PROJECT REPORT

ON

DESIGN OF SPRINKLER AND TOTAL FLOODING SYSTEMS

Submitted by

NAVEEN C. BABU

M-TECH HEALTH SAFETY ENVIRONMENT

College of Engineering

University of Petroleum and Energy Studies

Dehradun

CERTIFICATE

This is to certify that the project report entitled **"Design of Sprinkler & Total Flooding Systems"** *submitted by* **Mr. Naveen C Babu** *of* **M-Tech Health safety & Environment** , *College of Engineering, University of Petroleum and Energy studies , Dehradun is part of his main project in the Forth semester for the partial fulfillment of the requirements for the curriculum.*

Dr N.A.Siddique
Project Guide
M-Tech Health safety & Environment
College of Engineering
UPES,Dehradun

Dr. B.P Pandey
Dean ,Collge Of Engineering
UPES,Dehradun

ACKNOWLEDGEMENT

*I hereby express my cordial gratitude to the management of G.T.I, NOIDA for providing me an opportunity to carry out a project titled **"Design of Sprinkler & Total Flooding Systems"**, in their esteemed organization.*

I thank Mr. R.K Jain (Sr. Manager,F&S) and Mr. R. Suresh (Excecutive Director, GAIL, India) for their boundless co-operation and help extended to me for this project.

I also thank all the staff of the library and fire lab for their immense co-operation and help they provided during my project.

I also express my gratitude to Dr B P Pandey (Dean College of Engineering) Dr Sharaf, Dr N.A Siddique (Course Cordinator M-Tech HSE), for giving kind support and valuable suggestions in the completion of this project.

CONTENTS

(Kamal Bansal)

(G.C. Tewari)

(Dr. N.A. Siddiqui)

INTRODUCTION

TO

SPRINKLER SYSTEMS

SPRINKLER SYSTEMS

Sprinkler systems are designed to automatically distribute water through sprinklers that are placed at set intervals on a piping system, usually in the ceiling area, to extinguish or control the spread of fires .Most sprinkler head detect the heat of fires and begin to apply water directly over the source of heat. Sprinkler heads unless deluge type heads are heat sensitive devices that react to fixed temperature and disperse water in a specific pattern and quantity over a set area. Sprinkler systems are highly effective .in fact some people describe benefit of sprinkler as similar to having a fire fighter constantly on duty in a protected building .The NFPA publishes standards for installation of sprinkler systems and their inspection and maintenance

Sprinkler systems were originally designed in the late 1800s to protect property, especially business and factories, from total loss from fires. They are 100% effective. The times when they do not work properly work usually involve human actions like improper maintenance or turning of the water supply etc....In the early 1900 ,the idea that sprinkler might be able to save lives was beginning to take place

Sprinkler systems are also not totally effective in life safety in some other types of fires. These include slow burning and smothering fires that produce huge quantity of smoke with out having much heat to activate the system, flash fires that rapidly engulfs a person, or a fire in the immediate vicinity of the victim where the fires inflicts the injuries prior to system activation. Another situation is one in which victims are disabled or unable to remove themselves from the fire area. Protecting against all situations is not possible but residential sprinkler system combined with an effective smoke detection system is very effective

Sprinkler head design and operation

Sprinkler or sprinkler heads are the key components of the system. Fig: 12-7.Most important is the heat sensitive parts that usually detects heat and apply water to the fire. Sprinkler systems must be appropriate in design and performance, orientation application or environment and temperature for the type of property to be protected

Sprinkler head comes in many designs and that affects their performance. One main difference is the old and the new sprinkler heads. Fig: 12.8 .Sprinklers designed up to 1950's are called old ones .They deflected the majority of the water to the ceiling to further break up its pattern. The effect was that the water was concentrated in the small area

The new style or the standard ones have a much more or even flow across the coverage area and do not bounce the water of the ceiling Fig: 12-8standard sprinklers are marked with SSU (standard sprinkler upright) SSP (Standard sprinkler pendent) on to the deflector. Orientation means up, down or side ways. Upright sprinklers have the head vertically above the piping with the deflector at the top, while pendants have the heads suspended below the piping with deflector at the lowest point, Fig: 12-9.The design of side wall sprinklers allows them to be placed them near the wall and although the

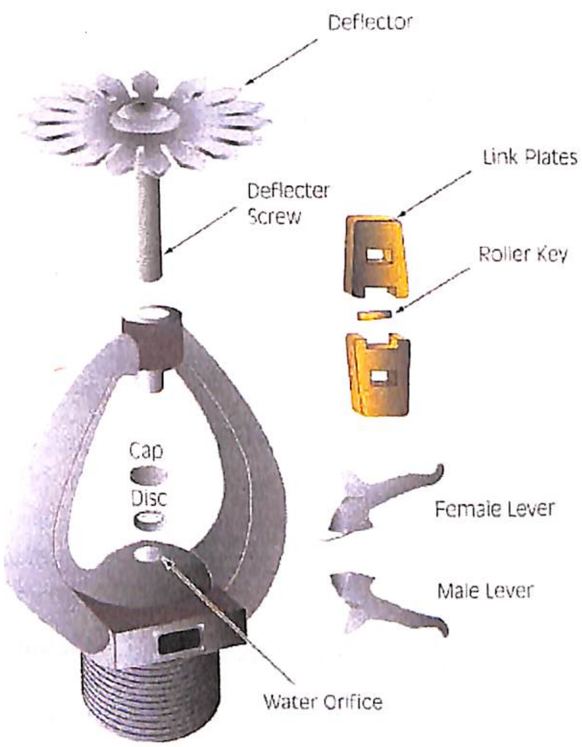


Figure 12-7 Sprinkler head parts.

deflector's looks bent, they provide the correct pattern. Side wall heads may be pendent, upright or horizontal. each must be properly positioned

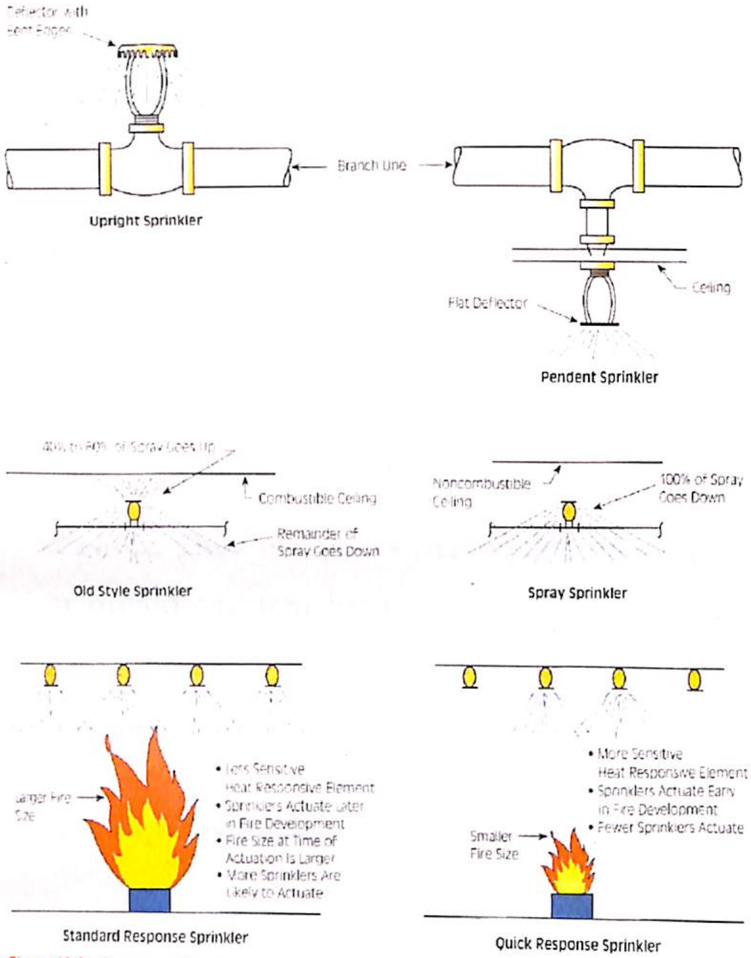


Figure 12-8 Sprinkler differences

Application and environment may require corrosion resistant head, special dry head with extension piping, rack storage head or decorative head. The orifice of the water opening varies from1/4 inch to 3/4 inch depending on the occupancy protected. Sizes other than 1/2and 17/32inch are noted on the sprinkler frame. Temperature ratings range from 135°F to an ultra high of 625 °F with the most common temperature being 165°F.

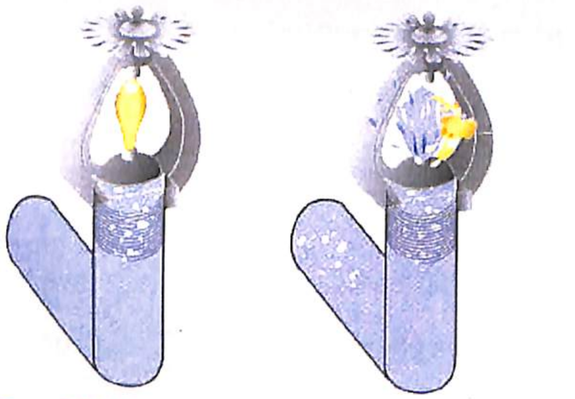


Figure 12-10 Sprinkler head closed and opened or operating.

The operation of sprinkler head begins with the fires heat raising the temperature of the sprinkler head and its fusible element to the fusing point. The fusible elements can be of three types .First is a fusible link that has a metal or solder that melts at fixed temperature. The second is a bubble filled with liquid leaving a small air bubble which expands and burst at a fixed temperature. The third type uses a chemical pellet which melts at fixed temperature. The fusible elements melts or bursts and the levers holding the cap then fall out. The caps pop out and the water flows striking the deflector and spraying in to the design pattern, Fig: 12-10.Another newer innovation is an on /off head that operates at a fixed temperature, but when the fire temperature drops, it operates a spring to close the water way and can reopen if the temperature rises again

Types of Sprinkler Systems

The four major types of sprinkler systems and the residential systems are discussed below. Specialty sprinkler systems include some combination type sprinkler systems and systems that cannot meet the standards for some reasons. They may have inadequate water supply or source or may be a partial or outside system Even if a system may not meet the standard completely, It provides a higher protection if no protection is available. Fire departments using special systems should become familiar with their limitations

Wet Pipe Systems

A wet pipe sprinkler system has automatic sprinkler attached to the pipes with water under pressure all the times, Fig: 12-11.This allows the quickest response when the head is opened. The wet pipe system is the simplest sprinkler system in design and operation. The main or alarm valve is the one way check or clapper valve that prevents the water from re-entering the water supply and when closed shuts off the water supply to the alarm line. Both sides of the alarm valve have pressure gauges that register the water pressure of the supply and the system. The system side gauge should read a slightly higher pressure, because the re closing of the clapper valve would trap any pressure surges .The alarm line piping usually have a retard chamber that usually prevent false alarms from a sudden pressure surge in the water supply, Fig 12-12..The chamber collects a small volume of water before allowing a continued flow to the alarm device. The water from surge is drained from small hole in the bottom of the collection chamber. A water flow indicator a vane or paddle in the waterway detects the water flow and activates an alarm signalling system.

A wet pipe system has three more valves. The first is the control valve, which is used to shut off the supply of water to the system and is usually an out side stem and yoke valve (OS&Y), Fig: 12-13.The second one is the main drain which allows the system to be drained for maintenance or to be restores from fire and the last valve is an inspector test valve. The test valve is at the farthest end of system and is used to stimulate the flow of a single head and to measure the response time of the system.

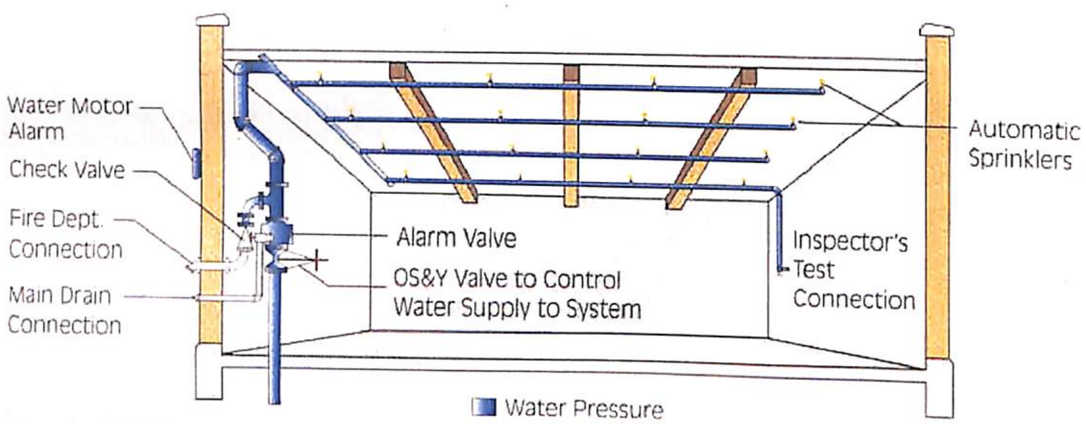


Figure 12-11 Wet pipe sprinkler system.

The operation of the wet pipe system starts with the fusing or bursting of the sprinkler head, which causes it to begin applying water tot fire. As the water pressure in the system begins to fall the main check valve opens and the water flows in to the system and the alarm line, filling the retard chamber and then activating the automatic alarm and the water motor gong. The alarm signal may be used to notify the fire dept: and the alarm company. After ensuring the fire is out or completely under control, the control valve is closed. Sprinkler maintenance personnel replace the head and restore the system. When the system is shut down the fire fighter with a radio is posted at the control valve and be ready to control the valve.

Dry Pipe Systems

In dry pipe system air under pressure replaces water to protect against freezing in cold conditions. The system uses a dry pipe valve to keep pressurized air maintained above with the supply water under pressure below the valve, Fig12-14; 12-15.A small amount of water at the seat of the valve called the priming water maintains the seal of the valve and is filled to the priming level. The clapper valve has a locking mechanism that keeps the clapper open until it is manually reset to prevent water columning

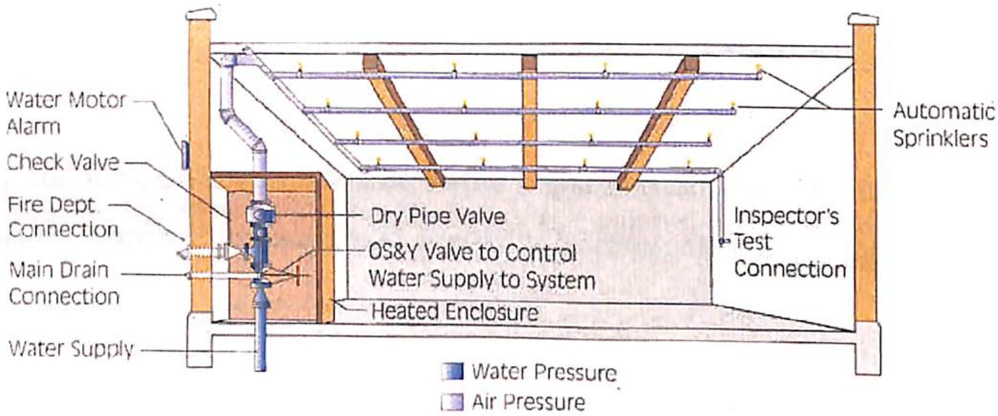


Figure 12-14 Dry pipe system schematic.

Dry pipe valves uses an air differential system having a smaller air pressure maintained over the larger head surface of the clapper valve, which keeps back the higher water pressure exerted on the smaller water side on the clapper valve. If water were allowed to fill the riser above the clapper, the water column weight will never allow the clapper to be forced open and make the system to be inoperative. When as sprinkler head is fused by heat air is first discharged. As the air pressure begins to drops below the supply water pressure, the clapper valve is opened and locked

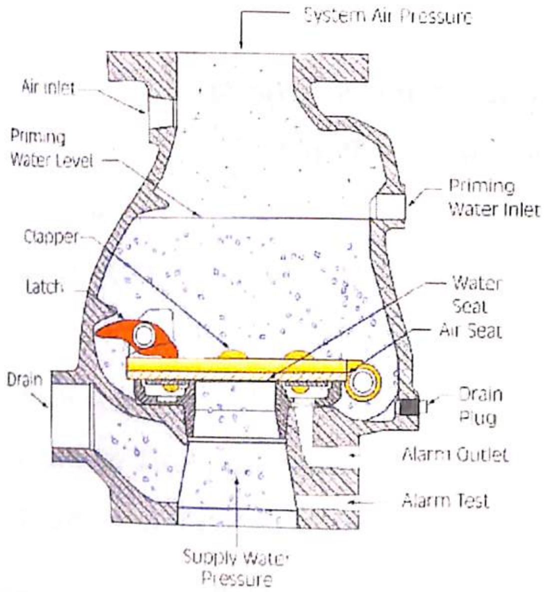


Figure 12-15 Dry pipe valve holds back the water with air pressure.

.because air is in the system rather than water, dry pipe systems are slightly lower to activate than wet pipe systems. Most systems either have an exhauster or accelerator to speed up the operation of the dry pipe valve. The exhauster detects the decrease in air pressure and helps bleed of air. The accelerator detects the decrease in air pressure and pipes air pressure below the valve, speeding its opening. Drain and alarm valves are similar to wet pipe systems. Dry pipe systems are used in unheated buildings, buildings that refrigerates or freeze materials and in outdoor applications where freezing temperature occurs, but the valve rooms must be heated. the dry pipe systems is more complex in design than a wet pipe system and also harder to restore because it requires a dry pipe valve cover to be opened after draining the system and resetting the lock on the valve. The valve is primed air pressure charged in the lines and the control valve opened carefully to prevent re tripping and creation of water column

Deluge Systems

Deluge systems are designed to protect areas that may have a fast spreading fire engulfing the entire area. All of its sprinkler heads are already open without any fusible elements in the head and when the system operates water flows to all heads, allowing total coverage. The system uses a deluge valve that operates when separate fire detection system senses the fire and sends a signal to trip the valve open, Fig: 12-16.some deluge systems uses foam instead of water. The valves trips open and water or foam flows through the piping and out all of the open sprinkler heads simultaneously. Because deluge systems are designed that's all the heads flow, the piping requirements are much larger than for other systems. Most deluge systems are such a size as to require fire pump supply the system with adequate volume and pressure. A foam system would also require a foam generation device. Deluge systems are also found in aircraft hangers, manufacturing facilities, petroleum handling facilities and other highly hazardous locations

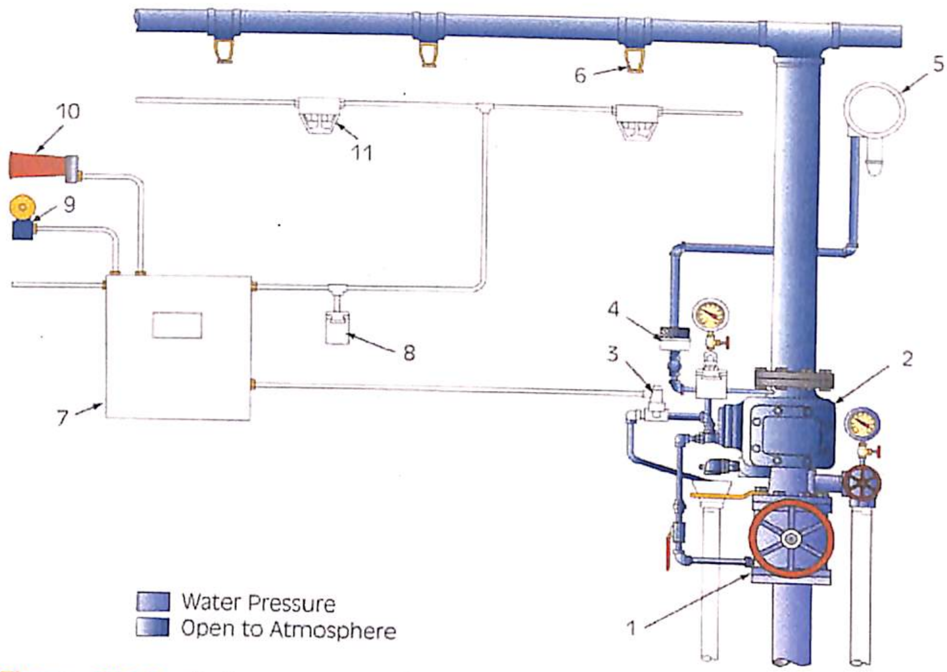


Figure 12-16 Deluge system schematic. 1, OS&Y valve; 2, deluge valve with basic trim; 3, solenoid valve and electric actuation trim; 4, pressure alarm switch; 5, water motor alarm; 6, spray nozzles or open sprinklers; 7, deluge releasing panel; 8, electric manual control stations; 9, fire alarm bell; 10, trouble horn; 11, heat detectors. *(Courtesy of Grinnell Fire Protection Systems Co.)*

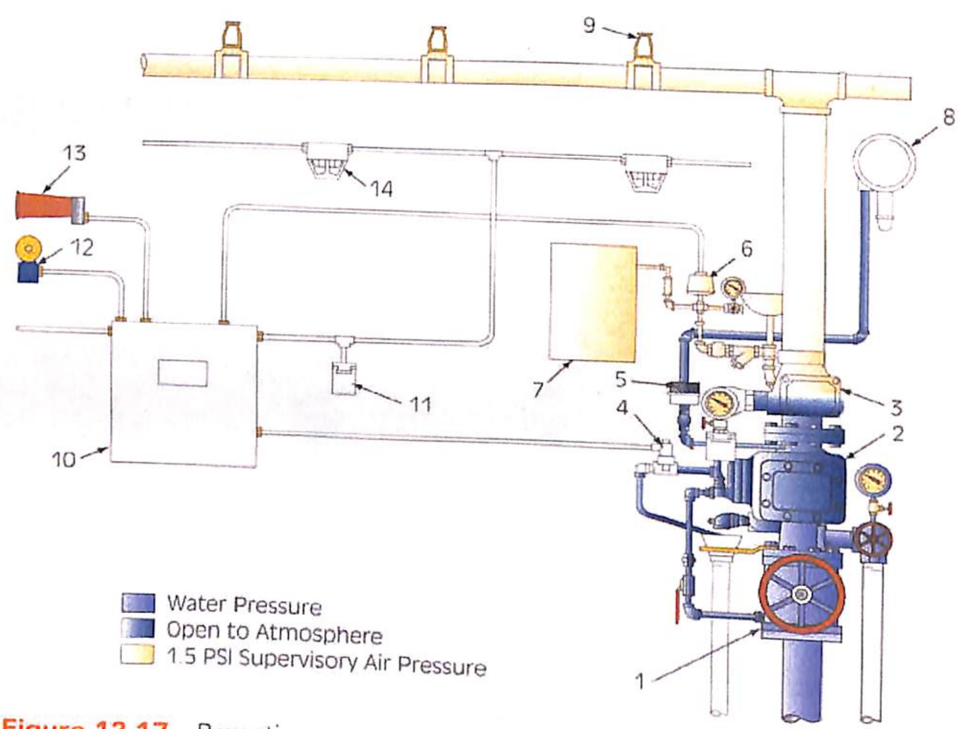


Figure 12-17 Preaction system schematic. 1, OS&Y valve; 2, deluge valve with basic trim; 3, check valve; 4, solenoid valve and electric actuation trim; 5, water pressure alarm switch; 6, 1.5-psi low air pressure alarm switch; 7, 1.5-psi supervisory air pressure control; 8, water motor alarm; 9, automatic sprinklers; 10, deluge releasing panel; 11, electric manual control stations; 12, fire alarm bell; 13, trouble horn; 14, heat detectors. *(Courtesy of Grinnell Fire Protection Systems Co.)*

Preaction Systems

Pre action systems are similar to dry pipe and deluge systems. the system has closed piping and heads with air under no or little pressure, but water will not flow until signalled open from separate fire detection systemFig:12-17.The preaction valves then opens and allows water to flow through the systems to the closed heads when an individual head is heat activated .it opens and water attacks the fire. Preaction systems are used in areas where the material protected are of high value and water damage would be expensive such as computer rooms and, historical items

Residential Sprinkler Systems

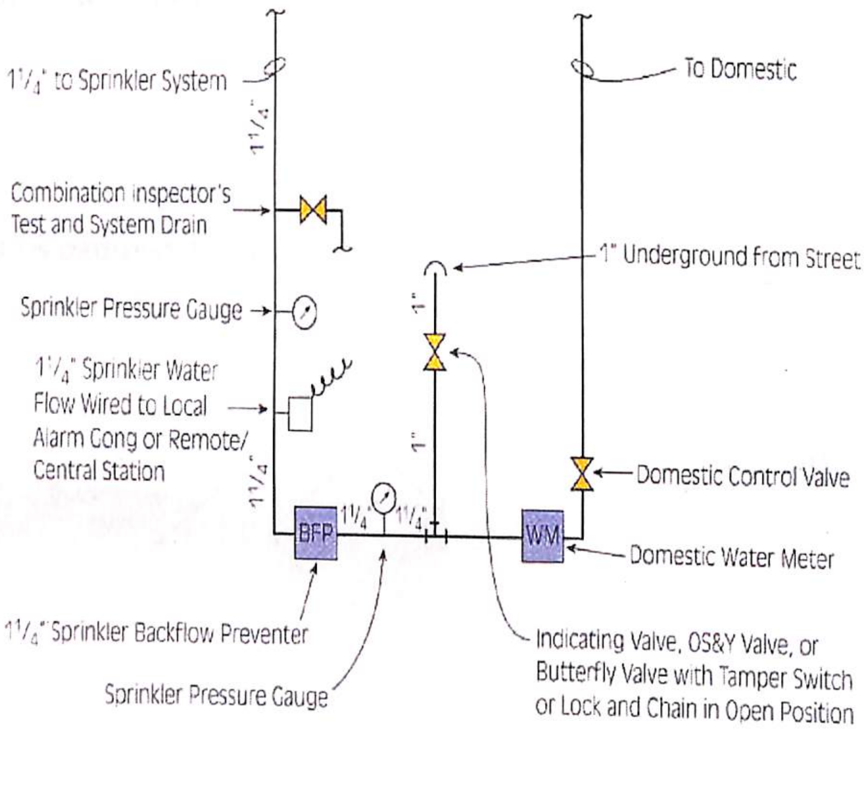


Figure 12-18 Schematic of residential sprinkler system.

Residential sprinkler systems are smaller and more affordable versions of wet or dry pipe sprinkler systems Fig: 12-18.They are designed to control the level of fire involvement so that the residents can escape . The water supply is combine with domestic water supply and the flow rates are designed for one or a few heads in operation. They have fast response time and use a lighter or smaller pipe than wet or dry pipe systems and were the first to use plastic piping. Residential systems use a check valve, water flow arms and drains similar to the bigger systems and are not required to have a fire department connection although some do have one .some residential systems use anti freeze to protect all or part of system

Sprinkler System Connections and Piping

The connections and piping for a sprinkler system provide the water from its source to the headstand they comprise most of the system. The main water supply can come from a public or private water company, the protected property's own supply system, a variety of tanks such as gravity or suction, or a cistern, pond, or stream. Depending on the requirements system and the water source, a fire may be included. A secondary water source is a fire department Siamese connection, which allows pampers to supplement the water supply, Fig: 12-19.

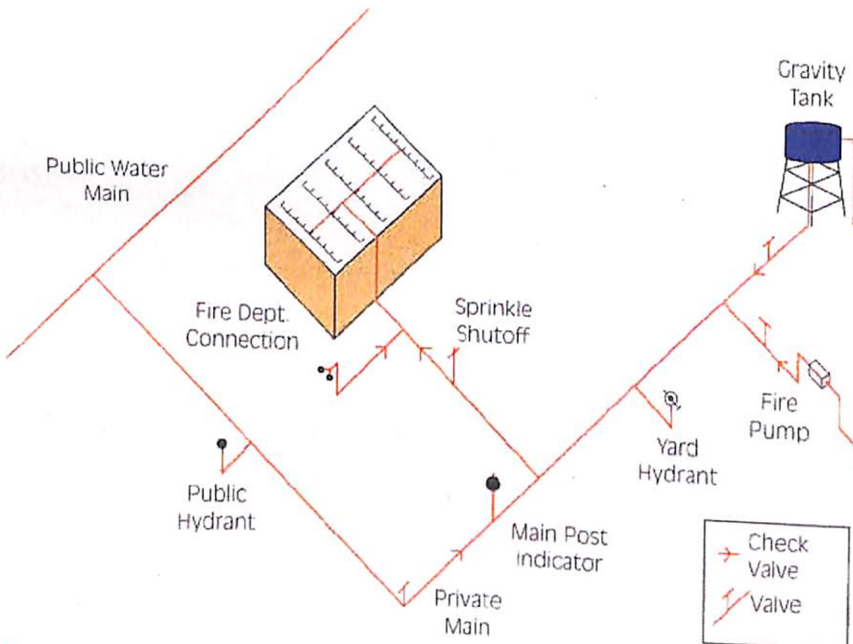


Figure 12-19 Various water supply systems to a sprinkler system.

Try to use a different water main or supply source than the one being used by the sprinkler system. The fire department connection is usually supplied piped in past the main control valve and can supply the system even if the main control valve is closed.

Another required valve in most systems is a back flow preventer, a set of one way check valves designed to keep water in a sprinkler or other system from re-entering the public water supply. These are an environmental requirement and most codes require and mandate them even on old systems. The system may have other control valves and check valves and will have a water control valve if connected to a public water supply.

Next inline is the main control valve which is wet, dry, deluge or preaction valve and above that is the riser. The riser pipe feed s the main that feeds the cross mains to the branch lines, Fig: 12-20.The branch lines have the sprinklers attached to them. Some larger systems have sectional valves that divide the systems in to sections or sub areas. The location of these valves may be important when shutting down the system or doing maintenance. They should be kept locked and supervised for tampering. Tamper alarms alert the company whenever someone operates the valve unauthorized valve operations can be easily checked to prevent an arsonist from disabling the system prior to setting a fire

Control Devices for Sprinkler Systems

The three main control devices for sprinkler and standpipe systems are the outside stem and yoke valve (OS&Y), the Post indicator valve (PIV), and the wall indicator valve (WIV) Figs: 1221,22,23.

Figure 12-12 Retard chamber.

Figure 12-13 OS&Y valves chained in the opened position.

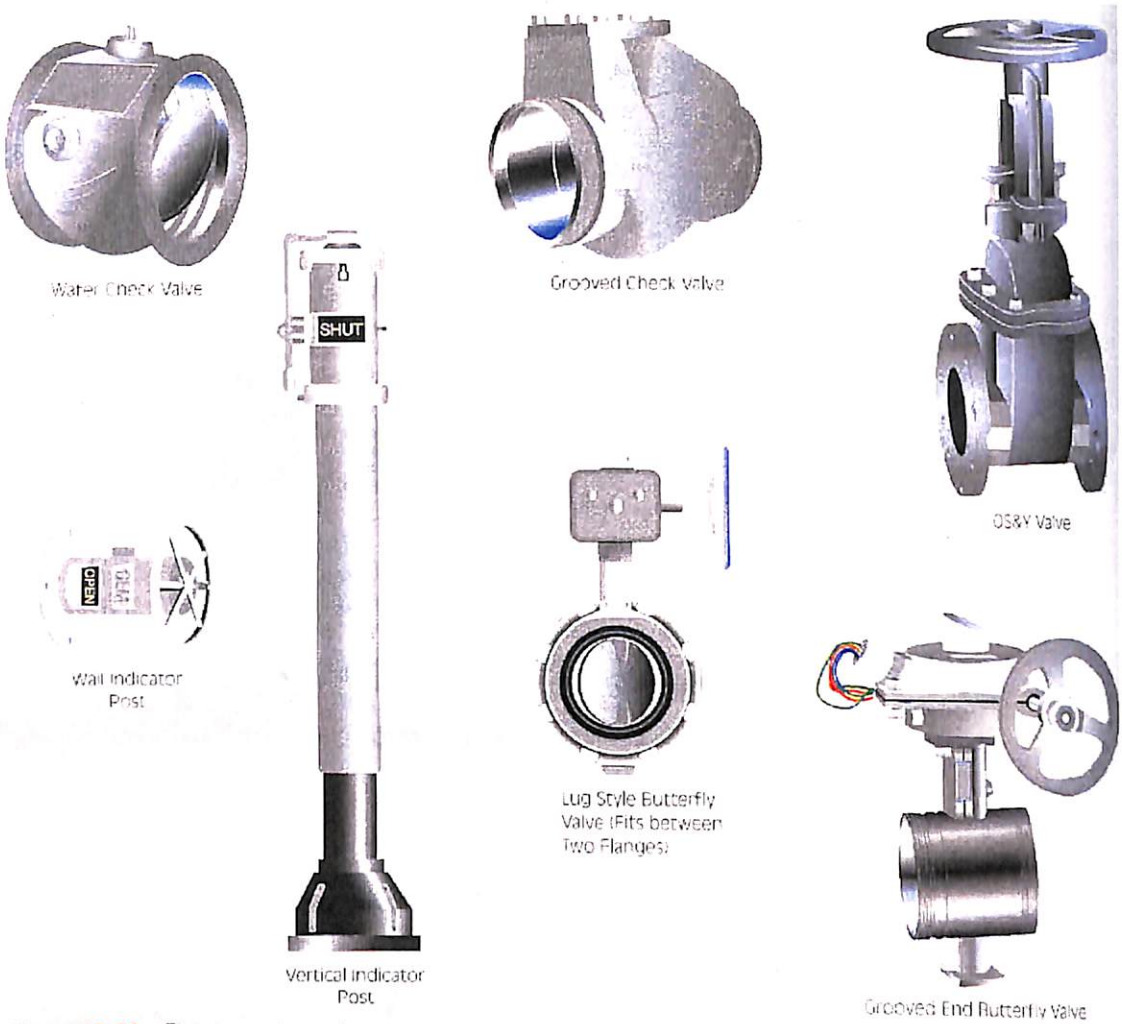


Figure 12-22 Fire protection valves.

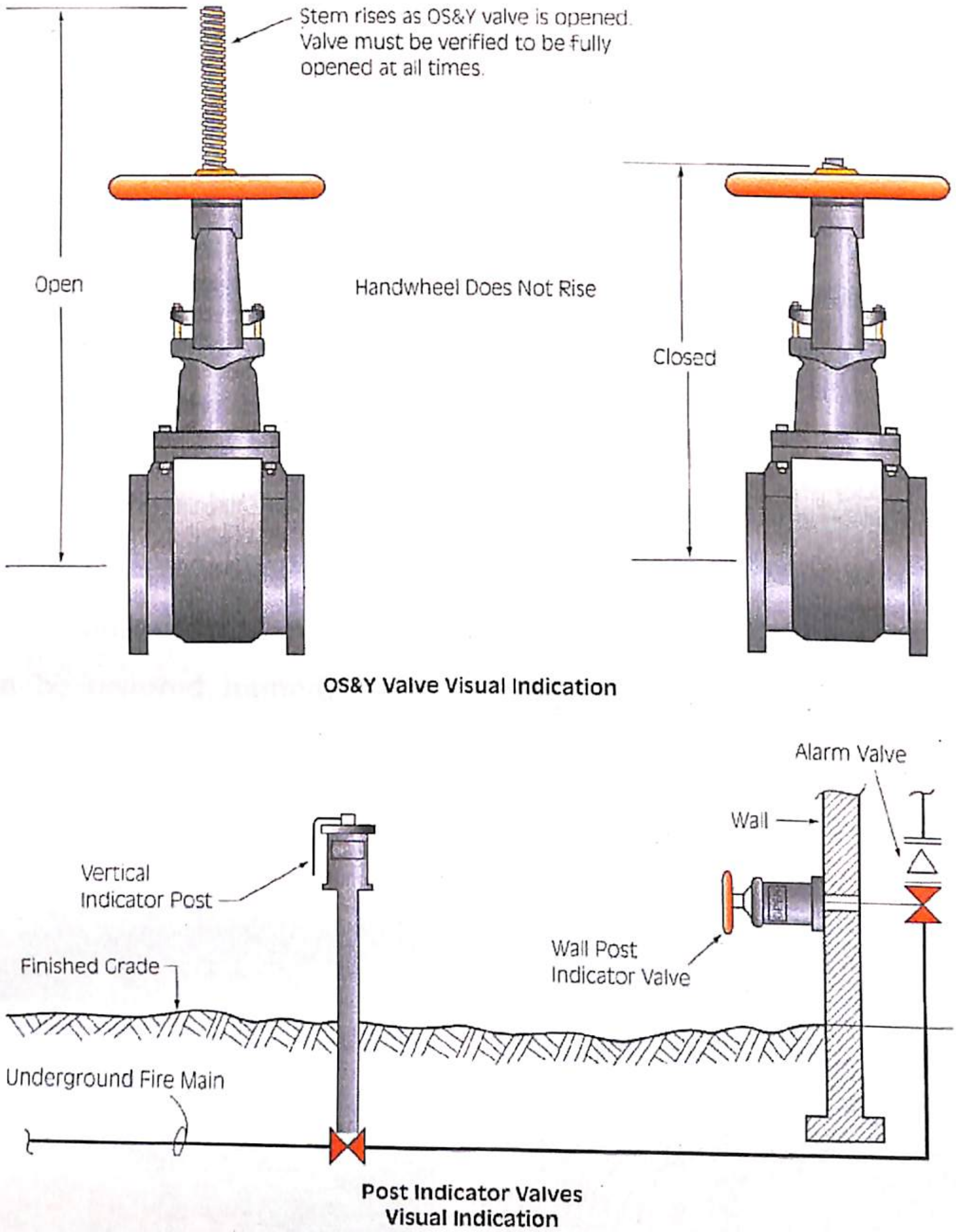


Figure 12-21 OS&Y valves and post indicator valves.

The valves have either a butterfly or gate valve type. The names come from the appearances of the valves. The OS&Y valve has awhile on stem housed in stoke or housing. When the stem is exposed or outside, the valve is open. These valves have a chain lock on them to prevent tampering and if the system is supervised a tamper switch is also found on the stem. PIV and WIV are also

Similar but one is mounted on post in the ground and others are mounted on a wall. Both valves are housed in a metal case with a small window, reading either "OPEN" or "SHUT". A wrench or steel controls the valves: a padlock and chain are used to lock them opened. Some water control valves are also of non indicating type

Restoring Sprinkler Systems To Service

Fire fighters must understand how to properly shutdown individual heads or entire systems to stop excessive water damage until the heads can be completely restored

When the fire is out first is to shut down any pump supplying water to the system. do not disconnect the hose lines at this point because the fire may reignite, so hose lines should stay until overhaul is completed If the system have to be restored immediately or a large number of sprinkler heads are opened either the main sprinkler valve or the sectional valve has to be shut down and drained. The sprinkler heads is to be replaced with the similar ones

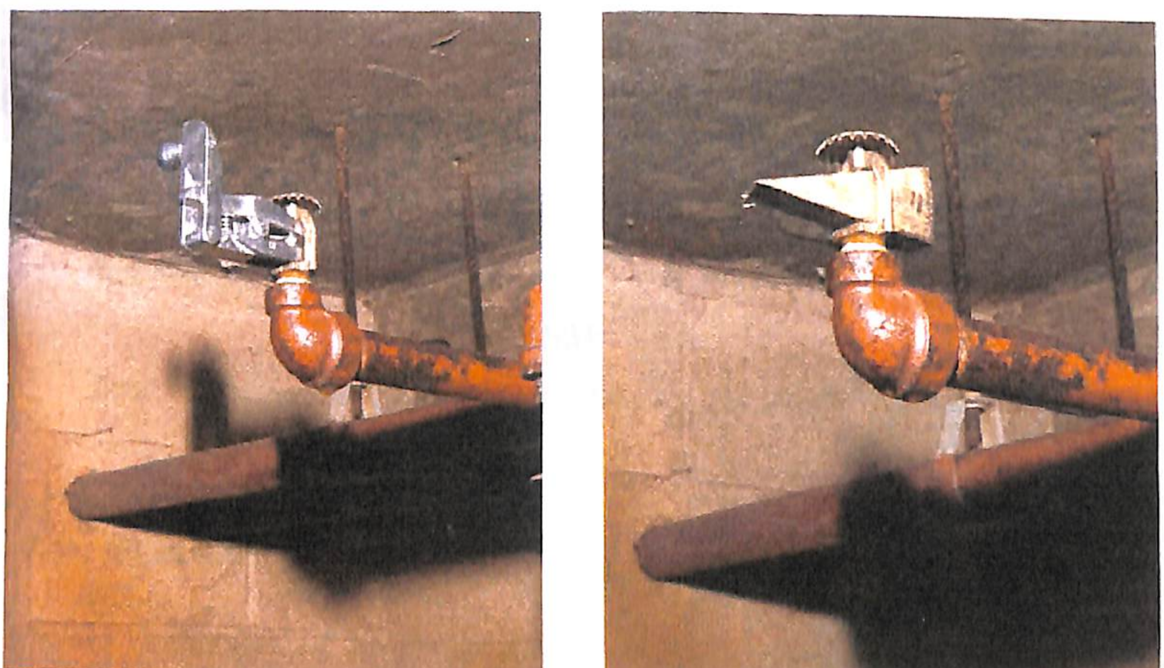
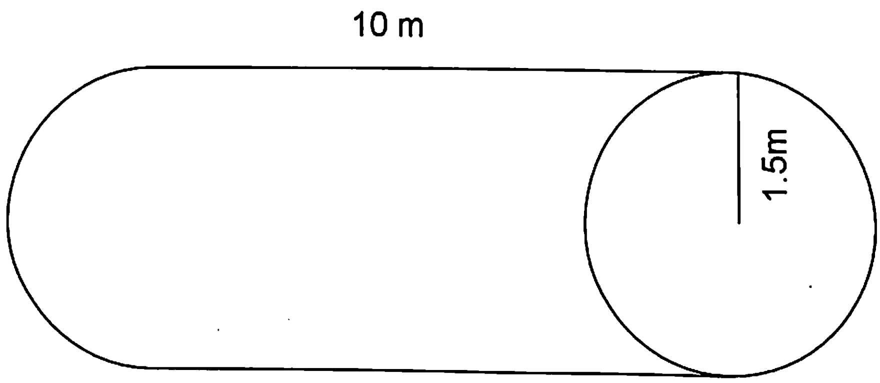


Figure 12-25 Sprinkler tongs and wood wedges stopping sprinkler flow.

The simplest way to stop a sprinkler flow is to insert tongs, wooden wedges or dowel rods between frame and orifice of the head, sealing off the water flow Fi: 12-24, 25.proper placement of seal will guarantee a good seal and no leakage. It is most often done prior to the system being shut off or completely drained to prevent more damage; the other ways to stop the sprinkler is the shut of the main valve or the sectional. Once system is shutdown and drained the heads may be replaced. The fire department can also request a fire watch until the system is back in operation.

Sprinkler Design for LPG Bullet at Training Ground



Dimensions of LPG Bullet

Lateral surface area	=	$2\pi rh$
r	=	1.5 m
h	=	10m
	=	$188.4m^2$
End surface area	=	$2\pi r^2$
	=	$56.52m^2$
Total surface area	=	$188.4 + 56.52 = 244.92m^2$
	≅	$245m^2$

Water requirement

10.2 L/min- m^2 is the water application rate to the surface for cooling as per NFPA AND OISD standards

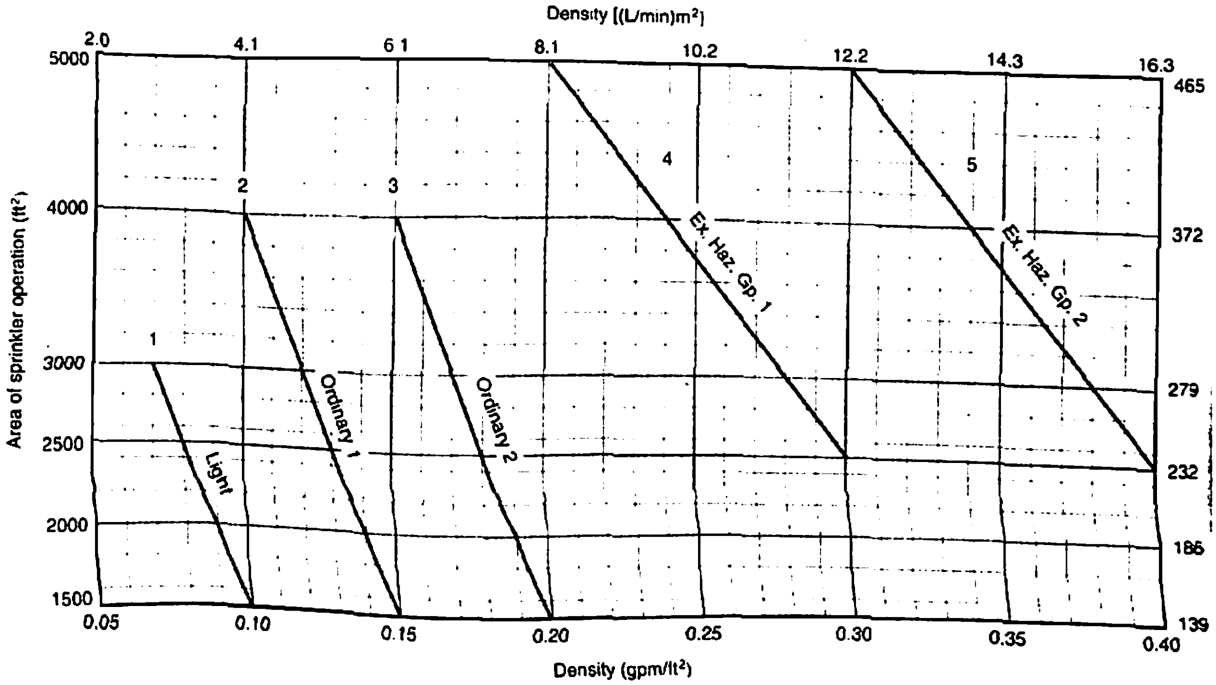


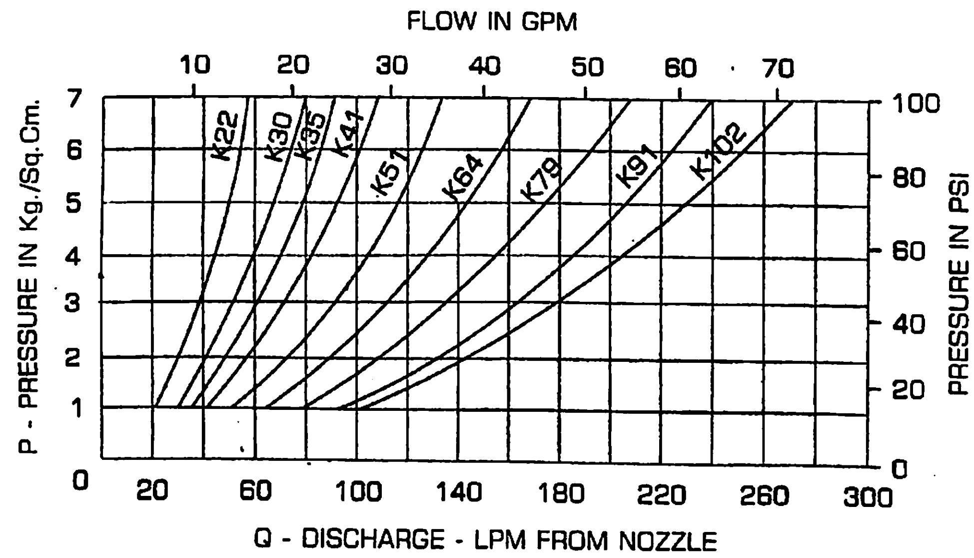
FIG 6-10R. Area-density curve.

For cooling the total surface area the quantity of water required = 10.2 L/m-m² × 245m² = 2499 L/min

≅ 2500 L/min

Amount of water required for 4 hour continues application = 2500 L/min × 4 × 60 = 600,000 L/min

The water discharge pressure is taken as 3.2 Kg/cm² as per OISD standards (to get a water mist atmosphere)



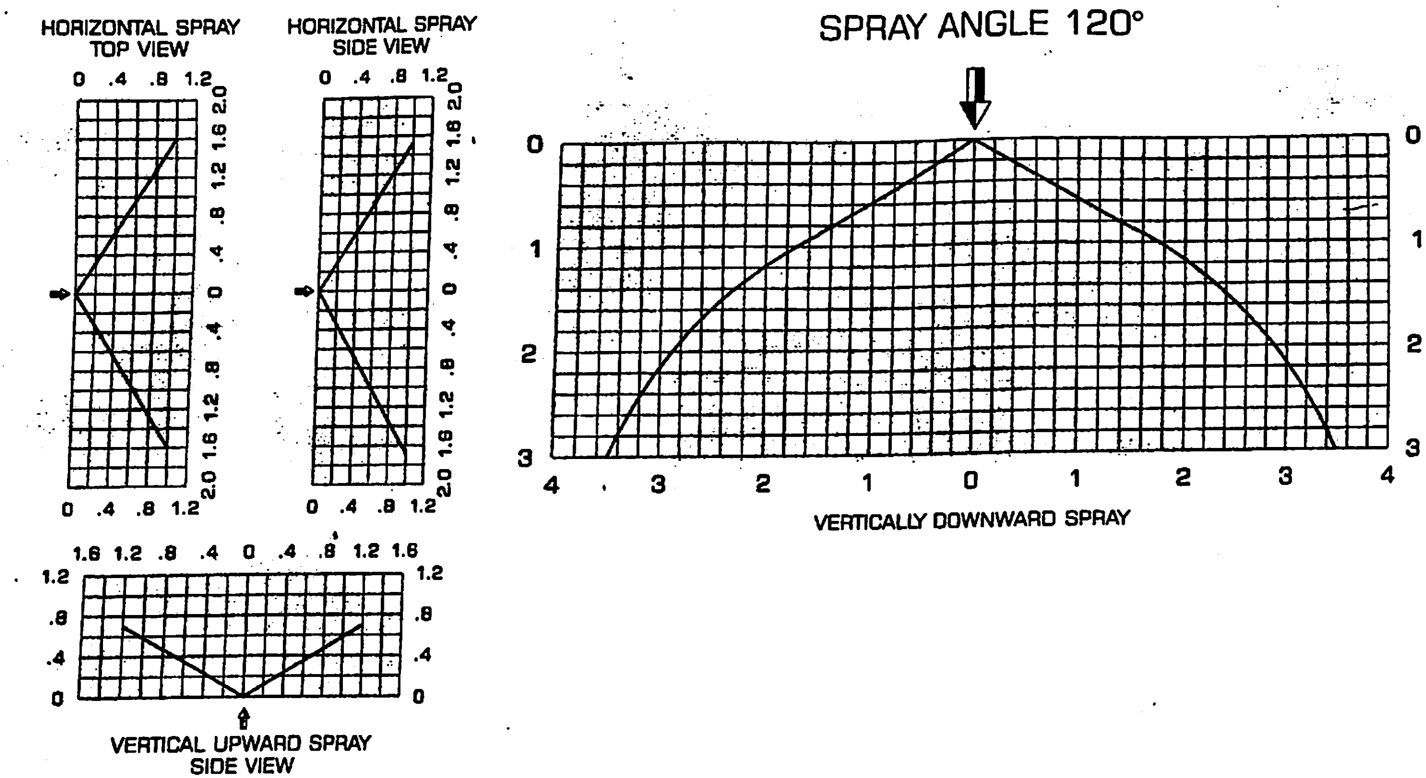
Q = K√P, where P is supply pressure in Kg./sq.cm., K-is nozzle constant in Metric
US K Factor = Metric K Factor ÷ 14.2745

Orifice size and K-factor

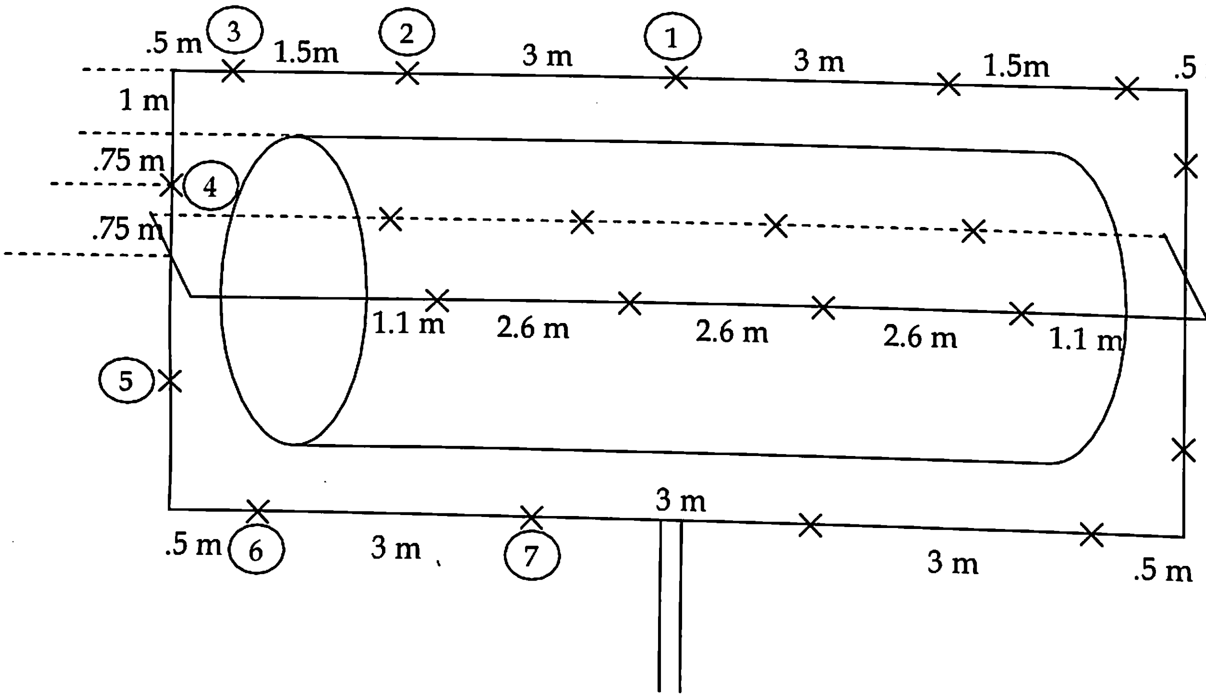
(mm) Inch)	Metric (US)
6.0 (0.236)	K22 (1.54)
7.0 (0.275)	K30 (2.10)
7.5 (0.295)	K35 (2.45)
8.0 (0.314)	K41 (2.87)
9.0 (0.354)	K51 (3.57)
10.0 (0.393)	K64 (4.48)
11.0 (0.433)	K79 (5.53)
12.0 (0.472)	K91 (6.37)
12.5 (0.492)	K102 (7.14)

Protection area and spacing of sprinklers

For sprinkler of 120° deflection angle and kept 1 m away from the surface of the tank, the protection area obtained from the graph.



SPRAY ANGLE 120°
HORIZONTAL SPRAY TOP VIEW
HORIZONTAL SPRAY SIDE VIEW
VERTICAL UPWARD SPRAY SIDE VIEW
VERTICALLY DOWNWARD SPRAY



Coverage areas of different sprinklers

For vertical downward spray (kept 1m away) = $\pi \times 1.8^2$

= $10.17 m^2$

Providing overlapping = $\pi \times 1.7^2$

= $9.07 m^2$

Actual horizontal spray = $\pi \times 1.4^2$

= $6.15 m^2$

Providing overlapping = $\pi \times 1.3^2$

= $5.3\ m^2$

Vertical upward spray (place .6 m away) = 5×1.2^2

= $4.52 m^2$

Providing overlapping = $\pi \times 1.1^2$

= $3.8 m^2$

Water at the top will come down and cover the protection areas of side and base sprinklers so we can take the average protection area as $9m^2$ so total sprinklers needed = 188.4/9

= 20.9

≅ 21

From the graph K can be selected as 102 US units

For P = 3.2 Kg/cm^2 (44.8 PSI) and Q = 10.2 $L/min\text{-}m^2$

So from the table diameter of orifice can be taken as 0.49 inch (12.5mm).

Discharge of the most remote sprinkler

$$Q = K\sqrt{P}$$

$$= 29.8cd^2\sqrt{p}$$

c = discharge coefficient (assumed as 1)

d = diameter of branch pipe in inches

p = pressure in PSI

Q = discharge in GPM

From the graph we can take the diameter of the branch pipe as 2 inches.

$$Q = 29.8 \times 1 \times 0.5^2 \times \sqrt{44.8}$$

$$= 49.86 \text{ GPM}$$

Velocity pressure is not a factor at the most remote sprinkler but it may be considered at all the other sprinklers some designers ignore the velocity pressure in their calculations as the error introduced is normally on the safe side, here also velocity pressures is not calculated

Equivalent Pipe Length Chart

	Fittings and Valves Expressed in Equivalent ft (m) of Pipe						
	3/4 in. (20 mm)	1 in. (25 mm)	1 1/4 in. (32 mm)	1 1/2 in. (40 mm)	2 in. (50 mm)	2 1/2 in. (50 mm)	3 in. (80 mm)
45° Elbow	1 (0.3)	1 (0.3)	1 (0.3)	2 (0.6)	2 (0.6)	3 (0.9)	3 (0.9)
90° Std. Elbow	2 (0.6)	2 (0.6)	3 (0.9)	4 (1.2)	5 (1.5)	6 (1.8)	7 (2.1)
90° Long turn E	1 (0.3)	2 (0.6)	2 (0.6)	2 (0.6)	3 (0.9)	4 (1.2)	5 (1.5)
Tee or Cross	4 (1.2)	5 (1.5)	6 (1.8)	8 (2.4)	10 (3.1)	12 (3.7)	15 (4.6)
Gate Valve	—	—	—	—	1 (0.3)	1 (0.3)	1 (0.3)
Butterfly Valve	—	—	—	—	6 (1.8)	7 (2.1)	10 (3.1)
Swing Check	4 (1.2)	5 (1.5)	7 (2.1)	9 (2.7)	11 (3.4)	14 (4.3)	16 (4.9)

	Fittings and Valves Expressed in Equivalent ft (m) of Pipe						
	3 1/2 in. (90 mm)	4 in. (100 mm)	5 in. (125 mm)	6 in. (150 mm)	8 in. (200 mm)	10 in. (250 mm)	12 in. (300 mm)
45° Elbow	3 (0.9)	4 (1.2)	5 (1.5)	7 (2.1)	9 (2.7)	11 (3.4)	13 (4.0)
90° Std. Elbow	8 (2.4)	10 (3.1)	12 (3.7)	14 (4.3)	18 (5.5)	22 (6.7)	27 (8.2)
90° Long turn E	5 (1.5)	6 (1.8)	8 (2.4)	9 (2.7)	13 (4.0)	16 (4.9)	18 (5.5)
Tee or Cross	17 (5.2)	20 (6.1)	25 (7.6)	30 (9.2)	35 (10.7)	50 (15.3)	60 (18.3)
Gate Valve	1 (0.3)	2 (0.6)	2 (0.6)	3 (0.9)	4 (1.2)	5 (1.5)	6 (1.8)
Butterfly Valve	—	12 (3.7)	9 (2.7)	10 (3.1)	12 (3.7)	19 (5.8)	21 (6.4)
Swing Check	19 (5.8)	22 (6.7)	27 (8.2)	32 (9.8)	45 (13.7)	55 (16.8)	65 (19.8)

Friction loss and pressure calculations

HAZEN-WILLIAMS formula for calculating frictional loss

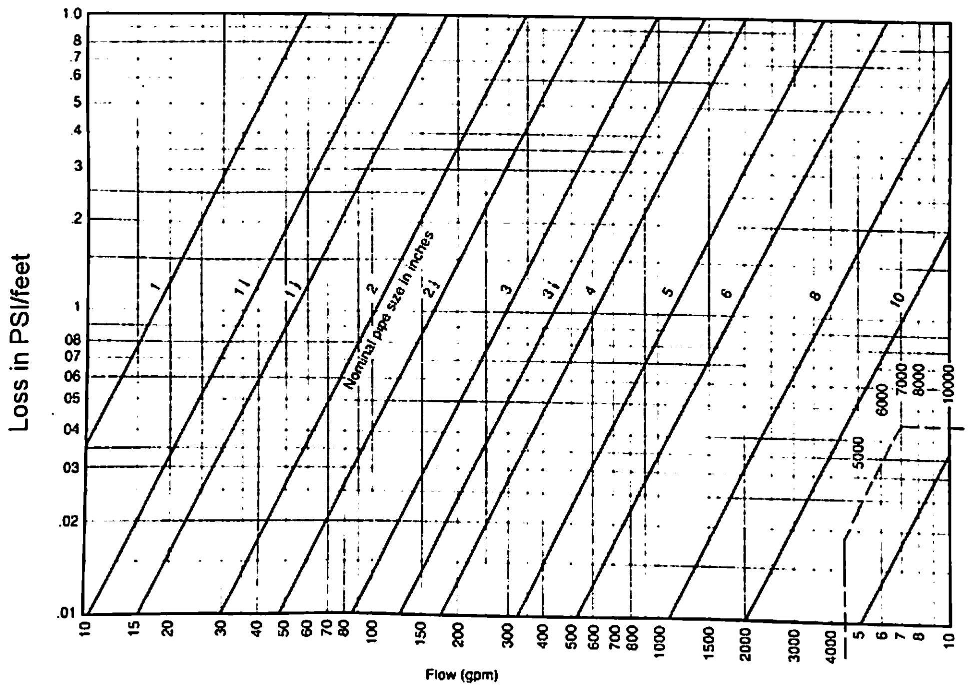
P = $4.52 \times Q^{1.85} / (C^{1.85} \times D^{4.87})$

P = Pressure loss in PSI/feet

C = Discharge coefficient

D = Dia of pipe in inches

Q = Discharge in GPM



?. *Friction loss in Schedule 40 steel pipe, Hazen-Williams C = 120. For other C values use: Value of C: 80 100 120 130 140 150; ...e factor: 2.12 1.40 1.00 0.86 0.75 0.66.*

Frictional loss between 1st and 2nd sprinkler

Q	=	49.86 GPM
C	=	120
D	=	2 inches

$$P = \frac{4.52 \times 49.86^{1.85}}{(120^{1.85} \times 2^{4.87})}$$

= 0.03 PSI/feet

Spacing between first and second sprinkler = 3 m

= 300cm/ 30.5cm

= 9.83 feet

So frictional loss = 9.83×0.03

= 0.295 PSI

So pressure at 2nd remote sprinkler P_2 = 44.8 +0.295

= 45.095PSI

Discharge at 2nd remote sprinkler

$$Q_2 = 29.8 \times 1 \times .5^2 \sqrt{p2}$$

$= 29.8 \times 1 \times .5^2 \sqrt{45.095}$

$= 50.02$ GPM

Frictional Loss between 2nd and 3rd sprinkler

P $= 4.52 \times Q_2^{1.85} / (C^{1.85} \times D^{4.87})$

$$P = \frac{4.52 \times 50.02^{1.85}}{(120^{1.85} \times 2^{4.87})}$$

$= 0.0306$ PSI/feet

Space between 2nd and 3rd sprinkler = 1.5m

= 4.91feet

So frictional loss $= 0.0306 \times 4.91$

= 0.1504 PSI

so pressure at 3rd sprinkler = 45.095+.1504

p_3 = 45.245 PSI

Discharged at 3rd remote sprinkler $= 29.8 \times 1 \times 0.5^2 \times \sqrt{p_3}$

$= 29.8 \times 1 \times 0.5^2 \times \sqrt{45.245}$

Q_3 = 50.112GPM

Pressure at 4th remote sprinkler

Frictional loss between 3rd and 4th sprinkler

P $= 4.52 \times Q_3^{1.85} / (C^{1.85} \times D^{4.87})$

$$= \frac{4.52 \times 50.112^{1.85}}{(120^{1.85} \times 2^{4.87})}$$

= 0.0307 PSI

Total length between the sprinklers = 0.5 + 1 + 0.75

= 2.25m

= 7.37 feet

So total pressure loss $= 0.0307 \times 7.37$

= 0.2264PSI

There is a 90° elbow coming in between 3rd and 4th sprinkler. So pressure loss due to elbow

Equivalent length due to elbow of 90° = 5 feet

From the graph the loss for 50 GPM flow is 0.025 PSI/feet.

So loss = 0.025×5

= 0.125 PSI

so total loss = 0.2264 + 0.125

= 0.3514 PSI

So pressure at 4th Sprinkler P_4 = p_3+.3514

= 45.245 + .3514

= 45.596 PSI

Discharge at 4th remote sprinkler = $29.8 \times 1 \times 0.5^2 \times \sqrt{p_4}$

= $29.8 \times 1 \times 0.5^2 \times \sqrt{45.596}$

Q4 = 50.3 GPM

Pressure at 5th remote sprinkler

The frictional loss between 4th and 5th

P = $4.52 \times Q_4^{1.85} / (C^{1.85} \times D^{4.87})$

$$= \frac{4.52 \times 50.3^{1.85}}{(120^{1.85} \times 2^{4.87})}$$

= 0.0309 PSI/feet

distance between 4th and 5th sprinkler = 2.4 m

= 0.0309×7.87 feet

= 0.2431 PSI

Loss in T joint

Equivalent length taken 10 feet from graph the loss for 50 GPM flow = 0.026 PSI/feet

so loss = 10×0.026

= 0.26 PSI

so pressure at fifth sprinkler P_5 = p_4+.26

= 45.596 + 0.26

= 45.856 PSI

Discharge at 5th remote sprinkler

Q_5 = $29.8 \times 1 \times 0.5^2 \times \sqrt{P_5}$

= $29.8 \times 1 \times 0.5^2 \times \sqrt{45.856}$

= 50.4 GPM

Pressure at 6th remote sprinkler

Frictional loss between 5th and 6th sprinklers

P = $4.52 \times Q_5^{1.85} / (C^{1.85} \times D^{4.87})$

$$= \frac{4.52 \times 50.4^{1.85}}{(120^{1.85} \times 2^{4.87})}$$

= 0.031 PSI/feet

Total length between 5th and 6th remote sprinklers

= 0.8 + 0.5

= 1.3m = 4.26ft

So total frictional loss = $4.26 \times 0.031 = 0.1321$ PSI

Loss due to 90° elbow

Equivalent length taken = 5 feet

From the graph the loss for 50.4 flow = 0.026×5 feet

= 0.13 PSI

Total loss = 0.13 + 0.1321

= 0.2621 PSI

So pressure at 6th remote sprinkler P_6 = P_5 + 0.2621

= 45.856+.2621= 46.118 PSI

Discharge at 6th remote sprinkler Q_6 = $29.8 \times 1 \times 0.5^2 \times \sqrt{P_6}$

= $29.8 \times 1 \times 0.5^2 \times \sqrt{46.118}$

= 50.59 GPM

Pressure at the 7 th remote sprinkler

Frictional loss between 6th and 7th sprinkler

P = $4.52 \times Q_6^{1.85} / (C^{1.85} \times D^{4.87})$

= $\dfrac{4.52 \times 50.59^{1.85}}{(120^{1.85} \times 2^{4.87})}$

= 0.0313 PSI/feet total

Total length between 6th and 7th sprinklers = 3m

= 9.83 ft

So loss = $9.83 \times .0103$

= 0.3079

Pressure 7th sprinkler P_7 = $P_6 + 0.3079$

= 46.118+.3079

= 46.43 PSI

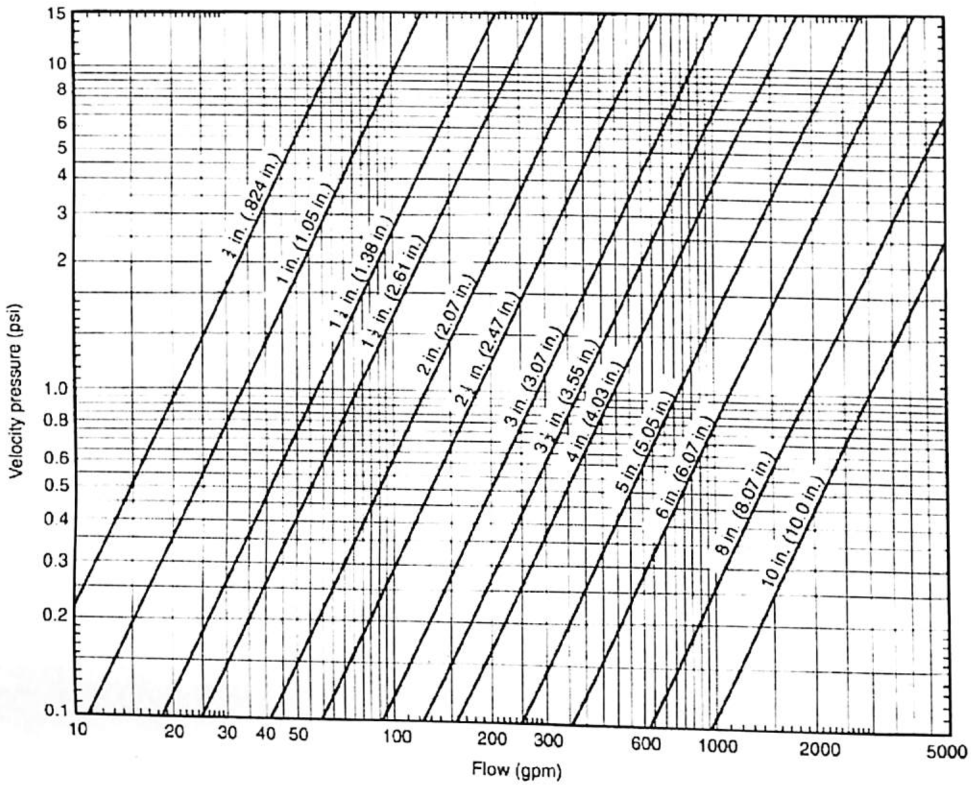
Discharge at 7th remote sprinkler = $29.8 \times 1 \times 0.5^2 \times \sqrt{P_7}$

= $29.8 \times 1 \times 0.5^2 \times \sqrt{46.43}$

= 50.7 GPM

Calculation Summary

Sprinkler no:	Discharge (GPM)	Total Pressure (PSI)
1	49.84	44.84
2	50.02	45.095
3	50.112	45.245
4	50.3	45.596
5	50.4	45.856
6	50.59	46.118
7	50.7	46.43



Graph for the determination of velocity pressure.

Temperature Ratings, Classifications, and Color Coding

TEMPERATURE RATING °F	°C	TEMPERATURE CLASSIFICATION	COLOR CODING	GLASS BULB COLORS
135–170	57–77	Ordinary	Uncolored or black	Orange or red
175–225	79–107	Intermediate	White	Yellow or green
250–300	121–149	High	Blue	Blue
325–375	163–191	Extra high	Red	Purple
400–475	204–246	Very extra high	Green	Black
500–575	260–302	Ultra high	Orange	Black
625	343	Ultra high	Orange	Black

The pressure required at the most remote sprinkler from the fire water main is 3.2 kg/cm2 (44.8 PSI) as per calculations the pressure required at the nearest sprinkler is 3.32 kg/cm2 so this means that in order to obtain the required pressure at the most remot4 sprinkler the pressure of 3.32 kg/cm2 or slightly above is to be maintained at the fire water main. As per OISD standards a pressure of 7 kg/cm2 should be maintained in the main fire water ring .with that pressure in the fire water main it is very easy to obtain 3.32 kg/cm2 or a slightly above pressure at the base of the design. So this design is able to deliver the expected pressure and the required water application rates

TOTAL FLOODING SYSTEM

TOTAL FLOODING SYSTEM

Total flooding systems are used to protect an entire area, room or building. These types of system using agents other than water have been in use for many years. The total flooding system discharges an extinguishing agent that completely fills or floods the area with the extinguishing agent's to smoother or cool the fire or break the chain reaction. Total flooding system can use carbon dioxide or other inert gases, halogenated or clean agents, dry chemicals, or foam as extinguishing agents. They are effective as long as the proper amount discharges the area is contained to prevent loose of agents or fire gas out prior to the ventilation of agent.

These systems protect enclosed or at least partially enclosed hazards. A sufficient quantity of extinguishing agent is discharged into the enclosure to provide a uniform fire extinguishing concentration of agent through out the entire enclosure. Example of total flooding system using halocarbon agents are found in computer room, electrical switch gear rooms, magnetic type storage vaults, aerosol filling rooms; machinery spaces in ships; cargo area in large transport aircraft, processing and storage areas for paints, solvents and other flammable liquids.

Halogenated Compounds as Extinguishing Agents

The use and development of halogenated fire extinguishing agents have evolved over many years. The first member of this family of chemical was carbon tetra chloride (Halon104) use as a fire extinguishing probably occurred before 1900 and by 1910 portable fire extinguishers tested by independent agencies had appeared.

Methyl bromide (Halon 1001) gained popularity after it was discovered in the late 1920s. Due to its high toxicity, it was never popular for use in portable extinguisher, although it was used in British and German air crafts and ships during World War II.

During World War II, Germany developed brome chloral methane (Halon 1011) to replace methyl bromide. In 1947 a report by under writes laboratories Inc (ul) showed that the toxicity of Halon 104 and Halon 1011 were comparable.

By the 1950s the era of the early Halon (Halon 104, Halon 1001, and Halon 1011) was ending. Increasing popularity of dry chemical had decrease the need for wide spread use of these early Halons, and growing concern with their toxic effects resulted in their official death by the 1960s.

In 1947, the produce research foundation conducted a systematic evaluation of more than 60 new candidate extinguishing agents. Simultaneously, the US army corps of Engineers under took toxicological study of these same chemicals. As a result four Halon were selected for further study: dibromodifluoromethane (Halon 1202), bromochlorodifluoromethane (Halon 1211) brome trifluoromethane (Halon 1301) and dibromotetrafluoro ethane (Halon 2402). Testing showed that Halon 1202 was the most effective fire extinguishant, but it was also the most toxic. Halon 1301 ranked second in fire extinguishing effectiveness and least toxic. Because of these basic researches, some general conclusions were drawn, based on the contribution of the various halogens to resistant characteristics of the Halon as a useful fire extinguishant.

During 1966, attention began to focus on the use of Halon 1301 to protect computer rooms and electronic data processing (EDP) equipment.

In 1972, following extensive testing by several major companies on the effects of Halon 1301 decomposition products on electronic equipment, NFPA committee on electronic computer data processing equipments recognized Halon 1301 total flooding system as suitable for protection of electronic computer data processing equipments with suitable precautions, such as time delays. Halon 1211 total flooding system have been used in Europe

Harmful Effects Of Halon 1301 & Halon 1211 On Human and To the Environment Physical properties of Halon.

Halon 1301 is a gas at 70°F (21°c) with a vapour pressure of 199 psig (1372KPa). Although this pressure would adequately expel the material, it decreases rapidly to 56psig (386KPa) at 0°F (-17°C) and to 17.2psig (119KPa) at 40°F.Halon 1211 is also a gas at 70°F (21°C) with a vapour pressure of 22psig and boiling point of 25°F (-4°C)

Toxic and Irritant Effects of Halon1301&Halon 1211

The toxicology of Halon1301and Halon1211 has been enabled studies extensively in both animals and humans.

Animals exposed to Halon concentration below lethal levels exhibit two distinct types of toxic effects.

1. Central nervous system changes such as tremors, convulsions, lethargy, and unconsciousness at high airborne concentration (above 30% by volume for Halon 1301 and 10% for Halon 1211).
2. Cardio vascular effects; including hypotension decreased heart rate, and occupation cardiac arrhythmia (lack of rhythm in the heart beat).Effects are transistor & disappear rapidly after exposure.

Human exposure to both Halon 1301 and Halon 1211 has shown that Halon 1301 concentration up to 7% by volume and Halon 1211 concentration below2-3% by volume have little noticeable effect on the subject. At Halon 1301 concentration between 7 and 10% and Halon 1211 concentration above 3 and 4% subject experienced dizziness and tingling of the extremities, indicating mild anaesthesia. At Halon 1301 concentration above 10% and Halon 1211 concentration above 4-5% the dizziness becomes pronounced the subjects feel as if they will lose consciousness and physical and mental dexterity is reduced.

Consideration of life safety during use of halogenated agents also must include the effects of break down products, which have a relatively higher toxicity to humans. Until the presence of available H_2 (from water vapour or the combustion process) itself, the main decomposition products of Halon 1301 and 1211 are hydrogen fluoride (HF), hydrogen bromide (HBr) and free bromine (Br_2) .Although small amounts of carboxyl halides (COF_2), ($COBr_2$) were reported in early tests .Even in minute concentration of only a few parts per million, the decomposition products of the halogenated agents have characteristically sharp, acrid odors.

Need for an alternative extinguishment agent for total flooding system.

All this harmful and toxic effect6s of Halon 1301 & Halon 1211 made to find a new better, less toxic, environmental friendly, clean streaming and clean total flooding extinguishing agents.

The evaluation of clean agent fire suppressants includes a consideration of environmental factors. International, national and local government regulations control the use of any alternative in this regards.

Principal Design and mechanism of a total flooding system.

As described earlier a total flooding system is one that develops a uniform extinguishing concentration of agent through out an enclosure, such as a room. The system should be capable of a extinguishing a fire with in the enclosure, regardless of the location of the fire .the main elements of a total flooding system are as follows.

1. Define the hazard which includes the dimensions and configurations of the enclosure, the maximum and minimum net volume, the fuels involve the expected temperature range in the hazard area ,ventilation and enclosable openings, and occupancy status.
2. Establish a minimum design concentration, based upon the fuels involved.

3. Calculate the minimum agent quantity, based upon the minimum design concentration the maximum net volume the minimum expected temperature of the enclosure,. and compensation for losses from ventilation, and enclosable openings.
4. Calculate the maximum possible concentration that could occur if the hazard is at the Conditions of minimum net volume and maximum temperature. This concentration must not be greater than that permitted by NFPA 12-A, or was permitted by NFPA12-B, for the occupancy status of the hazard.
5. Select the agent storage container based upon the design quantity of the agent and the sizes of the standard containers available from the equipment manufactures.
6. Determine the minimum agent flow rate by dividing the minimum design agent quantity by the maximum permissible discharge time. This time is currently set by NFPA 12 A, and was set by NFPA 12 B at 10 sec, but is subject to some discretion.
7. Determine the size of piping, considering the location of the agent storage containers and location of the discharge nozzles this step must be performed concurrently with the following step
8. Determine the number, size and location of discharge nozzles, discharge rate and nozzle area coverage data must be obtained from laboratory listings or from design manuals of the equipment manufactures

Extinguishing mechanism

Halocarbon clean agents extinguish fires by a combination of chemical and physical mechanisms, depending upon the compound. Chemical suppression mechanisms of HBFCand HFIC compounds are similar to Halon 1301.i.e., the Brand I species scavenge the flame radicals, there by interrupting the chemical chain reaction. Other replacement compounds suppress fires primarily by extracting heat from the flame reaction zone, reducing the flame temperature below that which is necessary to maintain sufficiently high reaction rates by a combination of heat of vaporization, heat capacity, and t6he energy absorbed by the decomposition of the agent.

Oxygen depletion also plays an important role in producing flame temperature. The energy absorbed in decomposing the agent by breaking fluorine and chlorine bonds is quite important, particularly with respect to decomposition production formation. There is undoubtedly some degree of "chemical" suppression action in flame radical combustion with halogens, but it is considered to be of minor importance, since it is not catalytic (e.g., one Radical combines with one H flame radical.

The lack of significant chemical reaction inhibition in the flame zone by HCFC, HFC, and FC compounds results in higher extinguishing concentrations, relatives to Halon 1301. The relative importance of the energy wink, represented by breaking halogen species bonds, results ion higher levels of agent decomposition, relative to Halon 1301.

Inert gas agents suppress flames by reducing the flame temperature below thresholds necessary to maintain combustion reactions. This is done by reducing the oxygen concentration and by raising the heat capacity of the atmosphere supporting the flame.

Design concentration

Design concentrations for various agents and fuel combination are generally determined by a combination of small scale testing, large scale testing, and independent laboratory approval of hardware and addition of design safety factors. The basic requirements for determining the design concentrations of clean agents in NFPA 2001 is two fold. First, the minimum extinguishing concentration as determined by the cup burner must be established after this minimum is established by the system manufacturers, full scale third party approval testing is conducted using the manufacturers hard ware on normal N-Heptanes, wood crib, and selected flammable liquids design concentrations for fire scenarios involving long reborn times in thick arrays of celluloses fuels may require additional testing. For most application where incidental quantities of celluloses materials may be involved and pre burn times are relatively short(less than 5 minutes) timeframes (i.e.: automatic actuation), the flame extinguishing concentration for class A fuels that are less than or equal to that of N-Heptanes can be used...The minimum design concentration is a function of the fuel, the agent, and the delivery system. Design concentration for specific hazards must be determined in accordance with the system manufactures, approval or listing.

Safety factors

The 20 % safety factor suggested by NFPA 2001 used for developing design concentration should be minimum. Consideration should be given in increasing the safety factor and hence the minimum design concentration where any of the following conditions apply

1. Where the nozzle is installed at or near its maximum listed ceiling height or area coverage;
2. For the protection of combustible or flammable liquid hazards where limiting quantity of thermal decomposition products or rapid (<15 sec) extinguishing times are required
3. Where a large number of highly imbalanced flow splits occurs in piping network protecting large and small enclosures simultaneously
4. Where floodable room volume is variable
5. Where unclosable openings exists
6. Where excessive post discharge agent leak is expected

Agent Quantity

Once the design concentration is established, the quantity of agent necessary to achieve that concentration is determined. The quantity of halocarbon agent necessary is determined by the following equation.

W = V/S(C/100-C).

Where W = Specific weight of agent required.

S = Specific volume (CU/FT/1bar m^3/kg.), and is determined by

S = k1+K2 (T).

Where T = minimum ambient temperature of the protected space.

K1and K2 is constants.

V = net volume of protected space, and

C = design concentration (%)

Value for k1 and K2 used in Equation 2 are given.

Specific Volume Constants

Agent	°F		°C	
	K_1	K_2	K_1	K_2
FC-3-1-10	1.409	0.0031	0.0941	0.0003
HCFC Blend A	3.612	0.0079	0.2413	0.00088
HCFC-124	2.352	0.0057	0.1578	0.0006
HFC-125	2.724	0.0063	0.1701	0.0007
HFC-227ea	1.885	0.0046	0.1269	0.0005
HFC-23	4.731	0.0107	0.2954	0.0012
IG-541	9.7261	0.0211	0.049	0.00237

The flooding factor in equation 1[C/(100-C)] implies that the agent/air mixture "lost" during discharge is well mixed and has an agent concentration .This formula makes no assumption regarding leakage of the enclosure. During UL/FMRC approval testing, the agent is evaluated with a flooding factor of (C/100), essentially assuming that losses during discharge are 100% air.

The quantity of agent which will be needed to produce the design concentration in a particular volume will depend on the temperature of the air into which the agent is discharge this is because the specific vapour volume (the volume of vapour released by a given weight of agent) varies with temperature the actual weight of a particular agent which will be needed to produce a given concentration in given volume and at a known minimum temperature can be calculated very readily from tables, graphs and nomographs in the standards.

Thermo Physical Properties

Tables 6-19 m and 6-19n give thermo physical properties of clean agent replacements from NFPA 2001 in U.S custom and SI units, respectively. Additional thermo physical and transport property data can be found in reference II for FM200 and a range of halocarbon alternatives.

Representative isometric diagram for various clean agents are given in tables for the respected clean agents. The features of a typical isometric diagram for a liquefied halocarbon super pressurized to 360 PSIG can be seen in table .The importance of an isometric diagram is that it determines the maximum fill density for an agent in a cylinder with a fixed pressure rating. The basic rule is that the cylinder must not become liquid full at 130°F (54°C) and/or the pressure developed at 130°F (54°C) must not exceed 5/4 cylinder design pressure. The pressure developed is a function of the agent, the super pressurization level and the temperature.

Agent Flow

If the flow velocity of the agent in the piping is not high enough the flow may separate into two distinct phases in the piping. When ever a liquid is flowing through a pipe the pressure at the discharge end will be lower than that of the input. This drop in pressure is due partly to the work done in moving the liquid, but mainly to the work done in over coming the friction between the liquid and the wall of the pipe. The discharge rate of a liquid through a simple nozzle can also be calculated from knowledge of the diameter of the orifice and the pressure at the nozzle. Thus, the discharge rate of water from a branch pipe or from a sprinkler can readily be calculated if we know the dimension of the hose (or pipes), the friction factor and the input pressure. Unfortunately a straight forward calculation like this cannot be used in designing a total flooding system this is because normal ambient temperatures are well above the boiling point of the agents, which must there fore be kept under pressure.

Nozzle Area coverage, Height limitations

In general maximum nozzle heights are of the order of 13 to 16ft nozzles area coverage on the order of 97 to 108 sqr ft and minimum nozzle pressure between 3 and 6 bars. It is critical to ensure that the nozzle spacing height and the minimum pressure limits are not exceeded for a particular manufacturer's hardware in a specific design

Compartment pressurisation

As the halocarbon agent is discharged in to the space. it vaporises rapidly, cooling the compartment and lowering the pressure. As the agent /air minute gains heat from the walls or other objects in the space the pressure recovers and as additional, the pressure increases over ambient as mass is added to other compartment

The expected maximum and minimum compartment pressure during discharge will be a function of

1) Thermodynamic state of the agent at the nozzle
2) Nozzle design
3) Compartment volume and wall surface area

4) Size of fire
5) Initial conditions in space
6) Leakage area from compartment
7) Agent flow rate

Agent Hold time &Leakage

Total flooding gas systems are required tot maintain a minimum concentration for a specified period of time (10-20) minutes after discharge, the minimum required time was a function of

1. Soak time required for deep seated class fuels
2. Response time of emergency personnel
3. Time required to prevent reflash due to presence of hot surfaces and other reignition sources, particularly in flammable and combustible liquid application

Commercialised Halon Replacement Nomenclature

Chemical Name	Trade Name	Designation	Formula
Perfluorobutane	CEA-410	FC-3-1-10	C4F10
Heptafluoropropane	FM-200	HFC-227ea	C3F7H
Trifluoromethane	FE-13	HFC-23	CHF3
Chlorotetrafluoroethane	FE-24	HCFC-124	C2HCIF4
Pentafluoroethane	FE-25	HCFC -125	C2HF5
Dichlorodifluoromethane (4.75%) Chlorodifluoromethane (82%) Chlorotetrafluroethane (9.5%) Isopropeny -1 methycyclohexene (3.75%)	NAF-SIII	HCFC Blend A	CHCI2CF3 CHCIF2 CHCIFCF3
Trifluoroiodide	Triodide	FIC-1311	CF3I
N2/Ar/CO2	Inergen	IG-541	N2 (52%) Ar (40%) CO2 (8%)
N2/Ar	Argonite	IG-55	N2 (50%) Ar (50%)
Argon	Argon	IG-01	Ar (100%)

Weight & storage volume Equivalent Data for New Technology Halocarbon Gaseous Alternatives

Trade Name	Designation	Formula	BP °C	Cup Burner %V/V	Min. Design Conc. % V/V	Ratio Agent Mass Req'd to H1301	Ratio Agent Storage Volume Req'd to H1301	Storage Pressure PSI 20°C
Halon 1301	Halon 1301	CF3Br	-58	2.9-3.9	5II	1	1	360
CEA-410	FC-3-1-10	C4F10	-2	5.0-5.9	6	1.9	1.7	360
FM-200	HFC-227ea	C3F7H	-16.4	5.8-6.6	7	1.7	1.6	360
FE-13	HFC-23	CHF3	-82.1	12-13	16	1.7	2.2	609
FE-25	HFC-125	C2HF5	-48.5	8.1-9.4	10.9	1.9	2.3	166
NAF-SIII	HCFC Blend A	HCFC-22 82% HCFC-123 4.75% HCFC-124 9.5% Organic 3.75%	>11%	8.6	1.1	1.4	360	
Triodide	FIC-1311	CF3I	-22.5	2.7-3.2	5.0	~1	~1	

Table

Trade Name	**Designation**	**Formula**	**NOAEL % V/V**	**LOAEL % V/V**	**LC50or ALC**
CEA-410	FC-3-1-10	C_4F_{10}	40	>40	>80%
FM-200	HFC-227ea	C_3F_7H	9.0	>10.5	>80%
FE-13	HFC-23	CHF_3	30	>50	>65%
FE-24	HCFC-124	C_2HClF_4	1	2.5	23-29
FE-25	HFC-125	CH_2HF_5	7.5	10.0	>70%
NAF-SIII	HCFC Blend A	HCFC-22 82% HCFC-123 4.75% HCFC-124 9.5% Organic 3.75%	10	>10	64%
Triodide	FIC-1311	CF31	0.2	--	--

Radio active Forcing of Climate Change: Global Warming Potentials, Referenced to the Absolute GWP for Co2 (The Typical uncertainty is + or - 35% relative to the CO2 reference.)

Species	Chemical Formula	Lifetime (Yr)	Global Warming Potential Time Horizon		
			20 Yr	100 Yr	500 Yr
CFC-13	$CClF_3$	640	8100	11700	13600
HCFC-225ca	$C_3F_3HCl_2$	2.5	550	170	52
HCFC-225cb	$C_3F_5HCl_2$	6.6	1700	530	170
HFC-23	CHF_3	250	9200	12100	9900
HFC-125	C_2HF_5	36	4800	3200	1100
HFC-227ea	C_3F_7H	41	4500	3300	1100

Environmental Factors For Halocarbon Clean Agents

Trade Name	Designation	Chemical Formula	ODP	GWP 100(Yr)	Atmospheric Lifetime(Yr)
Halon 1301	Halon 1301	CF_3Br	16	5800	100
CEA-410	FC-3-1-10	C_4F_{10}	0	5500	2600
FM-200	HFC-227ea	C_3F_7H	0	2050	31
FE-13	HFC-23	CHF_3	0	9000	280
FE-24	HCFC-124	C_2HClF_4	0.022	440	7
FE-25	HFC-125	CH_2HF_5	0	3400	41
NAF-SIII	HCFC Blend A	HCFC-22 82% HCFC-123 4.75% HCFC-124 9.5% Organic 3.75%	0.05	1600	16
Triodide	FIC-1311	CF_3I	<0.2	0	-

Selected Thermo physical properties of Agents

	FC-3-1-10	HCFC-227ea	HCFC-124	HFC-125	HFC-23
Boiling Point @0.101MPa(°C)	-2.0	-16.4	-13.2	-48.6	-82.1
Critical Temperature (°C)	113.2	101.7	122.5	66.3	25.6
Critical Pressure (MPa)	2.32	2.9	3.65	3.62	4.82
Vapor Pressure @25°C(MPa)	0.27	0.47	0.38	1.38	4.69
Liquid Density at 25°C(kg/m³)	1497	1395	1357	1190	0.685
Critical Density(kg/m³)	629	621	565	571	525
Liquid Heat Capacity @Boiling Point (kJ/kg K)	0.951	1.074	1.080	1.107	1.269
Liquid Heat Capacity at 25°C(kJ/kg K)	1.017	1.177	1.111	1.358	--
Latent Heat of Vaporization at Boiling Point (kJ/kg)	96	131	162	160	240

Extinguishing mechanism

Halocarbon clean agents extinguish fires by a combination of chemical and physical mechanisms ,depending upon the compound .chemical suppression mechanisms of HBFC and HFIC compounds are similar to Halon

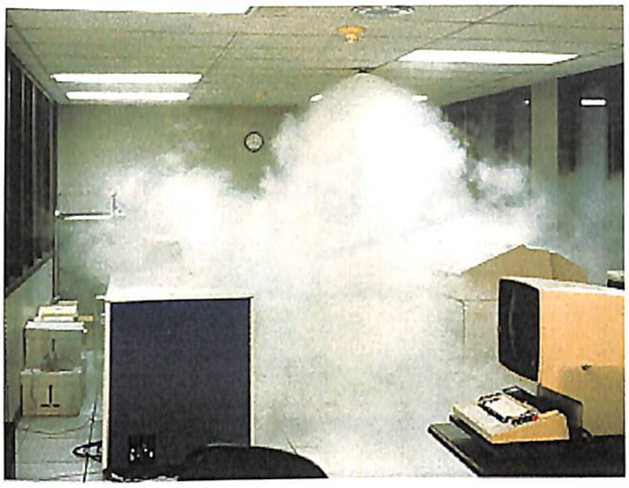
1301.i.e.,the Brand I species scavenge the flame radicals, there by interrupting the chemical chain reaction. Other replacement compounds suppress fires primarily by extracting heat from the flame reaction zone, reducing the flame temperature below that which is necessary to maintain sufficiently high reaction rates by a combination of heat of vaporization, heat capacity, and the energy absorbed by the decomposition of the agent.

Oxygen depletion also plays an important role in producing flame temperature. The energy absorbed in decomposing the agent by breaking fluorine and chlorine bonds is quite important, particularly with respect to decomposition production formation. There is undoubtedly some degree of "chemical" suppression action in flame radical combustion with halogens, but it is considered to be of minor importance, since it is not catalytic (e.g., one Radical combines with one H flame radical).

The lack of significant chemical reaction inhibition in the flame zone by HCFC, HFC, and FC compounds results in higher extinguishing concentrations, relatives to Halon 1301. The relative importance of the energy wink, represented by breaking halogen species bonds, results ion higher levels of agent decomposition, relative to Halon 1301.

Inert gas agents suppress flames by reducing the flame temperature below thresholds necessary to maintain combustion reactions. This is done by reducing the oxygen concentration and by raising the heat capacity of the atmosphere supporting the flame.

FM-200 (FM200) FIRE PROTECTION SYSTEMS



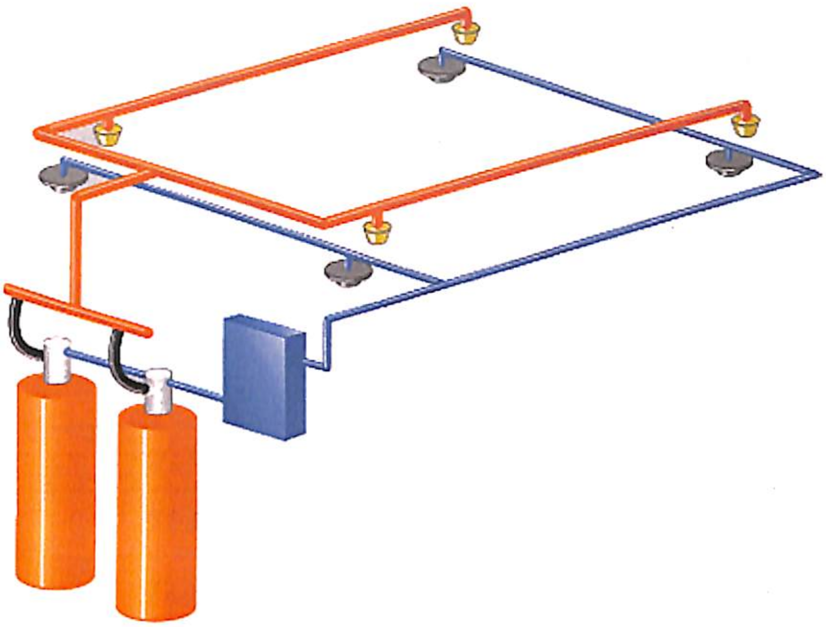
FM-200, chemically known as heptafluoropropane, is an alternative fire supression system agent manufactured in the United States at the Great Lakes Chemical facilities in Eldorado, Arkansas. It is also known within the industry as HFC-227 ea. It is a replacement for the ozone depleting Halon 1301 used extensively before 1994.

FM-200 has no ozone depletion potential. Its ODP is zero. FM-200 has found by leading toxicologists to be safe for use when people are present. Just as with Halon 1301, people can be exposed to normal extinguishing concentrations of without any fear of health problems.

Often FM-200 systems are employed to protect critical installations formerly protected by Halon 1301. These include:

- Date processing Centres
- Telephone Switches
- Process control Rooms
- Art and Historical Collections.
- Facilities where water damage from sprinklers must be avoided at all costs.

In a typical system the extinguishing agent is typically stored in cylinders or spheres. It is delivered to distribution nozzles through a system piping network.



Critical to the functioning of the system is the fire detection and control network. Typically smoke detectors sense the presence of fire in the protected facility. The detection and control panel then sounds an alarm shuts down air handlers, disconnects power from the protected equipment, and then releases agent into the protected area.

In this type of system Fike Intella- Scan Fire Detection Control panel is used to control the release of agent. The Intella-Scan II control system uses both intelligent addressable analog sensors and centralized decision making to virtually eliminate false alarms and unwanted agent releases. The sensors report environmental conditions on a real-time basis to the control unit where the microcontroller makes the ultimate alarm decision. And the control panel is modular to allow you to add on to the system as your requirements change over time.

Assembling all the components together into a workable system optimized for facility is the work of trained fire protection engineers.

Summary of fire Extinguishing Test Results of FM-200

Compartment Size	Design Concentration (%)	Fuel / fire type	Extinguishment Time(s)
56.6 M^3	8-10.8	Heptane/Pool Spray	7-26
840 M^3	9.2-10	3-8 MW Heptane & Diesel Spray / Pool / Wood Crib	4-28
560 M^3	7.0	Heptane / Diesel Spray / Pool	<2-17
1.2 M^3	5.8-9.2	Heptane Pans	3.2-22
29.1 M^3	7.3-9.4	50-250 KW Heptane Pans	5.1-9
72.2 M^3	7.0	Shredded Paper	8.2-25
72.5 M^3	7.0	Printed Circuit Board	2-13.3
72.5 M^3	7.0	PVC Cable / Heptane	–
72.5 M^3	7.0	35 KW Plastic Magnetic - Tape reels	5.7-32

TOTAL FLOODING DESIGN USING FM-200
AT THE SERVER ROOM OF GTI

Total flooding system design at Server room(GTI)

Total volume of room	=	85+11.578
	=	96.3578m³
Net volume	=	total volume – volume occupied by objects
Net Volume can be taken as	=	96.578-6.578
	=	90 m³

Clean Agent used FM200

Total Flooding Quantity

$$w = v/s[c/(100-c)]$$

$$s = k1+k2(T)$$

Nozzles are installed 4 M. above the ground

Specific Volume Constants

Agent	°F		°C	
	K_1	K_2	K_1	K_2
FC-3-1-10	1.409	0.0031	0.0941	0.0003
HCFC Blend A	3.612	0.0079	0.2413	0.00088
HCFC-124	2.352	0.0057	0.1578	0.0006
HFC-125	2.724	0.0063	0.1701	0.0007
HFC-227ea	1.885	0.0046	0.1269	0.0005
HFC-23	4.731	0.0107	0.2954	0.0012
IG-541	9.7261	0.0211	0.049	0.00237

K1,k2	=	constants specific to the clean agent used.
W	=	weight of clean agent used
T	=	minimum anticipated temperature of the protected volume
V	=	net volume /c=clean agent design concentration by volume%

V	=	90 m^3
s	=	0.1269
t	=	0°C
C	=	7%
There fore w	=	90/0.1269x7/(100-7)
	=	53.38kg

Giving a 10% leakage factor, weight becomes = 53.38+5.338

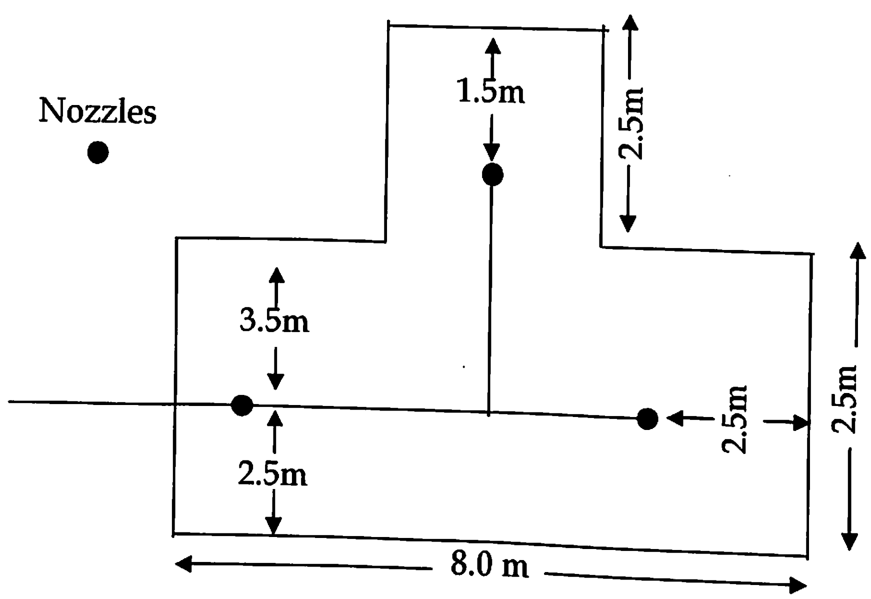
= 58.72kg

= 59kg

Discharge pressure = 1.2kg/cm^2

Time of extinguishments = 20 sec

90% of 59kg is to be discharged in 20 sec and the remaining in the next 40sec i.e 53 kg is to be discharged in 20 sec through 3 nozzles.



Design Layout of Total Flooding Systems at GTI Server Room

The critical density of FM200 = 621 kg/ m^3

53 kg in 20 sec,i.e53/621 m^3 = 0.085 in 20 sec

so volume to be discharged in 1 sec (main pipe)	=	0.085/20=0.0043 m^3/sec

Pipe of diameter 20 mm is to be selected

Giving a fractional lose of 10%

So effective dia becomes 18 mm

Clearance area of pipe	=	3.14/(4x81)
	=	.254mm^2
v=q/a=velocity of gas through the pipe	=	254x10^{-6}
	=	0.0043/(254x10^{-6})
	=	16.92 m/s

Flow of 17.67kg through each branch line - [53/3]

	=	0.00284m^3 in 20 sec

so in 1 sec=0.00142m^3/sec

10 mm pipe is to be selected

Cross sectional area of 10 mm pipe	=	78.5mm^2
velocity of the agent through the branch line	=	0.00142/78.5x10^{-6}
	=	18m/s

PREPARATION AFTER FM 200 RELEASE

Re-Establishment After Automatic Release

3. Alarms on the release panel are silenced.
4. The cylinders are replaced.
5. Empty cylinders are forwarded for refilling.

Re-Establishment After Electrical Manual release

1. Alarms on the release panel are silenced..
2. The glass of the manual call point is replaced.
3. The electrical actuator is renovated.
4. The cylinders are replaced.
5. The fire detecting and control panel is reset.

6. Empty cylinders are forwarded for refilling.

Re-establishment After Manual Release

1. Alarms on the release panel are silenced.
2. The handle of the manual/pneumatic actuator is put into starting position.
3. The cylinders are replaced.
4. The fire detecting and control panel is reset.
5. Empty cylinders are forwarded for refilling.

SAFETY SUGGESTIONS

Safeguards must be taken in using FM200 to ensure the safety of personnel in areas where the atmosphere could become hazardous by the discharge or thermal. decomposition of the extinguishing agent. The following list, which has been compiled from NFPA and ISO standards, indicated "steps and safeguards that may be necessary .

1. Warning and instructions signs at entrances to and inside the protected area informing personnel that a FM200 system is installed. These signs may contain additional instructions relevant to the hazard .
2. A time delay to enable evacuation of personnel before the commencement of FM200 discharge.
3. Alarms within the protected space that will operate immediately upon detection of the fire,
4. Continuous, alarms at entrances to the protected space until the atmosphere has been restored to normal.
5. Adequate aisle ways and exit routs, and ensuring that they are kept clear at all times.

6. Emergency lighting and directional signs as necessary to ensure quick, safe evacuation.

7. Prompt discovery and rescue of persons incapacitated in the protected space. This may be accomplished by having the area searched immediately by trained personnel equipped with proper breathing equipment. Self-contained breathing equipment and personnel trained in its use, and in rescue practices, including artificial respiration, should be readily available.

CONCLUSION

Total flooding and Sprinkler Systems are very effective means of fire protection systems if they are designed accurately as per standards and installed in places as mentioned. apart from proper designing, maintenance and testing is to be done periodically else they wont be effective during emergency.

REFERENCE

- Fire Fighters Handbook – Delmar Publications
- NFPA Hand Book
- NFPA Book-9/2001:1,3,4,A
- NFPA Book-1/13
- UNDERDOWN'S Manual of Practical precautions third edition-R-HIRST
- SFPEI - Fire Protection Engineering