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Fire Suppression Systems for Vertical Structures and Cost-Effective Solutions

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***Abstract* – The present study offers a detailed discussion on active fire protection solutions for storage buildings. These storages are to house only storage items while other building service such as water (except for fire suppression use), fuel, gas etc. are not permitted inside these storage facilities. These storages are usually connecting to other storage facilities.**
A case study of such storage facility in Connecticut, USA is carried out. The technical and commercial aspects of different possible fire protection solutions are discussed. This paper presents different configurations such as tree systems, grid systems and loop systems, different pipe sizes and different pipe materials are evaluated to provide cost effective solutions for construction costs of fire suppression systems.

***Keywords* – Hydraulic Analysis, Looped Systems, NFPA codes, Fire Suppression Systems.**

I. INTRODUCTION

storage facility plays vital role in maintaining functionality of the facility. The risk of fires in such ware house or storages is a growing concern for electric utilities, business owners, clients and connected facilities. Any fire incident in these spaces can be numerous and serious, which can cease business operations from days to months and leading to economic and personal losses.
Typically, storage facilities include combustible contents, storage of flammable liquids, gases and the unknown hazardous materials or liquids stored within. The enormous amount of sometimes densely packed, combustible contents is stored within though the people sign a rental agreement to avoid above contents.Previous past experiences of the storage fires are densely packaged combustible and flammable items, where triggers fire and eventually leading smoke damages to the facility. This creates negative impact on the business and threat to life safety. Any electrical distribution equipment such as fixed wiring, transformers, and circuit breakers; Chemical reactions between incompatible chemicals have also been known to ignite warehouse fires.
While it is understood that hazard levels are high, they have high potential for flash fires, explosion, rapid spread of fire and high toxicity of products of combustion (flame, heat and smoke). Fires in storages represent high hazards to lives and business.Preventing fires and stopping fires to spread is a goal from fire protection standpoint in this type of infrastructure. The solution is to provide active fire protection solution with active protection systems.

1. Objective:

Following are few objectives of fire suppression systems to perform while complying with NFPA standards and applicable building codes:

- Decrease the construction costs of overall fire suppression systems
- Suppressing fire while complying with performances NFPA codes
- To limit toxicity of combustion gases and high temperatures of material

2. General Assumptions:

- The following were assumed to conduct/perform study:
- No services such as gas and fuel are passing/included through in buildings
- This is a four-story building
- Passive fire protection system requirement is not considered for this case study
- Fire alarm systems requirement is considered for this case study
- Different fire protection systems life cycle costs are not accounted
- Storage cross-section is rectangle
- Pipe stress analysis and pipe support spacing are not included in this study

3. Applicable codes and standards

NFPA 13, “Standard for the Installation of Sprinkler Systems” 2016 Edition
NFPA 14, “Standard for the Installation of Standpipe Systems” 2016 Edition
NFPA 101 “Life Safety Code” 2016 edition
Fire Protection requirements from codes & standards:

- Required fire protection systems for storage buildings include wet risers, automatic sprinklers, and water mist system.
- NFPA, requires all high hazard industrial occupancies, or processes shall have approved supervised automatic extinguishing systems.

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- The wet standpipes systems are required per NFPA 14, section 7.2.2.3 and Class II is considered for the analysis. Flow rate required for most two most remote connection is 500 gpm and each fire hose valve requires 100psi.
- NFPA 14 classifies storage as ordinary hazard II, applicable sprinkler density of 0.2 gpm/sq.ft, minimum area of application is 1500 sq. ft - per NFPA 13 11.4.3.3.
- Hose demand of 250 gpm is assumed per NFPA 13, 2016.
- Required minimum pressure at each fire sprinkler at hydraulic most area is 7 psi, per NFPA 13 7.5
- Minimum sprinkler coverage area is 130 sq. ft for ordinary hazard II.

4. Hydraulic Analysis:

Basic system configurations are evaluated such as tree, loop and grid for hydraulic calculations so that the feed main, cross main, branches can be used with small pipe sizes. Higher pipe size means expensive and associated installation cost is high and manpower requirement is higher.Hydraulic remote area assumed for each scenario is 0.2 gpm per 1575 sq. ft.

- **Tree Systems:**

Tree system has larger pipe sizes near the riser. Piping gets smaller toward the most remote area, as the name tree- like branches on tree. Systems that are laid out very symmetrically with short branch lines have relatively low demands when compared with Long Branch lines. See Figure #1, there is no looped piping in a tree system.

- **Gridded Systems:**

Gridded systems provide large number of paths for the water to flow through from the point of available water supply. Adjacent branch lines are looped throughout the system. Designer should ensure that the pipes which are connected to branch lines are sized for the flow rates which they are expected to carry. See Figure #2.

- **Looped Systems:**

Looped systems provide several paths for water to travel to the discharge destination point, as such it has several interconnected pipes. The advantage is, each path results lower flow rate and also less friction loss per path, if each pipe paths are large enough to carry large

5. Percentage of total

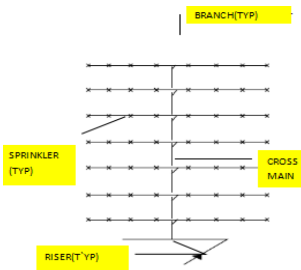


Fig.1.Tree Systems.

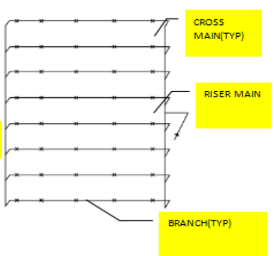


Fig.2.Grid Systems.

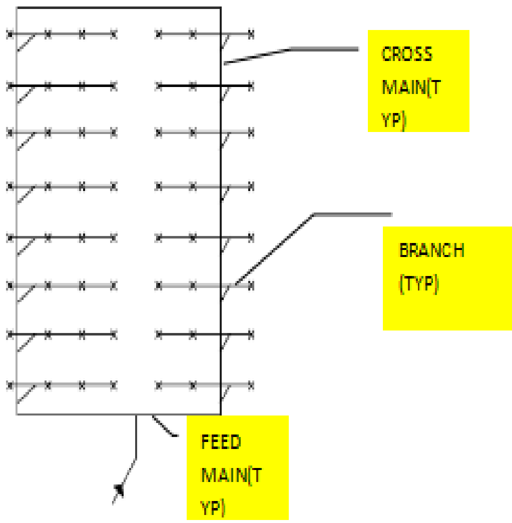


Fig.3. Loop Systems

6. Pipe Materials:

Different pipe friction loss coefficient for pipe wall roughness (Hazen-William, C-value) is evaluated. C ranges from 100 for dry steel systems and to a high of 150 for CPVC pipe.

The advantage of CPVC pipe is smoother than the metal pipes, for friction loss standpipe it means lower pressure loss because of the less friction.

2” or larger pipe is assumed to be schedule 10 pipe, 1 ½” or smaller pipe is assumed to be schedule 40 pipe and risers are at least 4” pipe.

Other benefits of CPVC pipe are it does not corrode while metal pipe corrodes. Hand tools can be used to cut CPVC pipe which reduces the cost savings for installation – for up to 20%. Above all, weight of CPVC pipe is lighter than metal pipe and as such number of pipe supports will be reduced which leads significant cost savings for pipe support material and labor costs.

7. Manifold Systems:

When compared with individual riser located on each floor feeding to fire sprinklers on each floor, manifold provides following benefits located in the fire riser room/mechanical room, see figure #4.

Provides accessibility to fire fighters to operate clearly from one location while communicating with team on different floors

Provide inspector’s one location for inspection and testing of different components

Provides maintenance access during periodic maintenance time frames

Above all, it may provide opportunity to avoid the necessity of using fire pump while complying with pressure requirement at the most hydraulically remote zone. This will be confirmed after performing the hydraulic calculations.

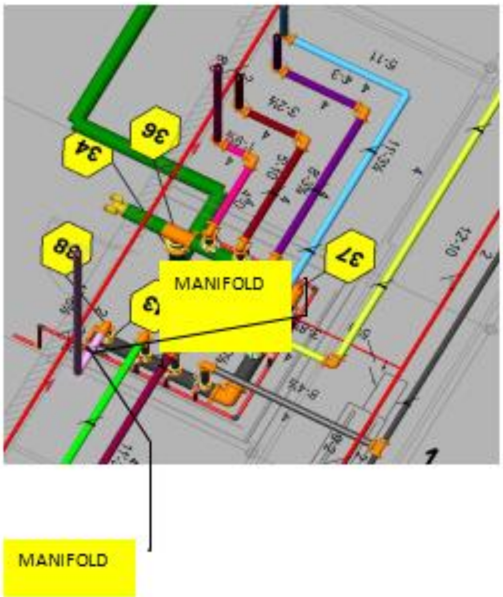


Fig.4.Manifold showing sprinkler risers and standpipe risers.

8. Hydraulic Results:

Hydraulic calculations are performed in a software program with different systems, different pipe sizes, schedules and different Hazen Williams (C-Factors) are evaluated for hydraulic performance. Following are the tables which show the results of different scenarios.

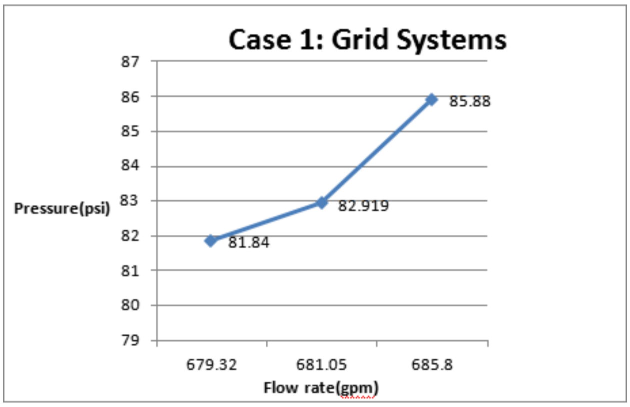
Notes Case -1

Case 1 refers to riser, feed main and cross main size as 4"

Case 1 refers to branch size as 3"

Case 1: Grid Systems

#	Hazen-Williams (C-Factor)	Total System Demand (gpm)	Required pressure(psi)	Safety Margin (%)
1c	150	679.32	81.84	16.84
1b	140	681.05	82.919	15.76
1a	120	685.8	85.88	12.778



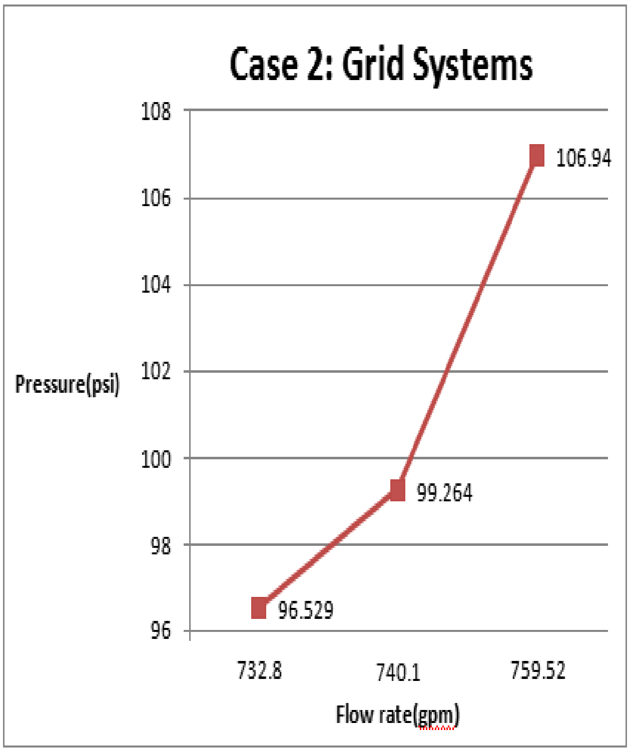
Case 2: Grid Systems

	Hazen-Williams (C-Factor)	Total System Demand (gpm)	Required pressure(psi)	Safety Margin (%)
2c	150	732.8	96.529	1.961
2b	140	740.1	99.264	-0.802
2a	120	759.52	106.94	-8.556

Notes:

1.Case 2 refers to riser, feed main and cross main size as 4"

2.Case 2 refers to branch size as 2"



Case 3: Tree Systems

	Hazen-Williams (C-Factor)	Total System Demand (gpm)	Required pressure(psi)	Safety Margin (%)
3c	150	800.02	186.3	-88
3b	140	808.59	198.9	-100.72
3a	120	831.7	235.445	-137.35

Notes:

1.Case 3 refers to riser, feed main and cross main size as 4"

2.Case 3 refers to branch size as 3"

Case 4: Tree Systems

	Hazen-Williams (C-Factor)	Total System Demand (gpm)	Required pressure(psi)	Safety Margin (%)
4c	150	1298	1467.5	-1372
4b	140	1343.4	1711.8	-1616.5
4a	120	1467.12	2490.2	-2395.62

Notes:

1.Case 4 refers to riser, feed main and cross main size as 4"

2.Case 4 refers to branch size as 2"

Case 5: Loop Systems

	Hazen-Williams (C-Factor)	Total System Demand (gpm)	Required pressure(psi)	Safety Margin(%)
5c	150	672.6	78.2	20.5
5b	140	674.2	78.96	19.74
5a	120	676.66	80.82	17.87

Notes:

1.Case 5 refers to riser, feed main and cross main size as 4"

2.Case 5 refers to branch size as 3"

Case 6: Loop Systems

	Hazen-Williams (C-Factor)	Total System Demand (gpm)	Required pressure(psi)	Safety Margin(%)
6c	150	729.7	91.2	7.337
6b	140	734.78	93.06	5.414
6a	120	748.4	98.34	0.088

Notes:

1.Case 6 refers to riser, feed main and cross main size as 4"

2.Case 6 refers to branch size as 2 "

Cost Savings with steel pipe and CPVC pipe:

Item Description	Steel pipe ($)	CPVC pipe ($)	Savings ($)	Savings (%)
Pipe Sch 10	144,135	128,283	15,852	11
Fittings and Valves	165,400	156,000	9,400	6
Sprinkler Heads	44,280	44,280	0	0
Labor	25,000	15,000	10,000	40
Fire Pump	0	0	0	0
GRAND TOTAL	378,815	343,563	35,252	9

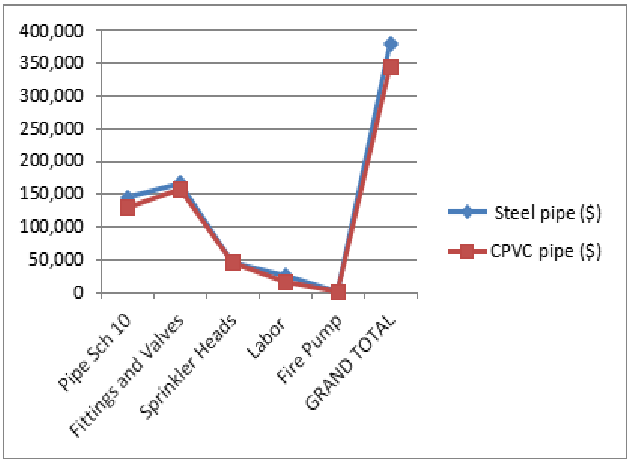


Fig.8.Cost comparison for different materials.

II. CONCLUSION

Based on the above hydraulic analysis, we have observed that the manifold in combination with loop systems (case 6) provides more safety factor while complying with NFPA requirements- see Section Fire protection requirements and standards. This will assist to meet the sprinkler pressure at the most hydraulically remote zone without using the fire pump.

While comparing the two different materials such as steel and CPVC pipes in terms of cost (See figure8), shows that the there is significant cost savings for labor about 40% when installing the piping and components, in addition to the material and fittings/valves savings.

Overall, savings is about 7% for fire suppression systems which benefits owners, contractor and provides reliability in terms maintenance because CPVC does not corrode and light in weight.

Designer needs to be aware that the number of supports and support spacing decrease which will result in additional cost savings up to 10% for similar project, which is not considered in this case study.

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