Fire Safety Guidelines for Open Plant Structures in Oil, Chemical and Process Industries

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The Working Group for the Guidelines was appointed by the above Organisations to assist in the preparation of the Guidelines. The Working Group comprises the following persons who contribute their views and experiences gained as professions in their companies and in their individual capacities:

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The Guidelines serve as an accepted fire safety requirement for open plant structure installation in Singapore. The Guidelines give plant developers clearer scope of work, thus save time and efforts. Plant developers are encouraged to use the Guidelines for project planning, technical guidance and scheduling of their project work. The Guidelines however does not exclude any best practices that aim to achieve even higher fire safety standards and other approach that plant developers wish to proceed or mitigate without lower the standard of this Guidelines. However, such alternate approach would certainly take more time and efforts for both the plant developer and the approving Authority as submission of studies and reviewing process for alternates are needed.

In short, the design and construction of the installation shall reduce fire safety risks to the possible minimum level through adopting international good engineering design and practices, including reasonable security measures to be considered. Plant developer adopting the alternate approach shall justify the alternate proposal through submission of relevant studies to show consequences or risks taking are adequately covered and accepted by the relevant Competent Authorities.

Content

1. Overview

1.1 Purpose

The purpose of this guideline is to provide fire safety guidelines, requirements and design for building open process structures and facilities in the oil, chemical and process industries.

1.2 Philosophy and Consideration

The design of open process structures and facilities intended for process operation with human access shall be such that reliance for safety to life does not depend solely on any single safeguard. Additional safeguards shall always be considered in case any single safeguard is ineffective due to inappropriate human actions or system failure.

The operation of oil, chemical and process plants (here called process plants) shall be planned and designed that they do not constitute significant fire or explosion risks to people in and around the facilities and to surrounding facilities within or outside of process plants.

This guideline provides guidance for open plant structure installation and shall apply to all new project and modification to existing facilities (see Notes 1 to 3 below).

Note:
(1) “Modification to existing facilities” means the addition of new equipment to the existing facilities or replacement of new equipment not in kind.
(2) “New equipment” means those 45 equipments/facilities covered in the Table 3.1 (do consult the relevant authorities for those which are not listed). “Replacement of new equipment not in kind” means the new equipment replacing the old equipment is not the same as the old equipment.
(3) In the case of modification to existing facilities that due to space constraint, plant owner shall propose alternate approach to mitigate for the approving Authority to consider.

1.2.1 Design Objectives

The design of open process structures and facilities containing high hazard contents shall begin with the identification of properties of hazardous materials to be stored, used, or handled. The design shall then provide adequate and reliable safeguards to accomplish the following objectives, considering both normal operations and possible abnormal conditions:

- Limit or prevent escalation of a fire by providing spacing that adequately separated the process unit, building, large structure and process drainage system.

- Avoid loss of life and serious injuries by providing adequate means of escape to personnel to evacuate safely, access for emergency responders to a fire and safe access for personnel to isolate plant and equipment.

- Contain and prevent the spread of fire by having early detection and warning devices and systems that enable emergency isolation, shut down and depressurizing of process equipment remotely to limit the volume of material released in the event of fire.

- Protect steel structures by providing passive and active fire protection systems in hazard areas.

1.2.2 Process Hazard Review

For any construction or addition of open process structure or facility, Owner shall consider credible major fire scenario, causes and evaluate the adequacy of the fire prevention features for the plant. A process hazard review shall be carried out prior to the construction that includes the change of fire causes based on the proposed layout of the plant and equipment and consider the resulting arrangement from the standpoint of fire hazards.

2. Scope of Fire Safety

The scope of fire safety in this guideline is to provide reasonable provisions for the protection of properties, personnel and surroundings from damages resulting from fires, explosions, and other unsafe conditions.

The Owner or Developer together with their QP (Qualified Person) are still require to consult the relevant Authorities, including SCDF, SPF, NEA, PUB and MOM, etc. for their respective requirements, including the need of QRA study, security measures, spillage and drainage control system, etc.

2.1 Layout and Spacing

The type of materials handled in facility will have influence to specific fire protection designs. Proper spacing of process facilities is important in both preventing and fighting a fire. Spacing prevents fire threat by reducing the risk of exposure to nearby facilities. In case of a fire occurs, good spacing will limit the spread of the fire from escalating to nearby surrounding. Proper spacing of equipment is one of the most important design considerations. When a fire occurs, adequate spacing is often a major line of defense in limiting the loss.

2.2 Drainage

Proper drainage ensures that spills of flammable materials are carried away from equipment and potential sources of ignition. A well designed drainage system also provides the removal of fire water from the scene at full application rate. This is to prevent hydrocarbons released that floats on top of the pools of water from spreading around the affected unit and to adjacent units.

2.3 Isolation, Deinventory and Depressurizing of Plant

The most effective way to extinguish a process fire is to remove the source of fuel from the fire. This is often done with isolation valves that can be remotely operated or manually accessed by operators during a fire. Isolation valves either stop the flow of fuel to the fire, or they direct the inventory of hydrocarbon to a safe location.

2.4 Means of Escape

Open process structures and facilities shall be provided with adequate means of escape for operators and emergency responders during an emergency. The facilities with the means of escape shall be designed and maintained to allow quick escape by operators as well as to provide reasonable safe access for fire fighters and emergency responders during search and rescue operations.

2.5 Passive Fire Protection

Careful use of fire resistant materials, such as fireproofing, fire rated cable and heat resistant wiring, can help to prevent a fire from spreading and limit its damage. Typically, fireproofing is provided for critical structures, vessel and column skirts and supports, exposed pipe-rack columns and control wirings and power cables necessary for safe plant shutdown.

2.6 Active Fire Protection

Fire water systems comprising hydrants, fire equipment boxes and fixed monitors are common features that installed in larger facilities. Fixed water spray systems are proven to be effective for certain applications, such as removing heat from a hot-oil pump fire thus protecting nearby equipment. Dry chemical extinguishers are used for quick extinguishment of small fires. Other agents such as foam, steam and carbon dioxide are also used to provide extinguishment capability.

Reliable supply of utility services in water, steam, and electric power is another factor of good plant design. Reliable and uninterrupted supply of utility services support the fighting of fire emergency that minimizes plant interruptions, abnormal conditions and ensures that firefighting crews have utilities services when they need them. Utility distribution systems for water, steam, and electric power shall be looped with block valves or other means at appropriate points so that, if any part of the system is damaged, supply can be obtained from another source.

The consumer electrical sub-station (including PUB sub-station) should be considered if possible to be sub-divided with at least 1 hour fire resistance for the two incoming power grids.

2.7 Emergency Response

Process fires are most frequently attacked by applying cooling water streams to the fire and to surrounding exposed equipment while simultaneously attempting to stop the flow of fuel to the fire. When designing a facility, take care to provide suitable access for emergency responders and emergency appliances and locate firefighting equipment, such as wheeled extinguishers and fixed foam/water monitors strategically to facilitate rescue and fire-fighting operations.

3. Fire Safety Protection and Provision

3.1 Scope for Process Equipments and Facilities

All process equipments such as columns, heat exchangers and vessels to name a few have to be designed according to the relevant international codes. These process equipments have design safeguard to protect against abnormal run-away temperature and overpressure. Open process structures and facilities that used for holding or supporting these process equipments and their associated piping in the hazardous zone need to be fire proofed. Pipe rack supports where piping containing hazardous substances such as refrigerated gases could leak or cause fires during emergency need to be protected with fire-proofing materials. The stairs, ladders, or other accesses to reach points in the process area for sampling, inspection, or maintenance are parts of the process structure.

3.2 Storage Tank

Storage tank is for storage of feedstock, intermediates and finished products for processing, temporary storage and delivery to end-users or transfer for further storage. Storage tank is usually sited away from the process units. Fire safety requirements for storage tank are outside the scope of this guideline. The requirements for atmospheric storage tanks are detailed in SS 532 "The storage of flammable liquids". For pressurised storage vessels, the requirements are detailed in NFPA 58, LP Gas code.

3.3 Layout and Spacing

3.3.1 General

Preventing a fire or explosion from spreading to adjacent property or equipment is to have adequate layout and spacing. Layout and spacing can also prevent a fire or explosion by separating potential sources of fuel from potential sources of ignition. Many factors must be considered when arranging and spacing process structures, facilities and equipment, including:

- Public safety and proximity to highly populated areas,
- Proximity to sensitive environmental habitats, groundwater conditions and etc,
- The cost of clearing and reclaiming land,
- Regulatory requirements,
- High hazard plant handling volatile materials will require larger spacing, and
- Facilities with limited internal emergency response support will require increased spacing and drainage control.

This guideline provides guidance for plant layout and spacing of individual pieces of equipment or facilities mentioned in Table 3.1.

3.3.2 Equipment Spacing and Electrical Classification

This guideline considers three key principles on equipment spacing.

Equipment spacing defined in this guideline is intended to minimize a vapor cloud from one piece of equipment from contacting a potential source of ignition. It is also intended to reduce the potential for a fire on one piece of equipment from damaging adjacent equipment. These distances are based on fire hazardous zones and historical fire spread.

Fire proofing describes when a piece of equipment or structure steel is within a fire hazardous zone and shall be fire proofed. While these distances will often resemble the equipment spacing distances, they will not be always the same.

Electrical area classifications (any other recognised international standards) contain distances describing potential areas in which a flammable vapor cloud may be present. Fixed electrical equipment within these areas must meet the described electrical classification criteria. These distances do not address fire hazardous zones, hence they may differ from both the fireproofing and equipment spacing distances.

Design engineers need to be aware of and apply all three principles when laying out equipment and buildings.

3.3.3 Layout Objectives

It is important to list out fundamental considerations for the protection of the public and surrounding communities against the hazardous exposure to spills, fire, explosions and hazardous releases. The process structures and facilities shall have the appropriate fire buffer zone as separation either by road, gravel or non combustible constructions (for detailed separation distance, refer to Table 3.1). The design layout of a buffer zone during a fire incident or gas release shall prevent the impact to other process units and allow proper drainage to prevent accumulation of flammable materials that may create a pool fire. The office and workshop shall be separated from process area by appropriate open space or roads. The process facilities shall be away from the main service roads to avoid moving vehicles from crashing into it.

3.3.3.1 Protection of Critical Equipment

Critical equipment shall be identified and designed for adequate separation. Critical equipment is defined as that equipment necessary for the safe plant operation and necessary for safe shutdown during plant emergencies. Critical equipment may include instrument air supplies, process control systems, electrical power, substations, main process block valves, certain pumps and compressors, emergency shutdown (ESD) and depressurising systems, and fire water systems. Highly valuable pieces of equipment may also warrant extra separation.

3.3.3.2 Protection for Utilities

It is prudent to have greater spacing between boiler plants, sub-stations and a high-pressure process plant than between two process plants as it is critical to the process plant.

3.3.3.3 Plant Equipment Access

Good layout and clear equipment access are critical to maintaining safe operations, routine maintenance and shutdowns and emergency response. Spacing and access area shall be checked against the size and turning radius of various cranes and other equipment required for maintenance and shutdowns.

3.3.3.4 Security

Border fencing and access control to the plant are necessary to prevent unauthorized personnel; from entering the plant area. Installation of CCTV at strategic locations and locking device to limit access to vital control instrument and hazardous materials shall be considered.

3.3.3.5 Evacuation

Evacuation routes shall take into account the location of potential releases, prevailing winds, drainage patterns, etc.

3.3.4 Block Layout and Roads

A process plant may compose of several process blocks that are laid out in an appropriate pattern such as a rectangular block with adequate roadways giving two-way access to process structures and facilities in the block. Roads that separate blocks are excellent fire breaks and can facilitate movement and use of firefighting equipment. Considerations shall be given to facilitate the emergency response, maintenance and heavy vehicles movements. Two directional accesses shall be considered for process blocks that consist of process equipments on both sides of the road. Maintenance considerations shall include access by large lift vehicles, if appropriate. Roadways and pipe-rack crossings shall be able to handle expected weight loads.

For the restricted road in between blocks of a process plant, the minimum width is 4 m . For unrestricted road anywhere in between process blocks or process plants, the minimum width of the road is 6 m, with 2 m buffer from the edge of the road to the nearest process equipment.

3.3.5 Separation and Spacing Table

The separation and spacing table in Table 3.1 gives minimum spacing guidelines for the following:

- Plant to plant,
- Plant to property line,
- Plant to equipment, and
- Equipment to equipment.

These guidelines have been developed through various companies' experience and industry standards. Where special circumstances allow less spacing, the facility or project team shall document the rationale and mitigation efforts.

NOTES

Equipment set back lines are used to establish plant spacing. They should clearly defined on all plot plans. The plot limit lines, which delineate the near edge of adjacent roads are not used to establish plant spacing.

1. For the spacing between the near edge of a road to a high- or low-hazard plants (the road bordering a main pipeway (piperack) and high- or low-hazard plants) may be reduced to 1.5 metres. All roads closer than 8 metres to high- or low- hazard plants are considered restricted roads.

2. Need to provide a 6 metres minimum vertical space between overhead air coolers and the top of pumps handling flammable or combustible liquids.

3. For spacing of flares, the minimum distance from flares is determined by calculations for tolerable radiant heat at the point closest to the flame where frequent occupancy by personnel is required. However, the minimum distance to equipment of handling flammable fluids should not be less than 61 metres (except equipment directly related to the system and normally located near base of the stack).

4. For plot limit valves, they should be accessible from grade or from a raised platform. Platform should be accessible by stairway and not located over pipeway (piperack) drainage channel.

5. In fire water distribution, primary fire water pumps and their spares should be 61 metres from process equipment when spaced together. Individual pumps 61 metres apart may be within 30 metres of the process units.

6. For main pipeways (piperack), triple spacing for pipe trenched.

7. For wharves and piers, distance from hydrocarbon pumps, manifolds, loading arms to process control rooms is greater.

8. Tank trucks traffic to tank truck loading bays should not interfere with process plant traffic.

9. Spacing of office building for process personnel is based on the potential explosions that can shatter glass, wood and other construction materials susceptible to explosion and fire damage. Single offices for field supervisors can be located in shops or control buildings.

10. Tank pumps should be outside tankfield (tankfarm) dikes and impounding basin. Pumps for tanks without dikes should be a minimum of 15 metres horizontally from the tank.

11. For pumps operating above 316 degree C should be separately considered - refer to Fire Code or relevant Documents.

12. High flash product tanks may be closer to facilities and equipment. Crude oil stored in cone roof tanks require special consideration. Refer to NFPA 30 for Tank Manual.

13. For the consideration of spacing from property lines that can be built on:
- Residential commercial = as given.
- Industrial zoned properties = 1/2 distance given.

14. For spacing of control building, refer to other Building Control Code or relevant documents.

15. For incineration-type vapour recovery units, the spacing requirement should meet the furnace spacing requirement.

16. For vehicle motor control centre, refer to electrical area classification API document.

No.	Item	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45
1	Process unit equipment set backline (Lo hazard <34 bar)	23																																												
2	Process unit equipment set backline (Hi hazard >34 bar)	30	30																																											
3	Product storage tanks	30	30	SS																																										
4	Floating roof/crude oil storage tanks	61	61	SS	SS																																									
5	Remote impounding basin	61	61	15	15	SS																																								
6	Tank field dikes	30	30	2	2	-	-																																							
7	Process cooling towers	15	15	61	61	15	8	15																																						
8	Main piperack	8	8	8	8	8	8	8	-																																					
9	Main electrical sub-station	23	30	30	30	61	30	15	15	ACC																																				
10	Utility boilers & power generators	46	61	30	30	61	30	15	8	-	ACC																																			
11	Plant instrument air compressor & dryer	23	23	30	30	61	30	15	8	3	8	ACC																																		
12	Oily water separator	15	15	15	15	-	-	15	8	15	15	15	-																																	
13	Process control room	15	15	23	23	30	15	15	8	15	15	15	30	BC																																
14	Unrestricted plant roads	8	8	-	-	-	-	8	5	3	8	8	8	3	-																															
15	Property lines of others can be built on	30	46	SS	-	15	3	61	15	15	61	61	30	BC	BC	-																														
16	Chemical Warehouses	30	30	30	30	61	30	30	8	15	30	15	8	-	-	-	BC																													
17	Office buildings for process personnel	91	91	61	61	61	30	61	15	15	61	30	30	BC	8	FC	61	BC																												
18	Primary fire water pumps	61	61	61	61	61	61	23	8	ACC	ACC	ACC	23	15	3	3	30	15	ACC																											
19	Tank truck loading bays	30	30	30	30	30	15	30	8	30	30	30	8	30	8	30	30	30	15	ACC																										
20	Wharves & piers	30	30	30	30	61	15	30	8	30	30	30	8	15	8	30	30	30	30	30	-																									
21	Power & instrument cables / Pole lines	15	23	8	8	8	8	23	2	-	-	8	8	ACC	ACC	ACC	ACC	ACC	ACC	15	15	-																								
22	Process flares	61	61	MS	MS	MS	30	MS	-	MS	MS	MS	MS	MS	30	MS	MS	91	MS	MS	MS	MS	MS																							
23	Flareline knock-out drums	ACC	ACC	8	8	15	2	15	2	15	15	8	8	15	8	61	30	61	30	30	30	8	30	ACC																						
24	Motor vehicle control centers	15	15	15	15	15	ACC	15	8	ACC	ACC	ACC	15	ACC	ACC	8	ACC	ACC	ACC	15	15	-	MS	15	ACC																					
25	Plot limit manifolds (piperack)	8	8	15	15	15	-	8	ACC	15	23	15	15	15	8	46	15	46	23	15	15	8	MS	8	15	8																				
26	Furnaces	ACC	ACC	46	46	30	30	30	8	23	-	15	15	30	8	61	30	61	30	30	30	15	MS	15	15	15	5																			
27	Gas compressors	-	-	8	8	8	8	15	8	15	23	15	15	15	8	61	30	30	30	30	15	15	MS	15	15	15	12	3																		
28	Process pumps	-	-	3	3	3	3	15	3	15	23	3	3	15	8	61	30	30	30	8	ACC	15	MS	8	15	15	12	8	2																	
29	Air-fan coolers	-	-	30	30	30	30	15	8	15	23	15	15	15	8	61	30	61	30	30	30	8	MS	8	15	8	12	3	3	ACC																
30	Process heat exchangers	-	-	15	15	15	15	-	8	15	23	15	-	15	8	61	30	61	30	15	ACC	8	MS	8	15	8	8	ACC	ACC	ACC	ACC															
31	Process drums	-	-	15	15	15	15	23	8	15	23	23	15	15	8	61	30	61	30	30	30	15	MS	8	15	8	8	3	3	ACC	ACC	2														
32	Process columns (Towers)	-	-	30	30	30	30	23	8	15	23	23	15	15	8	61	30	61	30	30	30	15	MS	8	15	15	8	3	3	ACC	ACC	ACC	3													
33	Process reactors	-	-	30	30	30	30	23	8	15	23	23	15	15	8	61	30	61	30	30	30	15	MS	8	15	23	8	3	3	ACC	ACC	ACC	ACC	3												
34	LPG spheres & drums	61	61	LPG	LPG	15	3	23	8	15	23	23	15	15	15	LPG	30	61	61	30	30	15	MS	LPG	15	15	61	15	15	15	15	15	15	15	LPG											
35	Auxiliary - building, shops, etc	15	15	23	23	30	15	15	8	15	15	15	15	-	-	BC	30	BC	30	30	61	-	MS	15	-	30	-	-	-	-	-	-	-	-	-	-										
36	Fire house/brigade	91	91	61	61	61	30	61	15	30	30	30	30	-	-	FC	30	FC	-	30	30	-	91	61	-	46	-	-	-	-	-	-	-	-	-	15	-									
37	Non-chemical/petroleum warehouses	30	30	61	61	61	61	15	8	15	61	30	30	15	-	BC	61	BC	30	30	61	-	91	61	-	30	-	-	-	-	-	-	-	-	-	-	-	-								
38	Vehicle parking lots	15	15	30	30	30	8	23	8	15	15	15	15	-	-	BC	15	BC	30	30	30	-	MS	15	8	15	-	-	-	-	-	-	-	-	-	-	15	-	-							
39	Construction site/area and material	23	30	30	30	30	8	23	8	15	15	15	15	30	-	-	BC	-	15	30	30	-	MS	8	-	15	-	-	-	-	-	-	-	-	-	30	30	8	-	-						
40	Fire fighting training area	91	91	91	91	91	91	91	30	91	91	91	91	152	-	91	91	152	91	91	91	-	91	91	91	91	-	-	-	-	-	-	-	-	-	152	91	91	30	30	-					
41	Company residence area	91	91	61	61	61	30	61	15	15	61	30	30	BC	8	BC	61	BC	15	61	61	-	91	61	ACC	46	-	-	-	-	-	-	-	-	-	61	-	30	-	30	152	-				
42	Motor highways	46	46	-	-	-	-	61	8	8	46	15	15	15	-	BC	8	BC	8	30	30	-	MS	15	8	15	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-			
43	Entrance of the Main Plant	30	30	30	30	30	30	30	8	8	15	8	30	15	-	BC	8	BC	15	30	15	-	MS	15	3	15	-	-	-	-	-	-	-	-	-	-	30	-	-	30	30	15	-	-		
44	Other entrances	15	15	15	15	15	15	30	5	8	8	15	15	30	-	BC	8	8	15	-	15	-	MS	8	3	15	-	-	-	-	-	-	-	-	-	-	30	-	-	30	30	15	-	30	-	
45	Vapour recovery units	15	15	15	15	3	3	15	8	15	15	15	15	15	3	15	30	30	15	15	8	-	MS	15	15	8	-	-	-	-	-	-	-	-	-	15	15	15	15	30	91	91	15	30	30	-

Legend
SS = Refer to Singapore Standard on tank separation & spacing.
MS = Minimum spacing of 61 metres or other consideration (see Note 5).
- = Meaning not relevant or not related directly.
ACC = Minimum access for personnel & maintenance are 0.8 metres & 1.2 metres respectively.
BC = Refer to Singapore Building Code & relevant documents.
LPG = Refer to API Standards for LPG spacing to property line & NFPA 58.
FC = Fire Code & relevant documents.

Table 3.1: Separation and Spacing Table (distance in metre)

3.3.6 Protection of the Public through Spacing

Where practical, offices, warehouses, and other low-risk buildings shall be in the buffer zone to ensure adequate spacing from process plants. Buffer zone can be the greenbelts, planted areas or any empty space in between. These areas give the industrial facility a friendly, modern image that can make them more acceptable to the public.

3.3.7 Plant-to-Plant Spacing

The major issues to consider in plant-to-plant spacing:

- Personnel safety and operator access,
- Explosion damage prevention,
- Spill spread control,
- Vapor releases and vapor cloud travel,
- Fire and fire spread,
- Flood control,
- Maintenance access,
- Firefighter access, and
- Radiant heat from fire.

3.3.7.1 High Hazard Process Unit

Spacing between process units is based on the estimated hazard of one or more facilities. High hazard facilities shall meet any one of the following criteria:

- Contain flammable material in process equipment at normal > 34 bar,
- Contain combustible liquid in process equipment when they are heated or handled at temperature above or within (minus) 8 degree C of their flash point and at nominal > 34 bar,
- Contain substantial amount of highly flammable gasses in process equipment, e.g., LPG, butane, hydrogen, ethylene, acetylene at any pressure, and
- Contain substantial highly reactive or toxic compounds in process equipment, such as hydrofluoric acid or anhydrous ammonia.

3.3.7.2 Low Hazard Process Unit

Most other process units operating at pressures below 34 bars would be considered low hazard facilities with regard to plant-to-plant spacing.

3.3.8 Spacing of Important Plant Support Facilities

Firefighting facilities, critical instrumentation systems, and utility plants shall be able to operate in the worst-case plant failure. They are the last line of defense in fire and incident control. Therefore, the plant layout shall allow greater spacing between these facilities and those that may be sources of toxic releases.

3.3.9 Spacing of Off-Plot and Unrelated Facilities

Non-processing facilities involved in packaging, shipping, and marketing may be located near process plants. Examples of such facilities are product loading stations, marketing terminals, warehousing distribution, and marine terminals. These facilities shall be treated as off plot facilities and spaced accordingly.

Consider prevailing winds when siting hydrocarbon tank truck loading station, flammable gaseous material such as LPG, ammonia storages, chlorine treating units, acid storage and related facilities which can contain toxic vapors. This minimizes the potential for a vapor release to travel into adjacent units, buildings, or public property. However, prevailing winds shall not result in shorter spacing on the upwind side of the facility.

Vehicle traffic in the plant area should not be affected by traffic from road tankers coming into the plant or traffic from workers arrival for work. Heavy traffic may interfere access of fire fighting appliances to the fire scene.

3.3.10 Process Equipment Spacing

3.3.10.1 General Philosophy

Process flow generally dictates the layout of equipment within an operating unit. The spacing between individual pieces of equipment is determined by requirements for piping flexibility, access for operation and maintenance, and fire protection.

Equipment spacing for fire protection is designed to provide:

- Protection against flammable vapor reaching sources of ignition,
- Protection against a fire on a piece of equipment from damaging adjacent equipment or piping,
- Access for fire control, and
- Protection of important equipment from fire.

Keep fired equipment away from equipment and portions of the plant where a flammable vapor release might occur. Where possible, locate furnaces on the outside edge of plants, upwind of other equipment.

General spacing requirements are shown in Table 3.1.

3.3.10.2 Pumps and Compressors

Mechanical equipment, such as pumps and compressors handling flammable liquids and vapors, is the equipment most likely to be a source of accidental leakage to the atmosphere.

A release of flammable liquids and vapors from these pumps could automatically ignite, resulting a fire in the vicinity of the pump. Therefore, pumps for hydrocarbon in this service are treated as high fire hazard equipment.

Use Table 3.1 for the separation and spacing:

- Locate pumps at least 12m from furnaces or potential heat sources.
- Place pumps 2m apart.
- Pumps shall be 3m from equipment handling flammables so that a packing gland fire or mechanical seal fire will not expose adjacent equipment.

Additional pump spacing recommendations should be considered if practicable:

- Locate pumps along the outer edge of the plot limit, outboard of columns and vessels, and with no equipment installed overhead.
- If it is necessary to locate such pumps alongside in-plant overhead pipe-rack, the process ends shall be 3m outside the extremities of the overhead pipe-rack.
- Where desirable to further reduce risk of fire loss, a pump may be separated by a spare pump or by increased spacing.
- Hydrocarbon pumps shall not be located adjacent to critical, high value equipment; under or adjacent to overhead fin fan coolers; or under main instrumentation and electrical cable runs.

3.3.10.3 Pumps Handling Hydrocarbons above Flash Point

A release from these pumps can result in a large vapor cloud which may likely find a source of ignition, resulting in a fire. At a minimum, the vapor cloud may inhibit personnel from accessing isolation valves and other adjacent equipment. Therefore these pumps should be treated with extra precautions. Use the same spacing guidelines described above for pumps handling hydrocarbon over the auto-ignition temperature.

3.3.10.4 Pumps Handling Combustible Hydrocarbons and Other Process Streams below Flash Point

These pumps are lower in fire risk than the pumps described above. In general, unless unusual conditions occur a release from these pumps is not likely to result in a fire. It is still inherently safer to locate pumps handling hydrocarbons at least 12m (Table 3.1) from furnaces. These pumps can be located adjacent to pipe-rack and overhead fin fan coolers.

3.3.10.5 Air-Cooled Heat Exchangers

It is preferable to locate air-cooled heat exchangers over areas where risks of serious fires are minimal. Do not locate them near pumps or other high fire hazard equipment.

3.3.10.6 Process Piping

Process piping should run above ground and preferably overhead. Do not install new below-grade pipe trenches if there is other alternative. Upgrade existing below grade pipe-racks that contain flammable materials and consider installation of underflow weirs that allow water to pass under a weir discharging from the pipe trench while containing floating hydrocarbons. Overhead pipe-racks provide excellent separation between equipment and generally run through the center of an operating unit. They also are less prone to external corrosion and can be inspected more easily. Do not locate mechanical equipment under overhead pipe-racks.

3.3.11 Specific Facilities

3.3.11.1 Building in Process Plants

Buildings and Control Rooms at facilities shall be studied to determine if the location and construction type are appropriate for potential hazards from the process areas. Potential hazards include: fire, toxic release and Vapor Cloud Explosion (VCE). For new control rooms and buildings (at facilities handling flammable or toxic materials), a hazard assessment shall be done to insure that the design requirements are sufficient to mitigate potential hazards. This could include blast resistant design, protected ventilation systems, or gas detectors.

Refer to API RP 752 that outlines a three-stage analysis process for identifying hazards and managing risk to building occupants from fires, toxic releases, and explosions. The staged approach systematically identifies and evaluates buildings in which occupants may be at risk.

3.4 Drainage

A well designed drainage system relating to fire protection and pollution must be able to:

- Contains spills, preferably within a closed system,
- Carries spills, rainwater and fire water to a safe location where the spill can be retained and recovered and
- Minimizes the spread and exposure area from spills and fires.

3.4.1 Drainage Systems

The typical types of drain system are:

3.4.1.1 Surface Water Drainage (Open and Closed Systems)

An open surface water drainage system is an open ditch drainage designed capable of removing water resulting from either the maximum natural flow of rainwater or firewater used on the plant surface in the worst case plant scenario. The surface water drainage shall include interceptors at around the open ditch system that are capable of diverting potential contaminated water or oily water into a catch basin or a closed drainage system, which shall have at least 3 hours of storing the contaminated water from either the heavier rainfall or firewater of a worst case plant scenario.

A closed surface water drainage system is similar to the sub-paragraph 3.4.1.2 “Equipment oily water drainage (closed system)”, except that the respective area drainage dikes are sufficient large enough to accommodate the rainwater or firewater of either from the maximum rainfall or worst case plant scenario respectively.

3.4.1.2 Equipment Oily Water Drainage (Closed System)

The oily water drainage system is designed to carry away the contaminated rainwater or fire water on individual (or group of them within the same dike) equipment areas usually within enclosed dikes through a closed draining system into underground or designated sump where such oily water will be stored before recovery. This drainage system also serves to drain away spill or contaminated hydrocarbon water due to miss-operation of plant upset.

3.4.2 Surface Water Drainage System – Some Design Highlights

3.4.2.1 Plant Area Division by Functional Category

Divide the plant area into categories by function, such as equipment areas, pipe-racks, and walkways so that drainage from one area does not pass through another area on the way to the catch basin or a closed drainage system. Note that special areas such as acid, caustic, hot oil furnace, or heat exchanger areas, etc may need further considerations, see Figure 3.1.

3.4.2.2 Segregation of Contaminated Oily/Chemical Surface Water Streams

Determine the extent to which contaminated oily/chemical surface water streams should be segregated for environmental, disposal, cross-contamination or reactivity reasons.
Acid, Caustic, Corrosive and Toxic Wastes should be handled in a segregated system until treated or rendered harmless.

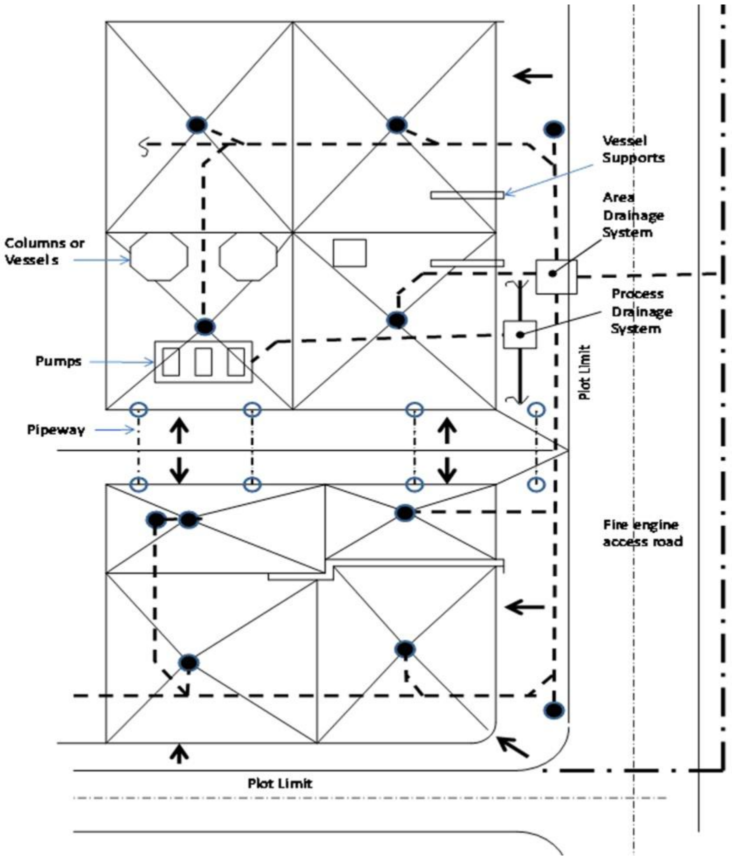


Fig 3.1 - Typical Surface Drainage Plan

3.4.2.3 Surface Water Drainage Area Layout and Capacity

Divide each category into approximate areas of 200m2 to 500m2 and size the catch basins or closed drainage system necessary to store contaminated fire water during the largest fire scenario or surface rainwater of typical heavy rainfall from open ditch, whichever is greater. Fire water requirements are determined by the size of the largest practical fire that could occur and the fire control techniques and equipment likely to be used.

Surface drainage capacity must be adequate to carry away approximately 75% of the maximum fire water application rate or the heavier possible rainfall. The larger flow from Fire water or rainfall shall be used in sizing the surface drainage system.

Although individual drainage areas vary in size and shape, they should have the following characteristics:

- Drainage inlets and sumps are centrally located,
- Outer edges or ridge lines of each drainage area are at a constant elevation,
- The preferred differential elevation from any ridge line to sump is 150mm to 250mm, and
- Slopes shall range from 1V:25H to 1V:100H. Around pumps and other areas where leaks are anticipated 1V:50H is preferred.

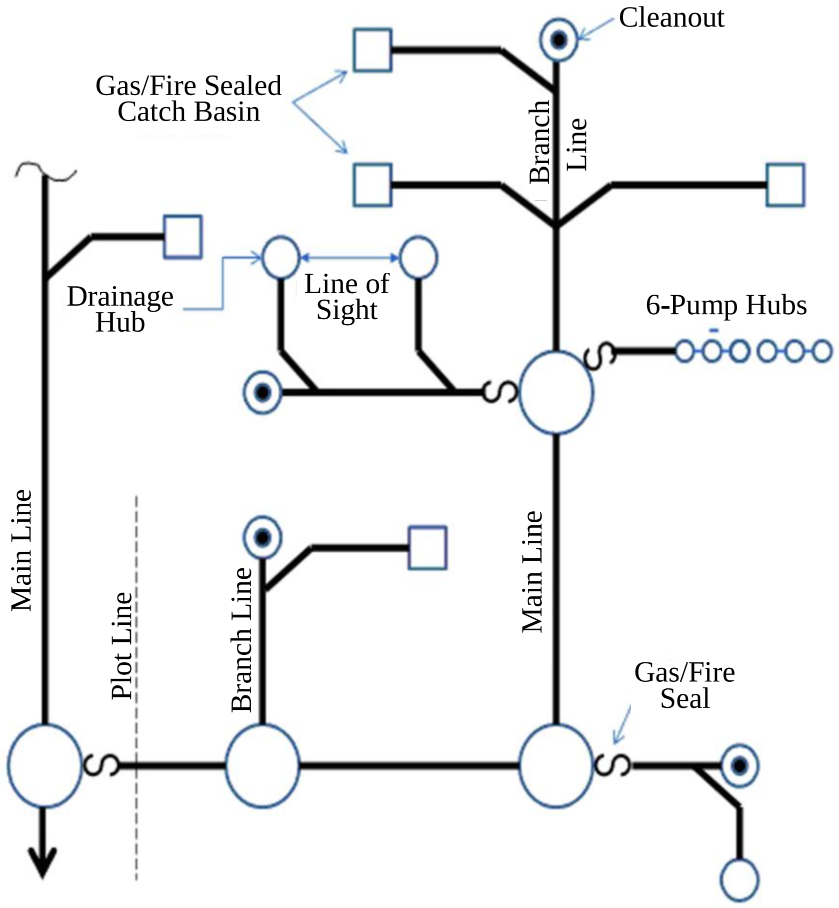


Fig. 3.2 - Drainage System Components

3.4.2.4 Peripheral Roads and Open Drain

Design surface drainage to quickly remove spilled hydrocarbons/chemicals. This minimizes exposure to flames should a fire occur. Isolate plant units by constructing peripheral roads that are 150mm higher than the high-point grade of adjacent units or equivalent means to prevent spillage across operating unit plots. This prevents spills, fire water, and rainwater from flowing from one unit across the road to adjacent plants. Open drain trenches of plant unit should eventually drain rainwater to open course and interconnecting different plant units is not allowed.

3.4.2.5 Network Design

- Combine up to 6 units of similar or compatible gravity flow drainage in the same drainage area if they are within line of sight of each other. ("Line of sight" means that all other drains are visible from any one drain. Such groups of drains must be sealed from other groups of pump or process drains by gas-sealed catch basins or gas-sealed manholes.)
- Branches and laterals in oily water systems must enter main lines through a gas-sealed manhole.
- Onplot main headers of both oily water systems may enter other main drain lines without gas seals if gas-sealed catch basins or gas-sealed manholes are used at upstream junctions.
- Main lines leaving a plot limit must be gas-sealed at the first off-plot manhole.

For fire protection purposes, drainage systems that may contain flammable vapors should be sealed both onplot and offplot. Otherwise, toxic and flammable gases may be released in an area well away from where the release occurred. Seal oil-water separators from both the inlet and outlet drainage lines. Unless drainage lines are sealed, fire and explosions could propagate through the system from offplot back to the separators.

3.4.3 Vents

Vent manholes (usually with 50mm diameter pipe) at an elevation 4.5m above the highest line or equipment within a 3m radius. The vent shall be at least 3.5m above grade or above any walkway or work platform within the 3m radius. The vent shall be at least 15m horizontal from furnaces. The vent opening shall point straight up.

3.4.4 Catch Basin

Catch basin in process plants have only 75mm to 100mm of water seal. The water seal is designed to prevent vapor releases and thus eliminate the need for flame arrestors.

3.4.5 Sealing Requirements

- Oily water drains need to have seals at catch basin or manhole,
- Chemical waste drain should be sealed to control toxics and odor,
- Miscellaneous wastes require seals if gas or odor is a problem, and

- Catch basin for surface drain does catch sediment and reduce plugging of the underground drain system.

3.4.6 Fire Stops

Install a solid transverse barrier as a fire stop at 90 to 150 m intervals in main below-grade pipe-racks (or pipe-track). This prevents a spill from a leaking line from spreading to the entire pipe-rack. If the spill ignites, the barrier prevents the spread of fire to other sections of the pipe-rack. Provide a drain inlet in each section of the pipe-rack to carry away the flow of leaks and fire water if a fire should occur.

3.5 Isolation, Deinventory and Depressurisation of Plant

The most effective way to extinguish a process fire is to remove the source of fuel from the fire. Vessel and equipment containing large inventories of flammable materials shall be equipped with isolation valves which are accessible in emergency conditions. All relief systems shall be in operating condition. For larger isolation valves or those in remote or inaccessible locations, consideration should be given to install remotely operated valves.

3.6 Means of Escape

The danger of immediate engulfment of personnel in flames and the effects of radiated heat in open process structure is likely and real. The provision of means by which personnel can move quickly away from a fire is, therefore, essential. Having escaped from the immediate area of the fire, it is not necessary for the person to come down to ground level straightaway, indeed, in some cases it will be safer to walk away from the fire at high level before descending to the ground. In short, the basic design principle for means of escape is to ensure all access & processing platforms to be linked and integrated so as to ensure individual have adequate paths of escape during emergency.

One factor which reduces the risk to life from heat and smoke in such interconnected spaces (the processing platforms are normally perforated or constructed with grating) is the increased chance of a person becoming aware of a fire in the early stages of its development, independent of the alarm being raised by others, where smoke and other products of combustion can pass upwards quickly through openings without initially threatening the escape routes.

Another that influences the means of escape provisions in such open structure plant is that only a small number of persons are likely to be present and they are able bodied and familiar with the premises. Upper levels are usually only visited occasionally by routine patrol (or to perform infrequent routine activities) or for maintenance purposes.

3.6.1 Escape Exits and Travel Distances

In general open process structure platform is provided with at least two escape paths, each with an exit staircase that such exits shall be sited at safest location and as remote as possible from one another, i.e. at least an escape route is not likely to be threatened by the same initial fire. The exits at ground level are preferably be sited at the perimeter of the open structure at extreme ends.

The type and number of escape exit of an open process structure platform will depend on travel distances. Travel distances are defined as the escape distance from anywhere within a platform to its nearest escape exit on the same platform; and the overall escape distance from anywhere within the platform to the ground level. These can be summarized as followings:

- Travel distance (A): Escape distance from anywhere within a platform to its nearest escape exit on the same platform, and
- Travel distance (B): Overall escape distance from anywhere within a platform to the ground level.

For normal and large open process structure platform with Travel distance (A) more than 12m or Travel distance (B) more than 15m shall require at least 2 escape staircases for each platform. Refer to the Table 3.2A "Maximum Allowable Travel Distance for Normal Platform" for the cap.

For small open process structure platform with Travel distance (A) less than 12m or Travel distance (B) less than 15m shall require one escape exits, in either escape staircase or cat-ladder. Refer to the Table 3.2B "Maximum Allowable Travel Distance for Small Platform" for details.

A Sub-Platform is a small open structure platform within a normal platform. Refer to the Table 3.2C "Maximum Allowable Travel Distance for Sub-Platform".

Means shall be provided to prevent scenario such as leakage, fire or explosion that will not affect or threaten more than one of such exits before personnel can evacuated safely at grad level. Consideration shall be taken that the exit at ground level be sited away from bund area or possible pool fire area. The plant owner shall conduct study that includes the surrounding structures on potential fire scenarios, their fire intensities, detection and alarm, emergency response, likely pool fire and drainage systems. Key consideration is the control of fire spread at ground level and the available of escape exits that are not threatened by the likely fire spread.

Maximum Allowable Travel Distance	
Travel Distance (A): Escape within platform to any one of the exit staircases.	Travel Distance (B): Overall travel distance from any point of the platform to ground level.
50m	100m

Table 3.2A: Maximum Allowable Travel Distance for Normal Platform

Maximum Allowable Travel Distance			
With one Escape Staircase		With one Escape Cat-Ladder	
Travel Distance (A): Escape within platform to any one of the exit staircases.	Travel Distance (B): Overall travel distance from any point of the platform to ground level.	Travel Distance (A): Escape within platform to any one of the exit staircases.	Travel Distance (B): Overall travel distance from any point of the platform to ground level.
12m	15m	9m	12m

Table 3.2B: Maximum Allowable Travel Distance for Small Platform

Maximum Allowable Travel Distance	
With one Escape Staircase	With one Cat-ladder
Escape distance from Sub-Platform to the next Platform Below.	Escape distance from Sub-Platform to the next Platform Below.
15m	12m

Table 3.2C: Maximum Allowable Travel Distance for Sub-Platform

Note:

- minimum width of staircase and cat-walk shall be 0.8m, and for cat-ladder, it shall meet MOM (Ministry Of Manpower) requirements;
- the same rules applied to pipe rack structures; and
- It is strongly advisable to provide photo luminescent marking/tap on all exits.

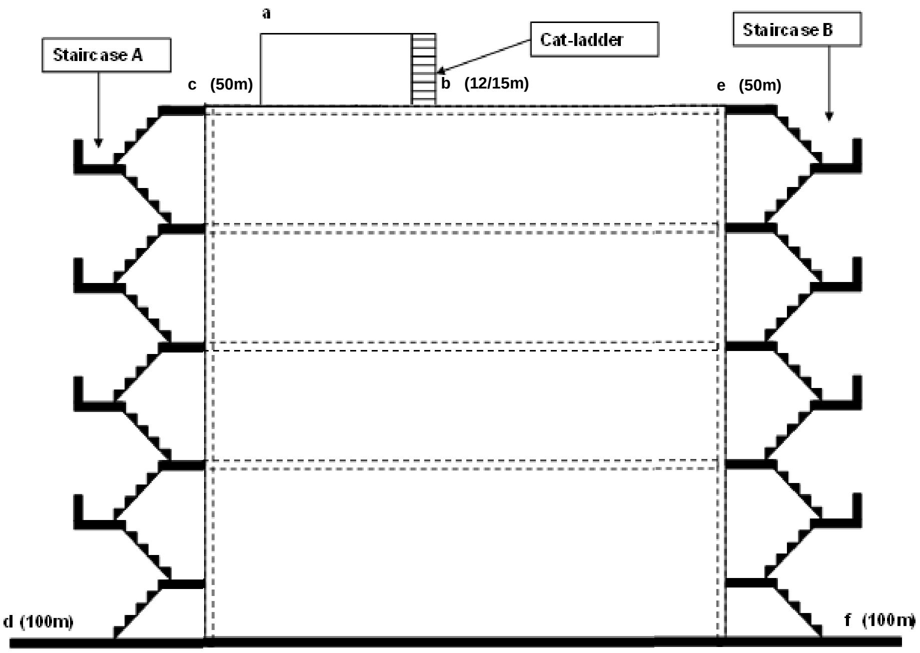


Figure 3.3 - Illustration of travel distance for process platform

Illustration Note:

1. Any point on sub-platform "a" to next level below "b", maximum is 12/15m;
2. Any point on platform or sub-platform, i.e. from “a” to “c” or “a” to “e”, maximum is 50m, and
3. Overall travel distance from any where on any platform to ground level, maximum is 100m.

3.6.2 Tall Free-Standing Structures

Tall vertical process equipment of plants such as columns and stills are isolated and free-standing and hence are deemed dead ends for means of escape purpose. Such process equipments are not frequently visited and it would not require alternative escape routes, even though the dead end travel distance may considerably exceed that given in the Table 3.2.

However, the basic design concept remained no change, i.e. to provide means to connect them together by walkway or catwalk so that alternative escape paths are always available.

In cases where such process equipment is frequently visited and the hazard does not support a relaxation of the travel distance and it is not reasonably practicable to provide an alternative escape route, other risk reduction measures such as modification to the plant to significantly reduce and ideally remove the need to visit the remote areas of the plant, while the hazard is present.

3.6.3 Assessment and Review

Not withstanding the recommendations as stipulated in the above, open process structure platforms should install with additional exits if possible.

Risk assessment shall be conducted to evaluate the location of exit staircases and escape routes are away from the potential fires and whether additional staircases, cat-ladders or interconnection of platforms (by walkway or cat-walk) should be provided.

3.7 Passive Fire Protection

3.7.1 Fireproofing

Fireproofing is a systematic process, including materials and its application, to provide a degree of fire resistance for protected substrates and assemblies.

The objectives of fireproofing are:

- To provide a temporary protection to the steel structures from the escalation of fires to an unacceptable level until full fire-fighting capabilities can be deployed to mitigate the fires.
- To provide plant equipment that must continue to operate during a fire, such as remote-operated emergency shut-off, depressurising valves and actuators and critical electrical and instrument cables, need fire proofing to stay operable for a defined period of time.
- To ensure that the fire proofing requirements integrate with drainage system.

3.7.2 Resistance Against A Fire

For companies that have established in-house fire brigade, a minimum of 60 minutes fire resistance against a process fire for steel structures in open plant structure shall be provided to ensure mechanical integrity. For companies without an in-house fire brigade, a minimum of 120 minutes fire resistance shall be provided. Longer fire resistance may be required depending on the type and function of plant equipment and risk factor.
The hydrocarbon fire test as defined in UL 1709 is applicable to all fireproofing systems provided on steel supports and structures within processing facilities. This fire is more severe than the cellulose type of fire which is usually referred to in building regulations. During the test, a protected steel column is exposed to a particular heat flux that produces a temperature of 1366.15 K (1093 ^{0}C). The test is terminated (failure point) when the average temperature of the steel substrate reaches 811.15 K (538 ^{0}C) and no thermocouple shall indicate a temperature greater than 922.15 K (649 ^{0}C) for the performance criteria.

3.7.3 High Fire Potential Equipment

The following examples are considered as high fire potential equipment:

- Pumps with a rated capacity over $34 m^3/h$ (150 gpm) handling light ends[1].
- Pumps with a rated capacity over $45 m^3/h$ (200 gpm) handling flammable liquids[2] or combustible liquids[2] at temperatures above or within 8 ^0C of their flash point (closed cup).
- Gas compressors over 150 KW (200 hp) handling flammable materials[3].
- Vessels, heat exchangers (including air-cooled) and other equipment containing flammable liquids at or above 588.15 K (315 ^0C), or above their auto-ignition temperature, whichever is less.
- Reactors that operate at or above 3448 KPa (34.48 Bar or 500 psig) pressure or are capable of producing exothermic or runaway reactions.
- Fired equipment, including heaters and furnaces that handle flammable materials that will ignite when released.
- Drums, exchangers, columns, and similar operating vessels that handle flammable materials and have a volume of more than 3.8 m^3 (1000 gallons) including their drainage paths.
- Plot-limit piping manifolds that contain flammable materials with ten or more valves.
- Tanks, spheres and spheroids that contain flammable materials including their drainage, relief path and impounding basins.

Note: [1] Light ends are flammable liquids having a Reid Vapor Pressure of 103 KPa (1.03 Bar or 15 psig) or greater.

[2] Flammable liquids are liquid with flash point below 311.15k (38 ^0C) and combustible liquids are those when they are handled at temperature above or within 8 degree C of their flash points.

[3] Flammable materials are flammable gases, hydrocarbon vapors, and other vapors, such as hydrogen and light-end hydrocarbon, including those mentioned in paragraph 3.3.7.1 (such as liquefied gases including refrigerant except bullet 4) and the above-mentioned note 1 & 2.. Such materials are readily ignitable when released to the atmosphere.

3.7.4 Fire Protection Zone

A Fire Protection Zone (FPZ) is a zone where there is a potential for causing process fire that steel supporting structures within the FPZ need to be fire proofed and it shall be designed with adequate drainage of potential spill of flammable liquids. A FPZ includes any of the following:

- The ground area within 9 m horizontally and 12 m vertically that contains a high fire potential equipment of a scenario of liquid fuel release.
- Elevated floors or platforms that could retain significant quantities of liquid hydrocarbons. Such elevated floors or platforms shall be treated as were on the ground floor level for calculating the vertical distance for fireproofing.

- The area within 9 m horizontally and from grade up to the highest level at which an aggregated volume of flammable or reactive/toxic materials storage from vessel(s) and equipment of more than 20 mM^3 is supported.

- The area within 9 m horizontally and 12 m vertically of the edge of an open drainage ditch that serves to transport spills from high fire potential equipment to a remote impounding basin.

- For rotating equipment, the 9m horizontal and 12 m vertical distance shall be taken from the expected source of leakage.

Figures 3.4 and 3.5 shown the necessary fire proofing for High Fire Potential Equipment and Non-High Fire Potential Equipment within Fire Protection Zone respectively.

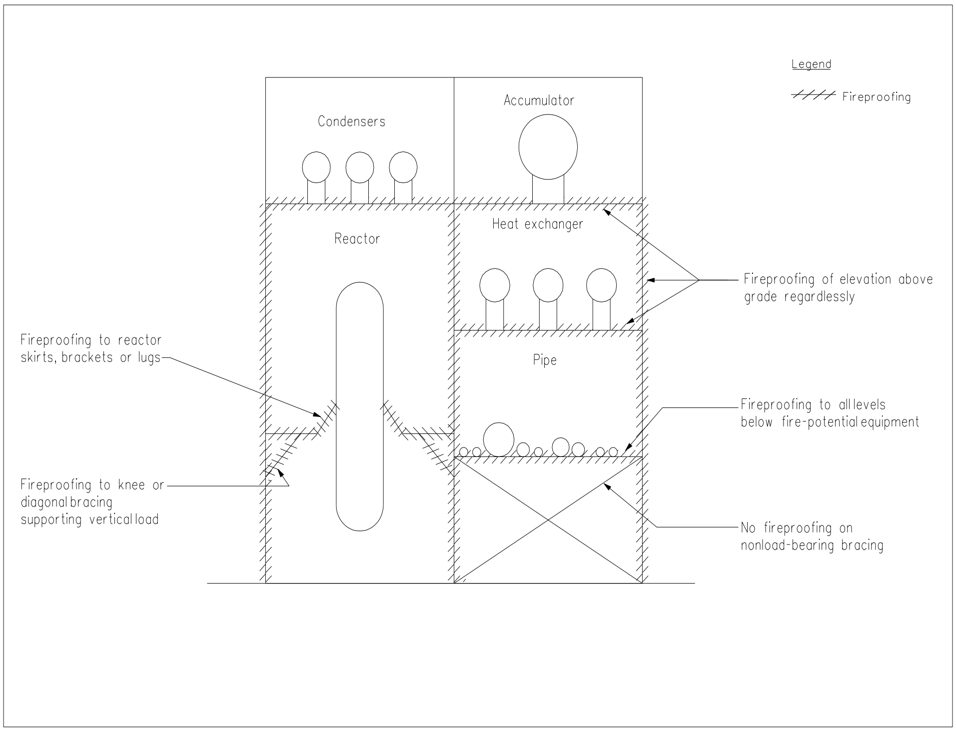


Figure 3.4: Structure supporting High Fire Potential equipment (having non-perforated platforms where spilled hydrocarbon can be accumulated)

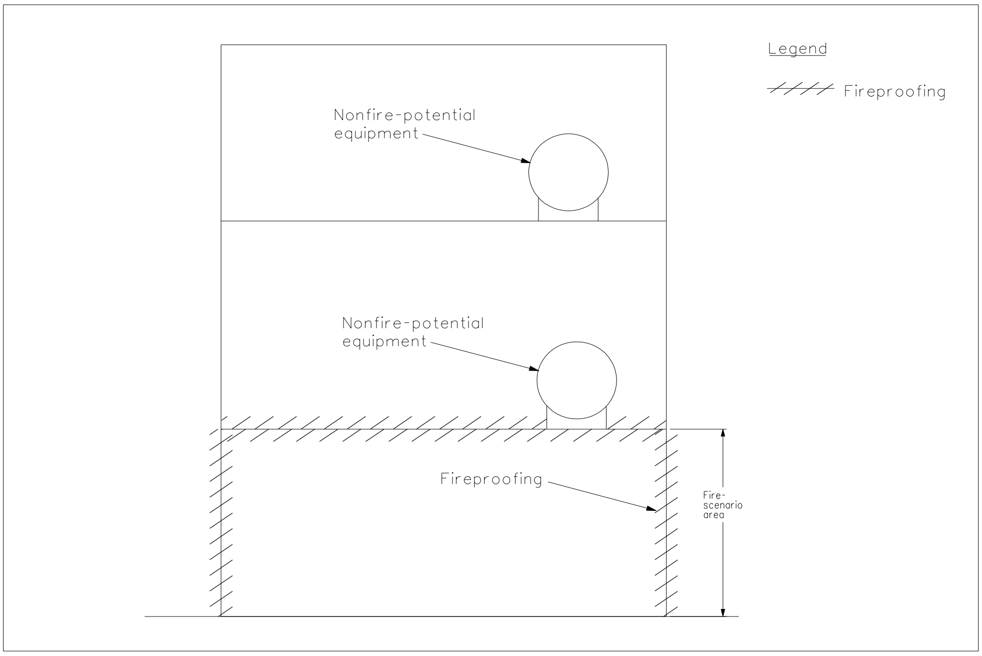


Figure 3.5: Structure supporting Non-High Fire Potential Equipment in a FPZ (having non-perforated platforms where spilled hydrocarbon can be accumulated)

3.7.5 Supports For Vessels, Including Pressure Storage Spheres and Shell and Tube Heat Exchangers

If a large structure supports vessels with diameters greater than 750 mm (30 in.), and the vessels contain flammable materials or combustible liquids, then those parts of the structure that support the vessels shall be fireproofed. This procedure shall be followed regardless of whether the immediate supports of these vessels (e.g. saddles) are fireproofed, according to Table 3.3 below.

When fireproofing of structural steel support members is required, the fireproofing shall cover:

(a) All columns, beams, saddles, struts and skirts.
(b) All bracing of members required for static strength or stability, up to and including those at the support level of the vessel.

Fireproofing shall not be required for bracing members that are intended solely as structural bracing for lateral loads (wind, earthquake or surge forces).

Fireproofing of supports for vessels, including pressure storage spheres, shall not cover any portion of the support where it is welded to the shell of the vessel. The maximum radial distance from the shell to the upper termination of the fireproofing shall be 300 mm (12 in.).

Structural steel support members for vessels, reactors, spheres, and heat exchangers containing flammable materials or combustible liquids, shall be fireproofed as indicated in Table 3.3 below. Examples of support members include columns, beams, saddles, struts, and skirts.

In some cases, vessels or exchangers are located on top of larger structures. These structures may fall, causing significant damage to other nearby equipment and contributing to the spread of the fire. Where such conditions exist, these structures shall be fireproofed from ground level to the highest vessel support level.

For horizontal vessels, fireproofing for immediate supports (e.g. saddles) are required only if the vessel diameter is >760 mm (>30 in.) and the support members are higher than 300 mm (12 in.) at the lowest point of measurement.

Equipment Type or Configuration	**Conditions Governing the Need for Fireproofing**		
	Location	**Service**	**Other Limiting Factors:**
Single horizontal vessel such as drum or shell and tube exchanger	Within process unit area	Flammable material	Fireproof supports if both of the following conditions exist: (1) Vessel diameter >760 mm (>30 in.) (2) Support members higher than 300 mm (12 in.) at the lowest point of measurement
	Outside process unit area	Flammable liquid only	
Stacked horizontal drums or shell and tube exchanger	Within process unit area	Flammable material	Fireproof supports to the bottom vessel and all intermediate vessels. Fireproof the supports for the top vessel only if both of the following conditions exist: (1) Vessel diameter >760 mm (>30 in.) (2) Support members higher than 300 mm (12 in.) at the lowest point of measurement
	Outside process unit area	Flammable liquid only	
Single vertical tower, drum, or shell and tube exchanger	Within process unit area	Flammable material	Fireproof all supports including inside of vessel skirts (not including vessel head).
	Outside process unit area	Flammable liquid only	
Any vessel or auxiliary equipment such as steam drums, waste heat boilers, and catalyst hoppers	Within process unit area only	Non flammable material	Fireproof supports if vessels or auxiliary equipment is located within a fire hazardous area if both conditions exist: (1) Vessel diameter >760 mm (> 30 in.) (2) Support members higher than 300 mm (12 in.) at the lowest point of measurement

Table 3.3: Fireproofing of Vessel Structural Supports

3.7.6 Support for Refrigerated Storage Tanks and Pressure Storage Spheres

Where fireproofing is provided for the supports of pressure storage spheres and foundations for storage tanks, and where such spheres/tanks contain liquids that auto-refrigerate upon release, such fireproofing shall be specified to withstand the anticipated thermal shock encountered following a spill.

3.7.7 Support for Fired Heaters and Associated Equipment

Structural members supporting fired heaters shall be fireproofed for heaters handling flammable materials or combustible liquids. Structural steel members supporting fired heaters in other services shall be fireproofed if located within a FPZ.

Fireproofing of fired heater supports shall cover support columns only. These shall be covered from the foundation to the bottom of the heater. Horizontal supports with a clearance of 300 mm or more below the underside of the heater floor shall be fireproofed.

Structural supports for elevated equipment associated with fired heaters, such as coke drums, transfer line exchangers, air pre-heaters, air inlet stacks, forced draft fans and ducts, shall be fireproofed if located with a FPZ.

3.7.8 Support for Compressors

Fireproofing of supports for elevated compressors shall cover columns and cross beams only. Such fireproofing shall extend up to and include the support level of the compressors.

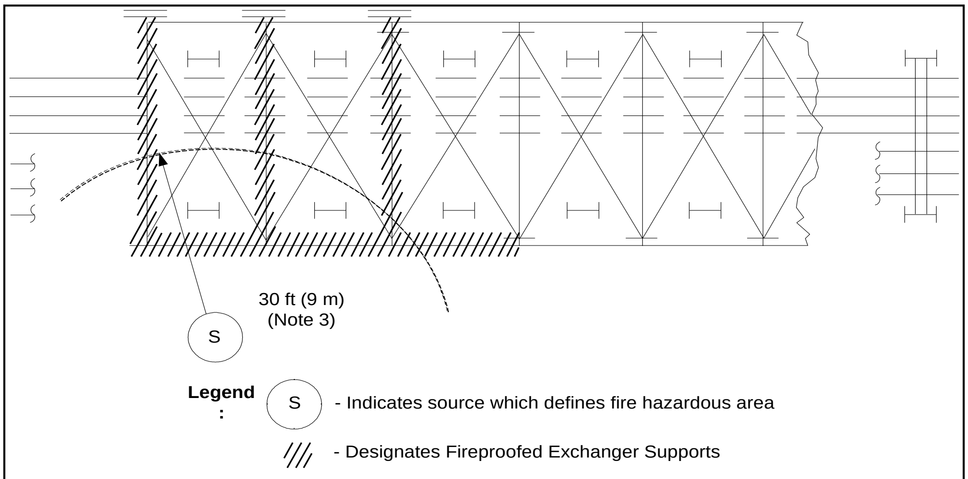
3.7.9 Support for Air-Cooled Heat Exchangers

Structural members supporting air-cooled heat exchangers shall be fireproofed as follows:

- If the structural members are within a FPZ (refer to Figure 3.6).
- If the exchanger unit is located above a vessel or equipment that contains flammable material (refer to Figure 3.7).
- All supports, when the exchanger handles flammable or combustible liquids that amount to greater than 15% of the exchanger volume and at an inlet temperature above auto ignition temperature, or above 588.15 K (315 ^{0}C), whichever is lower.

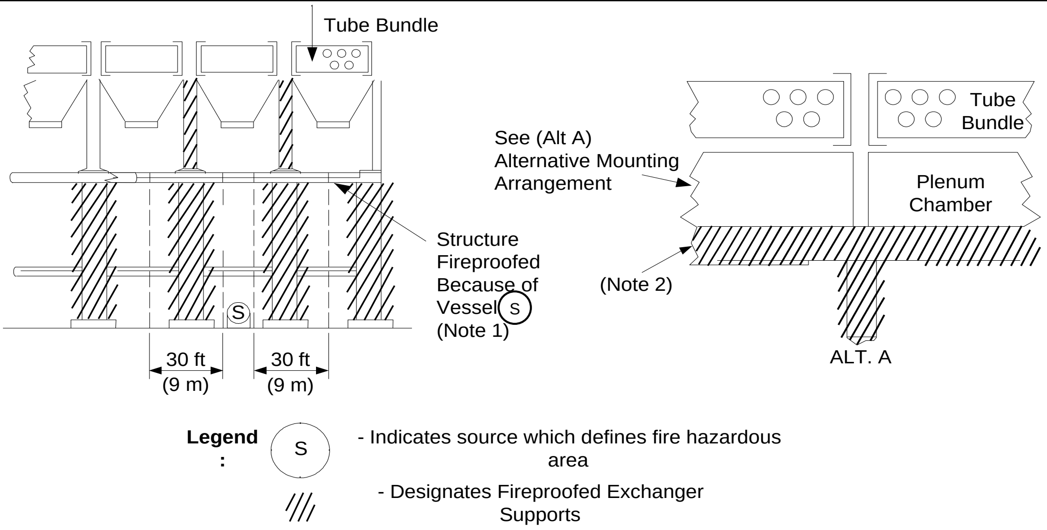
Fireproofing for air-cooled heat exchanger supports shall cover columns and cross beams.

- For induced draft units, the fireproofing shall extend upward to the support lever of the tube bundle.
- For forced draft units, fireproofing shall extend upward to the support level of the tube bundle or the fan plenum. (refer to Figure 3.7, ALT. A).



NOTES:
(1) Fireproofing of horizontal beams shall be carried to, and include the next supporting column.
(2) Exposed cross beams are to be fireproofed, bottom and two sides.
(3) 30 ft (9 m) is the horizontal distance measured from the nearest point of equipment with high fire potential

Figure 3.6: Fireproofing Structural Members supporting Air-cooled Heat Exchangers



NOTES:

(1) Fireproofing of horizontal beams shall be carried to, and include the next supporting column.
(2) Exposed cross beams are to be fireproofed, bottom and two sides.
(3) 30 ft (9 m) is the horizontal distance measured from the nearest point of equipment with high fire potential

Figure 3.7: Fireproofing Supports Air-cooled Heat Exchangers located above Other Equipment

3.7.10 Support for Pipe Racks and Piping

Pipe rack columns, cross beams, longitudinal support beams and other support members, which carry a direct pipe load, shall be fireproofed if:

- Flare line or an emergency depressurizing vent line within a FPZ.
- Pipe is carrying instrument air line or hydraulic control line whose loss would interfere with the ability to shut down the plant.
- Piping contains flammable materials, combustible liquids, or toxic materials and the pipe supports are located within a FPZ.
- Piping carries fire-fighting water and/or other utilities which would reduce the fire-fighting capability in the event of loss of support.
- Pipe supports are located within the spill containment area of a pressurized storage or refrigerated storage vessels. Fireproofing shall be designed to withstand the thermal shock encountered in a spill.
- Pipe supports are located beneath air-cooled heat exchangers which have their structural members fireproofed.
- Pipe that is connected to equipment which would be severely damaged in the event of loss of pipe support.

A “catch beam” (refer to Figure 3.8) shall be provided where all of the following apply:

- Piping is hung by rod or spring type connections from a pipe rack support member.
- Piping contains flammable materials, combustible liquids, or toxic materials.
- The rod or spring is in a FPZ.

The “catch beam” and its support members shall be fireproofed.
If pipe is hung by rod or spring type connections and such pipe is the only line on the pipe rack containing flammable materials, combustible liquids, or toxic materials; then pipe rack support members shall be fireproofed only to the extend that they support the “catch beam”.

“Dummy leg” pipe supports (refer to Figure 3.8) or equivalent structural members shall be fireproofed if:

- Such supports are attached to or resting on fireproofed members.
- Supported pipe contains flammable materials, combustible liquids, or toxic materials
- Failure of the supported pipe may damage other equipment that handles flammable materials, combustible liquids or toxic materials.

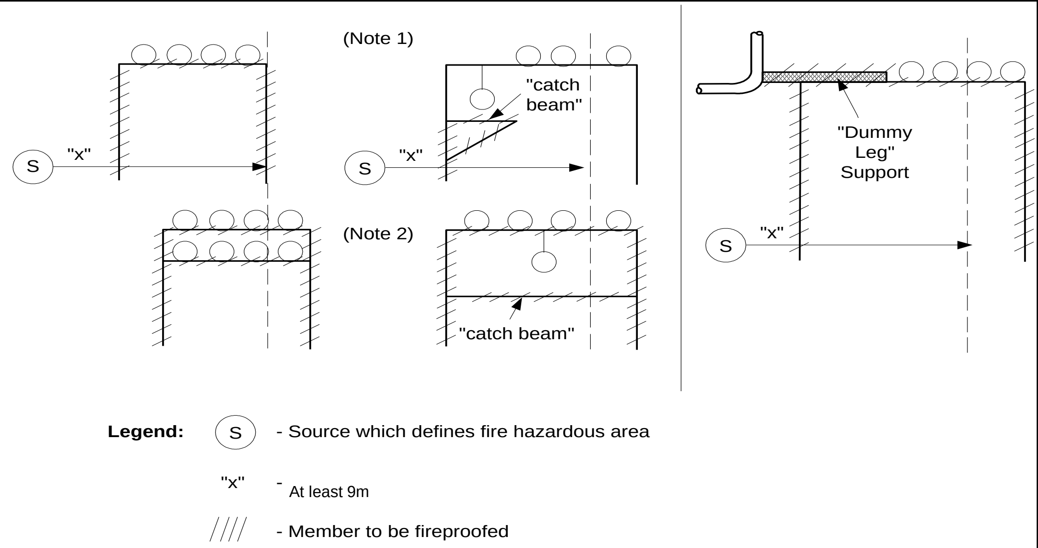
Frequently the layout of piping requires that auxiliary pipe supports be placed outside the main pipe rack. These supports include small lateral pipe racks, independent stanchions, individual T columns, and columns with brackets. Such members shall be fireproofed when all of the following apply:

- They are located within a FPZ.
- Support piping with a diameter greater than 75 mm.
- Support piping contains flammable materials, combustible liquids or toxic materials or important piping such as relief lines, blowdown lines, or pump suction lines from accumulators or towers, fireproofing should be considered.

Fireproofing for pipe supports shall be installed on the structural members supporting the pipe. Fireproofing shall not be installed on the pipe support shoes, or other direct attachments to the pipe. Fireproofing shall be installed in a manner that it would not impede possible thermal expansion movements of the supported piping.

The extent of fireproofing applied to pipe supports shall be governed by the following (refer to Figure 3.8):

- Fireproofing of columns and cross beam members shall extend up to the support level of the piping.
- Fireproofing of horizontal beams shall be carried up to and including the next supporting column.
- include long bolt flangeless valves on piping in combustible, flammable or high pressure gas service.



NOTES:

(1) Pipe hung by rod or spring type support is the only line on the pipe support, which contains flammable or combustible liquids, or toxic material.

(2) Other lines in addition to pipe hung by rod or spring contain flammable or combustible liquids, or toxic material.

Figure 3.8: Fireproofing on Pipe Supports

3.7.11 Fireproofing Requirements – Electrical and Instrumentation

Fireproofing shall be applied to electrical and instrumentation installations for the following systems that are within the battery limits for an onsite installation or within the FPZ.

3.7.11.1 Cabling

Critical instrument and power supply cabling serving safeguarding systems shall be installed in such a way that they are protected against direct heat radiation and flame impingement. If this is not possible special fire-resistant cables shall be used in accordance with UL 1709, i.e. able to withstand temperatures of at least 1366.15 K (1093 ^{0}C) for a period of 30 minutes.

3.7.11.2 Emergency Shutdown or Depressurizing System

A system that will shut down a plant or other facility under emergency conditions, either automatically or by remote push button; actuate remote block valves to stop the flow of flammable liquids or gases; stop heat input to process furnaces, boilers, or heaters; stop the rotation of associated machinery (especially pumps); or depressurize the equipment through a vent, if appropriate.

3.7.11.3 Emergency Isolation System

A system of remote-operated valves to isolate a piece of equipment or unit involved in a fire or other emergency, thus limiting the supply of fuel. This may be an individual pump, compressor, vessel, LPG sphere, etc., or it may encompass an entire area inside the plot limits of a plant or battery.

3.7.11.4 Critical Instrument or Electrical Cables

Cables or tubing associated with emergency shutdown, depressurizing, or isolation systems. These systems must maintain their operational integrity to facilitate safe unit shutdown.

3.7.11.5 Home Runs

Large groups of signal cables from the control house to the main junction boxes in the plant. Home runs are expensive to install and time consuming to repair. Their loss may cause damage to plant(s) outside the fire area as a result of loss of control.

3.7.11.6 Plot Limit Valves

The boundary valves for a plant area containing a complete operation or group of operations that may be shut down as a unit. These valves are used for isolation on turnarounds or fire emergencies. They shall have at least a 15m (50-foot) separation from other hydrocarbon-handling facilities.

3.8 Active Fire Protection

3.8.1 Active Fire Protection

The fire safety assessment shall determine the type of active fire protection system required against escalation of the fire for the process structure and facilities. An active fire protection system is a dormant system that requires to be activated in order to perform its function (e.g. water spray systems, deluge systems, sprinkler systems, fire-water monitors and steam rings around flanges). Such systems are activated once the information is received from the scene of the fire that protection is required.

3.8.2 Fire Water Supply System

3.8.2.1 General

The purpose of a fire water distribution system is to guarantee the supply of sufficient water for the prime purpose of fire control and possibly extinguishment, at the desired pressure in the required area.

Fire water should not be used for any other purpose. If under non-fire conditions the water mains system has to be used for service water, the take-off connection shall be of a size smaller than the nominal size of the hydrant valve and be provided with a restriction device or pressure reducing valve, to ensure that the required water flow can be supplied without causing the main fire-water pumps to start automatically as a result of pressure loss in the mains. Do provide the full details and consult the relevant authorities for further comments and concurrence.

3.8.2.2 Fire-Water Supply Quantity and Quality

Based on the fire scenarios both the required flow rate and duration of supply can be determined. Where possible, fire water should be supplied from open water, in which case the availability of the supply is unlimited.
To meet the fire-water requirements of a plant, fresh water with a low biological activity is preferred. Where the required quantity and quality are not available at acceptable cost, water storage facilities shall be provided.

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

In cases where the fire scenarios are not clear or where a longer duration fire cannot be excluded, a minimum of 3 hours uninterrupted water supply at maximum required rate shall be provided.

The installing of fire-water import facilities shall be considered. For instance, where reliable fire boats with sufficient pumping capacity are available they can be used to pump water into the fire-water distribution system (normally via a so-called “tugboat connection” at one or more jetties).

3.8.2.3 Fire-Water Pump Arrangement

Fire water is considered a vital utility for plant operation. Fire-water shall be provided by at least two identical pumps, each of which is able to supply the largest required flow rate to the fire-water ring mains system.

Another better alternative with higher reliability is the installation of three identical pumps, each able to supply 50% of the largest required flow rate.

The fire-water pumps shall be of the submerged vertical type if they draw from open water and of the horizontal type if they draw from a storage tank. The fire-water pumps shall be installed at a location which is considered to be safe in the event of fire anywhere in the plant, where it is unlikely to be engulfed in an explosive vapour cloud originating in the plant, and where it is unlikely to be damaged by collision with vehicles and/or ships.

For more detail of fire-water pump arrangement, refer to Singapore Standards SS 532.

3.8.2.4 Fire Water Distribution System

3.8.2.4.1 Fire-Water Ring Mains - General

Fire-water ring mains shall provide fire water at the required flow rate to all sections of the plant under all circumstances. In case there is a non-availability of a particular section in the fire-water ring mains distribution system, that shall not affect fire-water availability to anywhere in the plant. The ring main shall be provided with block valves so that sections can be isolated for maintenance.

Fire-water ring mains of the required capacity shall thus be laid to surround all processing units, storage facilities of flammable materials, loading facilities and stations of flammable materials for road vehicles, process filling facilities, tanker berthing area, utilities, process laboratories and plant control offices.

3.8.2.4.2 Fire-Water Ring Mains - Velocity and Pressure

The distribution system design shall provide for a maximum allowable velocity in the fire water piping of 3.5 m/s to prevent surging at these conditions.

The pipe sizes shall be calculated based on design flow rates at a pressure of 10 bar (g) at the take-off points of each appropriate section even if one of the supply sides has been blocked or is out of operation.

3.8.2.4.3 Fire-Water Ring Mains - Installation and Material Selection

To reduce the probability of losing the fire-water supply as a result of an explosion the fire-water ring main shall be laid underground within the 0.15 bar over-pressure contour in plant areas where explosions cannot be excluded.

As a general and conservative guideline, the fire main should be laid underground within a radius of 100 m from process plant equipment and pressurised storage tanks.

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

Good maintenance of the fire water mains is essential to prevent corrosion in the water mains.

3.8.2.4.4 Hydrants

Fire-water mains shall be provided with permanent hydrants, located in strategic positions around processing units/areas, loading/unloading facilities.

The hydrants shall be adequate in number spaced at appropriate distances of 80m and sized to give adequate cover to the process unit/area. Besides, the hydrants shall be sited at accessible location and at two sides of a process unit/area to allow fighting the fire from an upwind direction.

When selecting the type of hydrant coupling, consideration shall be given to the coupling type in use by SCDF.

3.8.2.4.5 Risers Stack

Riser stack system (either dry or wet system with standby fire horse) shall be provided for process unit with access platform more than 10m measured from the ground level. The landing valve with the standby fire hose shall be located immediately beside all the exit staircases and comply with The Fire Code.

The riser stack shall be considered for all level access platforms and the adopting of NFPA14 design concept (three types) is considered acceptable.

All breeching inlets shall be installed not exceeding 18m from the fire engine access road.

Isolation valve shall be provided and be sited at safe (away from area to be protected by such system) location when wet system is provided especially it is taped from the fire water ring main.

For those process plants less than 10m in height, beside the provision of portable fire extinguishers, it is strongly advisable to provide first-aid fire fighting measures such as the above-mentioned riser stack (i.e. to provide landing valves at strategic locations base on individual risk assessment) or hosereel, comply with NFPA 14.

3.8.2.4.6 Fire Foam/Water Monitors

Fixed manually adjustable and operated foam/water monitors with adjustable nozzles shall be installed at strategic points around and inside areas where fire hazards have been identified. The foam concentrate shall be placed beside the foam/water monitors for the purpose of foaming the required foam. In addition, portable foam/water monitors shall be provided.

The standard monitor has a water capacity of 120 m^3/h at a working pressure of 10 bar (g).

In congested plant sections where fixed ground level mounted water monitors may be less effective because of obstructions, elevated fixed adjustable water monitors operated manually from grade level may be used.

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

3.8.3 Exposure Protection Systems

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

Exposure protection can be provided by water spray systems, deluge systems or fire-water monitors.

3.8.3.1 Water Application Rates

Following are the recommended water spray application rate to the process equipment handling flammable materials in the event of fire:

3.8.3.1.1 Process Pumps

For process pumps, a rate of 40 l/min/m^2 of horizontal area shall be applied, while area extending 0.6m around the pump periphery, water shall be applied at a rate of 20 l/min/m^2 of horizontal area.

3.8.3.1.2 Compressors

For compressors, a rate of 40 l/min/m^2 of horizontal area shall be applied.

3.8.3.1.3 Vessels, Equipment, Structural Steel, Pipe Racks, Fin-Fan Cooler Etc

For vessels, columns and heat exchangers etc holding a liquid volume of 3.8 m^3 or more of butane or lighter products, the application rate shall be **10** l/min/m^2 equipment surface.
Wetting shall be provided up to a height of **12**m above the potential source of the fire. (**10** l/min/m^2 is a round up number and 12m is to be in lined with the FPZ).

3.8.3.2 Water Spray Systems

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

3.8.3.3 Automatic Water Spray - Deluge Systems

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

3.8.3.4 Water Drenching Systems

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

In cases where the tank cannot be wetted completely by the water drenching systems the system shall be combined with stationary fire water monitors or a dedicated water spray system for these areas.

3.8.3.5 Water Mist (Water Fog) Systems

Water mist systems apply water at a pre-determined application rate onto the equipment and the surrounding area. Water mist systems achieve their extinguishing power by the high momentum discharge of small water droplets. These systems discharge water, either under pressure or gas/air assisted, through small orifice nozzles. This produces a proportion of small droplets (typically 150 - 400 m) which can extinguish fires very rapidly by immediate vaporisation of the droplets. In view of the limited travel distance of the small droplets, a water mist system shall not be applied in spaces larger than about 300 m^3.

3.8.3.6 Water Curtains

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

3.8.3.7 Sprinkler Systems (Excluding Deluge Systems)

A wet-pipe sprinkler system is a permanently filled and pressurised water distribution piping system fitted with normally closed sprinkler nozzles.
Dry piped sprinkler systems can be used in computer installations where there is a need to prevent escalation from the computing facilities to other parts of the premises.
Design requirements shall be in accordance with NFPA 13 / CP 52.

3.8.4 Foam Spray System

The foam-water spray system shall consist of a simple foam induction unit distribution piping, and foam-water spray nozzles. The system shall be provided with local and remote (control room) operation.

The fire safety assessment shall determine the required foam-water application rate and duration. Typically, an application rate of 6.5 $dm^3/min/m^2$ for the floor surface area to be protected, maintained for duration of 30 minutes, shall be applied. Once the foam concentrate supply is depleted or switched off, the foam-water spray system shall continue to operate as a fire water spray system.

3.8.5 Dry Chemical Powder Systems

A number of dry chemicals can inhibit the oxidation process within the flame but they are only effective if applied in the diffusion zone of the fire. As such, it the dried powder extinguishing systems are only effective for small scare fire and those in enclosed or semi-enclosed spaces.

Dry powder systems shall be inspected and maintained by certified specialists

3.8.6 Gaseous Extinguishing Systems

The fire safety assessment shall determine the type of extinguishing agent, the spaces that will be protected by each system, and the method of activating the system. Only extinguishing agents which do not have a negative impact on the environment, non-toxic to humans and those who are not electrically conductive shall be applied in the systems. Gaseous extinguishing systems are only effective in enclosed or semi-enclosed spaces.

3.8.6.1 Carbon Dioxide Systems

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

3.8.6.2 Clean Agent Systems

Clean agents such as halocarbon agents have been introduced in response to international restrictions on the production and use of fire-fighting halons.

3.8.6.3 Inert Gas Systems

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

3.8.6.4 Steam Systems

Steam can be used to smother fires, to dilute gas/air mixtures in enclosed areas, to control flange fires in plants in hydrogen service and on equipment handling flammable products at or above their auto-ignition temperature.
Examples of fixed steam systems for these purposes are smothering steam systems on furnaces and boilers and steam ring systems on inaccessible flanges of plants in hydrogen service.

3.8.7 Fire Extinguisher

Portable fire extinguishers shall be provided to enable operating personnel to quickly attack small fires. They shall be located at process areas, berths, loading racks, pump areas, compressor houses, and similar facilities. Travel distance from the protected equipment to an extinguisher shall not exceed 15m (50 ft).

Three basic types of extinguishers are used:

- Dry chemical extinguishers (potassium bicarbonate powder pressurized with nitrogen) are provided for general use in process plants. They are suitable for flammable vapours 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. Carbon dioxide has limited effectiveness in the open, because of wind currents. Therefore, its use is normally restricted to 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.

The following shall apply in mounting hand-held fire extinguishers:
a) Mounted no more than 15 m from equipment or facilities being protected.
b) Located no closer than 5 m from high fire potential equipment.
c) Easily accessible.
d) Protected from moving equipment and mechanical or environmental abuse.

Wheeled dry chemical extinguishers (57 Kg type) shall be provided at loading racks and high risk process areas (normally one per process unit). Wheeled dry chemical extinguisher is particularly useful against running flammable liquid fires resulting from leakage or pipe fracture.

3.8.8 Detection and Alarm Systems

Detection and alarm systems provide prompt detection of a potentially hazardous condition. Prompt detection provides timely notification of personnel, activation of automatic fire suppression and control systems during the early stages of an incident, thereby minimizing the impact of the fire.

3.8.8.1 Means of Fire and Gas Detection

Fire and gas detectors can be classified as following four broad types:

- Smoke Sensing - These detectors respond to the presence of smoke particles. These detectors are primarily used indoors and in enclosed spaces.
- Heat Sensing - These detectors respond when the sensing device becomes heated to a predetermined level.
- Radiant Energy Sensing - These detectors respond to the radiant energy produced by burning substances. Fire detectors sense the radiant energy from open flames with background sunlight or ambient light. Spark/ember detectors sense sparks or embers in dark environments such as ductwork.
- Combustible Gas Sensing – These detectors respond to presence of combustible gases or vapour.

3.8.8.2 Fire Detection system

Fire detection system shall be installed as the first line of defence except for situation where the risk is solely from flammable gas leakage.

Fire detection system operates faster than the gas detection system. However both fire and gas detection system shall be considered if other flammable materials are present.

Automatic fire detection system linking up with the extinguishing system may be considered for particularly hazardous or remotely situated or unmanned facilities.

The recognised code of practice for detection and alarm system include Code of Practice 10, NFPA 72E etc.

3.8.8.3 Types of Detectors

3.8.8.3.1 Flame Detectors

<u>Ultraviolet (UV) and infrared (IR) flame detector</u> react to radiation emitted from the flame. They are located to "see" the flame directly and the detectors must be shielded from external sources to minimize false alarms. Their field of vision usually covers a larger area than heat detectors, but they do not detect a smoldering fire as quickly as some smoke detectors

<u>Radiant energy (flame) detectors</u> shall be used when there are multiple fire sources in an area. The flame detector covers a wide area and may be more economical than multiple point sources. Flame detectors also respond faster than heat sensing or smoke detectors. When rapid spread of a fire is expected, and automated response is required, the flame detector will provide faster response than the heat sensing device.

3.8.8.3.2 Heat Detectors

Heat detecting devices fall into two categories—those that respond when the detection element reaches a predetermined temperature (fixed-temperature types) and those that respond to an increase in temperature at a rate greater than some predetermined value (rate-of-rise types). Preferred types combine both the fixed-temperature and rate-of-rise principles.

Heat sensing detectors shall be employed when the potential source of the fire is well known.

Temperature sensitive devices shall be placed near each fire source. These heat sensing devices are usually not subject to false alarms. This makes them ideal for initiating automated responses to fires such as water deluge sprays.

3.8.8.3.3 Point Detectors

Point detector can be applied to specific locations where the likelihood of fire is higher. Pumps handling flammable liquids or liquids operating above their auto-ignition temperatures and exchangers operating above the process material auto-ignition temperature are possible point detector locations.

In certain cases air-pressurized, long-lasting, UV-resistant plastic tubes may be used as alternatives to traditional fire-sensing devices. The tubes are wrapped around the equipment they protect and, when they melt during a fire, the loss of their contained air pressure initiates an alarm. This type of fire-sensing device may be used, for example, in remote or congested areas, for pumps with liquids above their auto-ignition temperature, or for pumps utilizing dual sealing systems and meeting the criteria for possible monitoring due to fire potential.

3.8.8.3.4 Line Detector

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 likelihood. Equipment such as furnaces, long conveyor belts and switchgear 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 deluge systems.

Two systems that have been used are:

Pilot heads with a fusible plug are typically located 1.2-1.8 m from possible fire sources. The fusible plug can be selected to melt from 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, providing coverage for the whole area.

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

3.8.8.3.5 Fusible Detectors

Fusible links are made of low melting point materials designed to actuate fire protection systems fire doors etc as the fire melts the link. Fusible fittings that fit standard tubing systems are available as well. These fittings are filled with a low melting point material.

Fusible links shall not be covered or painted.

3.8.8.3.6 Smoke Detectors

Smoke detectors are usually employed only in confined spaces such as control house buildings or electrical substations.

Buildings with sub-floors containing cables are required to have separate detection zones above and below the floor. There have been numerous fires in electrical substations, despite proper electrical design. All new substations shall have smoke detection, tied to a central control house alarm. Smoke detection shall also be considered for retrofit of any existing substations. The large amount of electrical equipment in control house buildings is also a potential source of fire. Smoke detection is not employed in outdoor process areas because wind currents make detection unreliable.

There are two types of smoke detectors, ionization and photoelectric. Ionization detectors are usually preferred for electrical or high energy flaming fires, which generate small smoke particles, for example in control rooms and electrical substations. Photoelectric detectors are usually preferred for low energy smoldering fires. Additional detail on smoke detectors is available in NFPA 72.

3.8.8.3.7 Fixed Combustible Gas Detectors

Fixed combustible gas detectors sample the atmosphere continuously or periodically and give warnings if preset levels of combustible gas or vapor are present. The alarm signal may be located away from the sampling point, and usually is actuated at a concentration of 20% of the lower flammable limit.

Fixed combustible gas detectors are recommended only for locations that are partially or wholly unattended, locations where the consequences of an undetected leak may be serious and locations where required by the authority having jurisdiction.

Typical applications for fixed combustible gas detectors include:

- Air intakes for building pressurization systems and gas turbines. These detectors shall alarm at 20% lower flammable limit (LFL) and shut down the air intake at 60% LFL.
- Cooling towers to monitor for process exchanger leaks. (Other methods can be used also.)
- Pumps and compressor areas, particularly when enclosed.
- Activate traffic lights to instruct vehicle driver to stop engine running i.e. ignition source.

Routine inspection and testing of combustible gas detection systems is recommended as many flammable chemicals and solvents can poison detector elements. During the normal maintenance program, diffusion sensor head and flame arrestors should be remove and cleaned. The alarm set points and instrument calibration should be conducted periodically as per the manufacturer's instructions.

3.8.8.4 Fire Alarm

The type and design of a fire alarm, control, and annunciation system should be selected to best meet the needs of the facility. Facilities which have a central process control center may desire to have the fire detectors and alarms monitored there.

However, fire alarm systems and annunciators should remain separate and distinct from process controls. The primary location of the fire alarm annunciation/panel must be in an area continuously manned by attentive trained personnel to ensure prompt and adequate response to all emergencies. The fire alarm systems shall be linked to a Decentralised Fire Alarm Monitoring System (DECAM) company.

Audible forms of fire alarm signals should be distinguished from other alarms. In areas where audible alarms may be ineffective (background noise is excessive), emergency / strobe light with visual alarm shall be provided. In general, visual signals shall not be used in place of audible alarms. The intensity of the light shall be sufficient to draw the attention of people in the vicinity

3.9 Emergency Response

3.9.1 General

Process plant shall establish a Company Emergency Response Team (CERT) meeting the requirements of SCDF. Details of CERT requirements are available in SCDF internet website.

Process plant that has an established in-house fire brigade meeting following requirements could reduce the provision on fire resistance rating to its process plant structures.

3.9.2 Company In-house Fire Brigade (CFB)

The organization and capability of the Company Fire Brigade shall be based on the following site-specific factors:

- The size, location and complexity of the installation(s).
- Site criticality.
- Fire-fighting Strategy.
- The available plant manpower (on-shift and call-out).
- The role, technical capabilities (manual and mobile equipment) and expected response time of SCDF.
- Statutory requirements.
- Mutual aid arrangements with neighbouring companies.

3.9.3 Pre-Incident Planning

Pre-incident planning, which forms part of the site emergency plans, addresses the selection of likely and realistic scenarios. It assesses how quickly the personnel responsible for addressing an emergency can become aware of an incident, determines which operational actions are required to reduce the fuel feeding the fire, quantifies the vapour cloud or fire, sets priorities for fire protection measures and quantifies the required fire fighting capacities (equipment and manpower) to bring the incident under control in the most efficient and effective way. It further addresses the consequences of toxic product leakage and of contaminated fire water.

3.9.4 Facilities

3.9.4.1 Communication

The speed and effectiveness of the various actions to be taken are also dependent on the availability of a reliable communications system. This system serves to receive messages from the plant via telephone, radio and alarm systems. It is used to call out duty personnel, CFB, SCDF, the police and if necessary, ambulances. It is also used to activate key plant personnel.

3.9.4.2 Fire-Fighting Vehicles

The required number and capacity of the fire-fighting vehicles is based on the largest determined fire scenario, which dictates the foam generating capacity and the number of personnel available for fire-fighting operations.

Acquisition of a foam transport vehicle as well as a general purpose vehicle for transport of protective clothing, additional hoses, additional portable monitors and tools shall also be considered.

3.9.4.3 Mobile foam monitors

Adequate mobile foam monitors are needed to supplement the sub-surface and semi-sub-surface foam injection systems on fixed roof storage tanks in the event of a major fire and when fixed fire protection systems are damaged by explosion.

3.9.4.4 Fire Station

The provision of a fire station shall be considered to protect fire appliances and mobile fire fighting equipment from degradation due to exposure to the weather. There should be provision of maintenance workshop for fire-fighting equipment and storage space for fire-fighting agents e.g. foam compounds, dry chemical powder for fire-fighting purpose.

3.9.4.5 Fire Training

Fire-fighting training shall be given to CFB in handling flammable products. This training shall cover the use portable, mobile, fixed fire protection equipment and breathing apparatus. For process plant that handles toxic or corrosive chemicals, the training should expand to cover such emergency as well as including neutralizing and decontamination of the hazardous chemicals.

3.9.4.6 Other Requirements

The SCDF may impose additional requirements on CFB from time to time.

4. Quick Reference List

References

1. NFPA Handbook, Section 21, Chapter 6, Sixteenth Ed. 1986.
2. Lees, F.P., Loss Prevention in the Process Industry, Volume 1, Section 16.7, Butterworth & Co. Ltd, 1980.
3. Martinsen, W.E., D.W. Johnson, and S.B. Millsap, Determining Spacing by Radiant Heat Limits, 1987 API Meeting, Energy Analysts, Norman, Ok, 1987.
4. Cruice, W.J., NFPA Fire Protection Handbook, Sixteenth Ed. Section 4, Chapter 2, 1986.
5. Baker, et al., "Vapor Cloud Explosion Analysis," presented at the AICHE Loss Prevention Symposium, April 1994.
6. Seelye, Elwyn E., Data Book for Civil Engineers—Design, Volume One.
7. Handbook of Concrete Culvert Pipe Hydraulics, Portland Cement Association.
8. Design Data, American Concrete Pipe Association.
9. Water Control Federation Manual of Practice No. 9 or ASCE Manual of Engineering Practice No. 37, Design and Construction of Sanitary and Storm Sewers.

American Petroleum Industry (API)

API 2G	Production Facilities on Offshore Structures
API 2L	Planning, Designing and Constructing Heliports for Fixed Offshore Platforms
API 14C	Recommended Practice for Analysis, Design Installation and Testing of Basic Surface Safety Systems on Offshore Production Platforms
API 14F	Design and Installation of Electrical Systems for Offshore Production Platforms (included in the *Electrical Manual*)
API 14G	Fire Prevention and Control on Open Type Offshore Production Platforms
API 4322	Fugitive Hydrocarbon Emissions from Petroleum Production Operations, Volumes I and II (1980)
API 540	Electrical Installations in Petroleum Refineries (included in the *Electrical Manual*)
API 500	Classification of Locations for Electrical Installation in Petroleum Facilities
API 521	Guide for Pressure-Relieving and Depressuring Systems
API 752	Management of Hazards Associated with Location of Process Plant Buildings
API 2021	Guide for Fighting Fires In and Around Petroleum Storage Tanks
API 2218	Guideline for Fireproofing Practices in Petroleum and Petrochemical Processing Plants
API 2510A	Fire-Protection Considerations for the Design and Operation of Liquefied Petroleum Gas (LPG) Storage Facilities

API Guide for the Inspection of Refinery Equipment, Chapter XVI, Pressure-Relieving Devices

National Fire Protection Association (NFPA)

NFPA 10	Portable Fire Extinguishers
NFPA 11	Low Expansion Foam and Combined Agent Systems
NFPA 11A	Medium and High-Expansion Foam Systems
NFPA 11B	Synthetic Foam, Combined Agent Systems
NFPA 11C	Mobile Foam Apparatus
NFPA 12	Carbon Dioxide Extinguishing Systems
NFPA 12A	Halon 1301 Fire Extinguishing Systems
NFPA 12B	Halon 1211 Fire Extinguishing Systems

NFPA 13	Installation of Sprinkler Systems
NFPA 13A	Inspection, Testing, and Maintenance of Sprinkler Systems
NFPA 15	Water Spray Fixed Systems
NFPA 17	Dry Chemical Extinguishing Systems
NFPA 20	Installation of Centrifugal Fire Pumps
NFPA 24	Installation of Private Fire Service Mains and Their Appurtenances
NFPA 30	Flammable and Combustible Liquids Code (included in this manual)
NFPA 30A	Automotive and Marine Service Station Code
NFPA 45	Fire Protection for Laboratories Using Chemicals
NFPA 50A	Gaseous Hydrogen Systems at Consumer Sites
NFPA 58	Storage and Handling of Liquefied Petroleum Gases
NFPA 59	Storage and Handling of Liquefied Petroleum Gases at Utility Gas Plants
NFPA 68	Venting of Deflagrations
NFPA 69	Explosion Prevention Systems
NFPA 70	National Electrical Code
NFPA 194	Fire Hose Connections
NFPA 291	Fire Flow Testing and Marking of Hydrants
NFPA 321	Basic Classification of Flammable and Combustible Liquids
NFPA 325M	Fire Hazard Properties of Flammable Liquids, Gases and Volatile Solids
NFPA 496	Purged and Pressurized Enclosures for Electrical Equipment in Hazardous Classified Areas
NFPA 497A	Classification of Class I Hazardous Locations for Electrical Installations in Chemical Plants
NFPA 497M	Classification of Gases, Vapors and Dusts for Electrical Equipment in Hazardous Classified Locations
NFPA 505	Powered Industrial Trucks Including Type Designations, Areas of Use, Maintenance and Operation
NFPA 1901	Automotive Fire Apparatus
NFPA 1961	Fire Hose
NFPA 1962	Care, Maintenance and Use of Fire Hose
NFPA 1971	Protective Clothing for Structural Fire Fighting

Center for Chemical Process Safety (CCPS)

Chemical Process Quantitative Risk Analysis, 1989
Evaluating the Characteristics of Vapor Cloud Explosions, Flash Fires and BLEVES, 1994
Hazard Evaluation Procedures, 2nd Edition with Worked Examples, 1992

Canadian Standard Association (CSA)

CSA-C22.2 No. 30 Explosion-proof Enclosures for Use in Class I Hazardous Locations
CSA-C22.2 No. 157 Intrinsically Safe and Non-Incendive Equipment for Use in Hazardous Locations

Environmental Protection Agency (EPA)

Protocols for Generating Unit-Specific Emission Estimates for Equipment Leaks of VOC and HAP, 1987 (Document No. 87-222-124-10-02)

Underwriters' Laboratories, Inc. (UL)

UL 674 Safety Standard for Electric Motors and Generators for Use in Hazardous Locations, Class I, Group C and D, Class II, Groups E, F and G

UL 698	Standard for Industrial Control Equipment for Use in Hazardous Locations, Class I, Groups A, B, C and D, and Class II, Groups E, F and G
UL 844	Standard for Electrical Lighting Fixtures for Use in Hazardous Locations (Class I and II)
UL 913	Intrinsically Safe Apparatus and Associated Apparatus for Use in Class I, II and III, Division 1, Hazardous Locations
UL 1604	Electrical Equipment for Use in Hazardous Locations, Class I and II, Division 2, and Class III, Division 1 and 2
UL 1709	Standard for Rapid Rise Fire Tests of Protection Materials for Structural Steel

CUSA Standard Drawings

GB-128461	Deluge System
GA-128462	Spray System
GD-S99633	Hose Reels
GD-S99643	Fire Hose Box
GB-S1007	Fire Monitor

International Fire Service Training Association (IFSTA)

IFSTA 106	Introduction to Fire Apparatus Practices (available from IFSTA Headquarters, Customer Services, Fire Protection Publications, Oklahoma State University, Stillwater, OK 74078, Phone (405) 624-5723)

Occupational Safety and Health Administration (OSHA)
OSHA 29 CFR 1910.156, “Fire Brigades”

United Nations Environmental Programme (UNEP)
Montreal Protocol

American Society for Testing Materials (ASTM)
ASTM E-119, “Fire Tests of Building Construction and Materials”
PIPSTS03001, “Plain and Reinforced Concrete”

National Association of Corrosion Engineers
NACE RP 0198, “The Control of Corrosion Under Thermal Insulation and Fireproofing Materials—A Systems Approach”

American Society of Mechanical Engineers (ASME)
ASME Boiler and Pressure Vessel Code

Department of Transportation (DOT)
United States Coast Guard (USCG)33 CFR Part 154 Guidelines for Detonation Flame Arrestors

Underwriters Laboratories
UL525 Flame Arrestors