flanges in the pipe risers to the hose (or loading arm) connections provide the best assurance against arcing at the point of connection and disconnection of the hose (or loading arm). Insulating flanges at the shore end of wharf piping are effective where stray currents arise from onshore facilities. Insulating flanges are employed at both locations to prevent arcing at the connections and to prevent the flow of stray or cathodic-protection currents between the wharf and shore piping. If there are insulating flanges at both the shore and pipe riser, the pipe between the shore and the riser must be grounded. In any case, a conductive path between the riser and the ship must exist. Where flexible hose strings connect the ship and wharf piping, an alternative to the insulating flange is to include one length of nonconductive hose in each string to block current flow between the ship and the wharf.

When insulation is used to prevent stray currents, no electrically conductive objects, such as metal flanges, should be isolated in the cargo lines as they could accumulate static electricity. An example of this would be isolated flanges or couplings if more than one nonconductive length of hose were used. (See OCIMF International Safety Guide for Oil Tankers and Terminals for more information.). Multiple, oversize bond cables with very low contact resistance at the bonding point can effectively reduce the amount of stray current but can create a burdensome and impractical operating problem.

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Process Safety

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