Sudan University of Science and Technology
College of Engineering
Mechanical Engineering

Modeling of Firefighting System

A Research Submitted in partial Fulfillment for the Requirement of the Degree of B.Sc. (Honors) in Mechanical Engineering

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بسم الله الرحمن الرحيم

ٱللَّهُ نُورُ ٱلسَّمَٰوَٰتِ وَٱلۡأَرۡضِ مَثَلُ
نُورِهِۦ كَمِشۡكَوٰةٖ فِيهَا مِصۡبَاحٌۖ ٱلۡمِصۡبَاحُ فِى زُجَاجَةٍۖ ٱلزُّجَاجَةُ
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بِكُلِّ شَيۡءٍ عَلِيمٞ ٣٥

صدق الله العظيم

سورة النور الآية **(35)**

EDICATION

To

Our parents, family, teachers, friends and all persons who be devoted to me.

To

All those heroes who have lost their altruistic lives during firefighting and fire rescue.

ACKNOWLEDGEMENT

First we thank God that helps us with his blessings to accomplish this dissertation.

The full support and encouragement from Dr. Alsawi Abdallah yahya who supervises this research very closely and guides us up all the time to develop this thesis.

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I wish to thank our families and our friends. Especially thanks to our parents for their love and support all through our life.

Abstract

Fire is the main hazard that is enough to cause a huge damage, so fire safety is a system of work that is paramount system for different engineering works such as architecture, electrical and mechanical engineering. Fire fighting system is consider aims very effectively which could be implemented by; prevention to make sure fires don’t start, precaution to minimise the damage from fire and procedures as an action to take in the event of fire.

Different systems can be used to design a fire fighting system depend on the agent that uses in the system. In this thesis two cases used to analysis two firefighting systems. first case is storge building for clothes,in this case compared between analytical calculation and software simulation of wet sprinkler system. In the second case FM-200 system applied separately in office storge managemen , using software simulations.

المستخلص

الحرائق من المخاطر الرئيسية التي تتسبب في أضرار وخيمة, لذا فإن نظام الحماية من الحريق يعتبر نظاما مهما لمختلف مجالات الهندسة مثل هندسة المعمار والهندسة الكهربائية والهندسة الميكانيكية. نظام مكافحة الحريق يراعي عمليا مجموعة أهداف مثل ؛ منع اندلاع النيران وتقليل الأضرار الناجمة عن النيران و عمل بعض الإجراءات في حال إندلاع النيران.

هناك العديد من الأنظمة التي تستخدم في تصميم أنظمة مكافحة الحريق إعتمادا علي المادة العاملة المستخدمة في النظام. في هذا المشروع تم إستخدام حالتين مختلفتين لتحليل نظامين من أنظمة مكافحة الحريق , الحالة الأولي عبارة عن مستودع تخزين الملابس , في هذه الحالة تم تطبيق نظام الرشاشات الرطب بإستخدام الطريقة التحليلية و برنامج المحاكاة وتمت المقارنة بينهما ,أما الحالة الثانية فقد تم فيها تطبيق نظام الغازات النظيفة (FM-200) لمكتب أدارة المستودع بإستخدام برنامج (FM-200 calculation) .

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ABBREVIATIONS

APW	Air-Pressurized Water
As	Area of coverage per sprinkler
C	Friction loss coefficient
CO2	Carbon dioxide
d	Actual internal diameter of pipe in inches
Dd	Designing density
FM	Factory Mutual research global
GPM	Gallon per minute
HFCs	Hydro fluoro Carbons
K	Nozzle Factor
L	Larger distance between sprinklers
NFPA	National Fire Protection Association
ODP	Ozone Depletion Potential
P	Pdrop Frictional resistance in psi per foot of pipe Pressure drop

CHAPTER ONE

INTRODUCTION

1.1. Introduction

Modeling of firefighting system is the one of the most benefits technique that used to estimate the damage of fire , study and analysis of firefighting system .

Unfortunately, tragic lessons were learnt from recent building and structural fires. The aftermath was devastating, resulting in the damage to assets and loss of lives. Fires in a building with inadequate fire protection features can present severe problems and create complexity in a fire fighting operation. This inevitably causes deficiency in the protection of occupants and contains from fire and smoke during the egress or evacuation.

The fire professionals, consultants and contractors have been adopting mostly on standards from the NFPA (National Fire Protection Association) with regards to the life safety design, building construction, fire protection, firefighting, fire alarm and smoke ventilation systems. This thesis will analyze different two firefighting systems depend on the agent that use to fight the fire, these systems are; wet sprinkler system, FM-200 agent system .

1.2. Problem Definition

Through firefighting system design, companies are differ on applying, the following parameters:

. Fluid sciences

. Pipes diameter, length and material.

. Cost saving.

This thesis will describe the appropriate implementation of the parameters above.

1.3. Purpose of the Thesis

Fire is the main hazard that is enough to cause a huge damage, so fire safety is a system attends wide scope in engineering field. Fire safety could be implemented by

• PREVENTION: Make sure fires don't start

• PRECAUTIONS: Minimize the damage from fire

• PROCEDURES: Action to take in the event of fire

So a fire fighting system is to consider the mentioned aims very effectively. For these considerations study of fighting system is very important. The main objectives of this research are:

• Study firefighting system principles.

• Firefighting network classification.

• Modeling and simulation of firefighting system by using rivet mep.

1.4. Scope

Modeling and simulation of firefighting systems in building by using wet sprinkler system , FM-200 agent system and analyze the results.

1.5. Methodology

Using NFPA, the thesis work focus on designing two types of firefighting according to fluid used such as: wet sprinkler system and FM-200 system.

CHAPTER TWO

Fire Safety

2.1. Definition of fire

Fire is rapid oxidation of a material in the exothermic chemical process of combustion releasing heat , light , and various reaction products slower oxidative processes like rusting or digestion are not included by this definition.

2.2. Definition of firefighting

Is the act of attempting to prevent the spread of and extinguish significant unwanted fires in buildings, vehicles, woodland, etc. a fire fighter suppresses and extinguishes fires to property lives and to prevent the destruction of property and of the environment. Firefighters may provide other services to their communities. [24].

2.3. Basics of a Fire

Fire is a phenomenon with which everyone is familiar. We use it daily to heat our homes and cook our meals. When harnessed, the power and energy from fire serves us well; however, when it is uncontrolled a fire can quickly consume and destroy whatever lies in its path.

While we are all familiar with fire, few of us are aware of its nature and complex processes this section examines the phenomena and various mechanisms at work within a fire and is intended to provide a better understanding of the requirements in fire-fighting scenarios. [23].

2.4. The Fire Triangle

Fire safety, at its most basic, is based upon the principle of keeping fuel sources and ignition sources separate. Three things together produce the chemical reaction that is fire. Take away any of these things and the fire will be extinguished. These three things must be present at the same time to produce fire:

- Enough OXYGEN to sustain combustion
- Enough HEAT to reach ignition temperature
- Some FUEL or combustible material

2.5.Classification of Fire

Class A: Wood, paper, cloth, trash, plastics—solids that are not metals. Class B: Flammable liquids—gasoline, oil, grease, acetone. Includes flammable gases.

Class C: Electrical energized electrical equipment. As long as it's "plugged in."

Class D: Metals potassium, sodium, aluminum, magnesium. Requires Metal-X, foam, and other special extinguishing agents. Most fire extinguishers will have a pictograph label telling that which types of fire the extinguisher is designed to fight. Show table (2.1). [25].

Table (2-1) fire classification

ISO Standard 3941	*NFPA 10*
Class A: Fires involving solid materials, usually of an organic nature, in which combustion normally takes place with the formation of glowing embers	***Class A***: Fires in ordinary combustible materials, such as wood, cloth, paper, rubber and many plastics.
Class B: Fires involving liquids or liquefiable solids.	***Class B***: Fires in flammable liquids, oils, greases, tars, oil-based paints, lacquers and flammable gases.
Class C: Fires involving gases.	***Class C***: Fires which involve energized electrical equipment where the electrical non-conductivity of the extinguishing medium is of importance.
Class D: Fires involving metals.	***Class D***: Fires in combustible metals, such as magnesium, titanium, zirconium, sodium, lithium and potassium.

2.6. The Fire Tetrahedron

a tetrahedron is a solid figure with four triangular faces and is useful for illustrating the combustion process because it shows the chain reaction and each face touches the other three faces, show figure (2.1) [23]

figure (2.1) fire tetrahedron

2.7. Firefighting system classification

2.7.1. Water system

- Sprinkler system
- Hazel system
- Fire hydrant system

2.7.2. Gas system

- Fire Extinguisher
- FM-200, CO_2, FE-13

2.8. Types of Fire Extinguishers

Different types of fire extinguishers are designed to fight different classes of fire. The 3 most common types of fire extinguishers are:

- Water fire extinguishers
- Carbon Dioxide fire extinguishers
- Dry Chemical fire extinguishers
- Foam fire extinguishers
- Dry poder fire extinguishers

Show figure (2.2) Types of fire extinguishers. [23]

Figure (2.2) Types of Fire Extinguishers

2.8.1. Water Fire Extinguishers

Large silver fire extinguishers that stand about 2 feet tall and weight about 25 pounds when full. APW stands for “Air-Pressurized Water.” Filled with ordinary tap water and pressurized air, they are essentially large squirt guns. The characteristics of APWs are:

• Extinguish fire by taking away the “heat” element of the Fire Triangle.

• Designed for Class A fires only: wood, paper, cloth. Using water on a flammable liquid fire could cause the fire to spread. Using water on an electrical fire increases the risk of electrocution. If there have no choice but to use an APW on an electrical fire, electrical equipment must be un-plugged or de-energized.

• They will be found in older buildings, particularly in public hallways, as well as in residence halls, they will also be found in computer laboratories. It is important to remember, however, that computer equipment must be disconnected from its electrical source before using a water extinguisher on it.

2.8.2. Carbon Dioxide Fire Extinguisher

The pressure in a CO_2 extinguisher is so great, bits of dry ice may shoot out of the horn. The characteristics of CO_2 are:

• Their cylinders are red. They range in size from 5 lbs to 100 lbs or larger. On larger sizes, the horn will be at the end of a long, flexible hose.

• They are designed for Class B and C (Flammable Liquids and Electrical Sources) fires only.

• They will frequently be found in laboratories, mechanical rooms, kitchens, and flammable liquid storage areas.

• All CO_2 extinguishers must undergo hydrostatic testing and recharge every 5 years. Carbon dioxide is a non-flammable gas that takes away the oxygen element of the fire triangle. Without oxygen, there is no.

• Very cold as it comes out of the extinguisher, so it cools the fuel as well.

• Ineffective in extinguishing a Class A fire because it may not be able to displace enough oxygen to successfully put the fire out. Class A materials may also smolder and re-ignite.

•

2.8.3. Dry Chemical (ABC) Fire Extinguishers

Dry chemical extinguishers calls (ABC) fire extinguishers depending on class A, B and C of fire. They put out fire by coating the fuel with a thin layer of dust. This separates the fuel from the oxygen in the air. The powder also works to interrupt the chemical reaction of fire. These extinguishers are very effective at putting out fire. ABC extinguishers are red. On campus, they range in size from 5 to 20 lbs. ABC fire extinguishers are filled with a fine yellow/white powder. The greatest portion of this powder is composed of mono ammonium phosphate. the extinguishers are pressurized with nitrogen. Dry chemical extinguishers come in a variety of types; DC (for “Dry Chemical”), ABC (can be used on Class A, B, or C fires) and BC (designed for use on Class B and C fires). It is extremely important to identify which types of dry chemical extinguishers are located in the design area; An “ABC” extinguisher will have a label, indicating it may be used on Class A, B and C fires. Dry chemical extinguishers with powder designed for Class B and C fires (“BC” extinguishers) may be located in places such as commercial kitchens and areas with flammable liquids. On campus, ABC’s can be found in public hallways of new buildings, in laboratories, break rooms, offices, chemical storage areas, mechanical rooms, University vehicles, etc [3].

2.8.4. Foam fire extinguishers

Foam fire extinguishers or (AFFF fire extinguishers) are more versatile than water and are lighter in weight compared with water equivalents delivering similar suppressant performance Foam fire extinguishers can be used for class A&B fires but are not recommended for fires involving electricity unless the electrical current can be disconnected first. Foam fire extinguishers are colour coded with a cream label. A Foam fire extinguishers discharges a foam solution under pressure that forms a blank or film on the surface of a burning liquid creating a barrier between the fire vapours and the air necessary to support combustion thereby smothering the fire. [5]

2.8.5. Dry powder fire extinguishers

Dry powder fire extinguishers are similar to dry chemical except that they extinguish the fire by separating the fuel from the oxygen element or by removing the heat element of the fire triangle.

However, dry powder extinguishers are for class D or combustible metal fires , only they are ineffective on all other classes of fires. [25]

2.9. Literature Review

There are so many studies in firefighting, some engineers designed samples of firefighting systems.

In 2006 model of sprinkler system was designed by engineer Tamer A. Ghbai, a wet riser sprinkler selected using tree network to complete design including the hydraulic calculation that required to the sprinkler network [1]

In March 2010 Ahmed M.Sami represent a project of sprinkler system using NFPA13, the calculation of the system expressed using the Elite for Firefighting Calculation program, the system was designed by Gulf Consulting Group in Doha [2].

CHAPTER THREE

SPRINKLER SYSTEM

&

FM-200AGENT SYSTEM

3. sprinkler system

3.1. Background

National Fire Protection Association (NFPA 13), Standard for the installation of sprinkler systems, was prepared by the technical committee on hanging and bracing of water-based fire protection systems, the technical committee on sprinkler system discharge criteria, and the technical committee on sprinkler system installation criteria, released by the technical correlating committee on automatic sprinkler systems, and acted on by the National Fire Protection Association, Inc., at its May meeting held May 17-20, 1999, in Baltimore. It was issued by the standards council on July 22, 1999, with an effective date of August 13, 1999 [4].

3.2. SprinklerSystem

3.2.1 Definition of Sprinkler System

For fire protection purposes, an integrated system of underground and overhead piping designed in accordance with fire protection engineering standards. The installation includes one or more automatic water supplies.

The portion of the sprinkler system aboveground is a network of specially sized or hydraulically designed piping installed in a building, structure, or area, generally overhead, and to which sprinklers are attached in a systematic pattern. The valve controlling each system riser is located in the system riser or its supply piping.

Each sprinkler system riser includes a device for actuating an alarm when the system is in operation.National Fire Protection Association (NFPA

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Each sprinkler system riser includes a device for actuating an alarm when the system is in operation The system is usually activated by heat from a fire and discharges water over the fire area[4].

3.2.2. Types of SprinklerSystems

3.2.2.1. Antifreeze SprinklerSystem

A wet pipe sprinkler system employing automatic sprinklers that are attached to a piping system ,that contains an antifreeze solution and that are connected to a water supply.

The antifreeze solution is discharged, followed by water, immediately upon operation of sprinklers opened by heat from afire.

3.2.2.2 Circulating Closed-Loop Sprinkler System

Awet pipe sprinkler system having non-fire protection connections to automatic sprinkler systems in a closed-loop piping arrangement for the purpose of utilizing sprinkler piping to conduct water for heating or cooling, where water is not removed or used from the system but only circulated through the piping system.

3.2.2.3. Combined Dry Pipe-Pre action SprinklerSystem

A sprinkler system employing automatic sprinklers attached to a piping system containing air under pressure with a supplemental detection system installed in the same areas as the sprinklers.

Operation of the detection system actuates tripping devices that open dry pipe valves simultaneously and without loss of air pressure in the system. Operation of the detection system also opens listed air exhaust valves at the end of the feed main, which usually precedes the opening of sprinklers. The detection system also serves as an automatic fire alarmsystem.

3.2.2.4 Deluge SprinklerSystem

A sprinkler system employing open sprinklers that are attached to a piping system that is connected to a water supply through a valve that is opened by the operation of a detection system installed in the same areas as the sprinklers.

When this valve opens, water flows into the piping system and discharges from all sprinklers attachedthereto.

3.2.2.5 Dry Pipe SprinklerSystem

A sprinkler system employing automatic sprinklers that are attached to a piping system containing air or nitrogen under pressure, the release of which (as from the opening of a sprinkler) permits the water pressure to open a valve known as a dry pipe valve, and the water then flows into the piping system and out the opened sprinklers.

3.2.2.6 Gridded SprinklerSystem

A sprinkler system in which parallel cross mains are connected by multiple branch lines.An operating sprinkler will receive water from both endsofitsbranchlinewhileotherbranchlineshelptransferwaterbetween crossmains.

3.2.2.7 Looped SprinklerSystem

A sprinkler system in which multiple cross mains are tied together so as to provide more than one path for water to flow to an operating sprinkler and branch lines are not tied together.

3.2.2.8 Preaction SprinklerSystem

A sprinkler system employing automatic sprinklers that are attached to a piping system that contains air that might or might not be under pressure, with a supplemental detection system installed in the same areas as the sprinklers.

3.2.2.9 Wet Pipe SprinklerSystem

A sprinkler system employing automatic sprinklers attached to a piping system containing water and connected to a water supply so that water discharges immediately from sprinklers opened by heat from a fire.

3.2.3. System Components

3.2.3.1. Branch Lines

The pipes in which the sprinklers are placed, either directly or through risers.

3.2.3.2. Cross Mains

The pipes supplying the branch lines, either directly or through risers.

3.2.3.3. Feed Mains

The pipes supplying cross mains, either directly or through risers

3.2.3.4. Flexible Listed Pipe Coupling

A listed coupling or fitting that allows axial displacement, rotation, and at least 1 degree of angular movement of the pipe without inducing harm on the pipe. For pipe diameters of 8 in. (203.2 mm) and larger, the angular movement shall be permitted to be less than 1 degree but not less than 0.5 degree sprinkler systems.

3.2.3.5. System Riser

The aboveground horizontal or vertical pipe between the water supply and the mains (cross or feed) that contains a control valve (either directly or within its supply pipe) and a water flow alarm device.

3.2.4. Classification of Sprinklers

Sprinklers are classified in two categories; according to design and performance characteristics and according to orientation for these types.

3.2.4.1. Suppression Fast-Response (SFR)Sprinkler

A type of fast-response sprinkler is listed for its capability to provide fire suppression of specific high-challenge fire hazards.

3.2.4.2. Extended Coverage Sprinkler

A type of spray sprinkler with maximum coverage areas.

3.2.4.3. Large Drop Sprinkler

A type of sprinkler that is capable of producing characteristic large water droplets and that is listed for its capability to provide fire control of specific high-challenge fire hazards.

3.2.4.4. Nozzles

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

3. 2.4.5. Old-Style/Conventional Sprinkler

A sprinkler that directs from 40 percent to 60 percent of the total water initially in a downward direction and that is designed to be installed with the deflector either upright or pendent.

3. 2.4.6. Open Sprinkler

A sprinkler that does not have actuators or heat-responsive elements.

3.2.4.7. Quick-Response Early Suppression (QRES)Sprinkler

A type of quick-response sprinkler that is listed for its capability to provide fire suppression of specific fire hazards.

3.2.4.8. Quick-Response Extended Coverage Sprinkler

A type of quick-response sprinkler that complies with the extended protection areas.

3.2.4.9. Quick-Response (QR)Sprinkler

A type of spray sprinkler that is listed as a quick-response sprinkler for its intended use.

3.2.4.10. Residential Sprinkler

A type of fast-response sprinkler that has been specifically investigated for its ability to enhance survivability in the room of fire origin and is listed for use in the protection of dwelling units.

3.2.4.11 Special Sprinkler

A sprinkler that has been tested.

3.2.4.12. Spray Sprinkler

A type of sprinkler listed for its capability to provide fire control for a wide range of fire hazards.

3.2.4.13. Standard Spray Sprinkler

A spray sprinkler with maximum coverage areas.

3.2.4.14. Concealed Sprinkler

A recessed sprinkler with cover plates.

3.2.4.15. Flush Sprinkler

A sprinkler in which all or part of the body, including the shank thread, is mounted above the lower plane of the ceiling.

3.2.4.16. Pendent Sprinkler

A sprinkler designed to be installed in such a way that the water stream is directed downward against the deflector.

3.2.4.17. Recessed Sprinkler

A sprinkler in which all or part of the body, other than the shank thread, is mounted within a recessed housing.

3.2.4.18. Sidewall Sprinkler

A sprinkler having special deflectors that are designed to discharge most of the water away from the nearby wall in a pattern resembling one-quarter of a sphere, with a small portion of the discharge directed at the wall behind the sprinkler.

3.2.4.19. Upright Sprinkler

A sprinkler designed to be installed in such a way that the water spray is directed upwards against the deflector.

3.2.5. Classification of Occupancies

Occupancy classifications for this standard shall relate to sprinklerdesign, installation, and water supply requirements only.

They shall notbeintended to be a general classification of occupancy hazards.

3.2.5.1.Light Hazard Occupancies

Light hazard occupancies shall be occupancies or portions of other occupancies where the quantity and/or combustibility of contents is low and fires with relatively low rates of heat release are expected.

3.2.5.2.Ordinary Hazard Occupancies

Ordinary hazard divided in two groups; ordinary hazard (Group 1) occupancies shall be occupancies or portions of other occupancies where combustibility is low, quantity of combustibles is moderate, stockpiles of combustibles do not exceed 8 ft (2.4 m), and fires with moderate rates of heat release are expected.

Ordinary hazard (Group 2) occupancies shall be occupancies or portions of other occupancies where the quantity and combustibility of contents is moderate to high, stockpiles do not exceed 12 ft (3.7 m), and fires with moderate to high rates of heat release areexpected.

3.2.5.3.Extra Hazard Occupancies

Extra hazard also is divided in two groups; (Group 1) occupancies shall be occupancies or portions of other occupancies where the quantity andcombustibilityofcontentsisveryhighanddust,lint,orothermaterials are present, introducing the probability of rapidly developing fires with high rates of heat release but with little or no combustible or flammable liquids.

And extra hazard (Group 2) occupancies shall include occupancies with moderate to substantial amounts of flammable or combustible liquids or occupancies where shielding of combustibles is extensive.

3.2.6.Position, Location, Spacing, and Use of Sprinklers

3.2.6.1.General

Sprinklers shall be located, spaced, and positioned in accordance with the requirements of this section. Sprinklers shall be positioned to provide protection of the area consistent with the overall objectives of this standard by controlling the positioning and allowable area of coverage for eachsprinkler.

3.2.6.2. Protection Areas perSprinkler

3.2.6.2.1. Determination of the Protection Area ofCoverage

The protection area of coverage per sprinkler (As) shall be determined as; Along Branch Lines. Determine distance between sprinklers (or to wall or obstruction inthe case of the end sprinkler on the branch line) upstream and downstream.

Choose the larger of either twice the distance to the wall or the distance to the next sprinkler. This dimension will be defined as S. And Between Branch Lines. Determine perpendicular distance to the sprinkler on the adjacent branch line (or to a wall or obstruction in the case of the last branch line) on each side of the branch line on which the subject sprinkler is positioned.

Choose the larger of either twice the distance to the wall or obstruction or the distance to the next sprinkler. This dimension will be defined as L.

The protection area of coverage of the sprinkler shall be established by multiplying the S dimension by the L dimension, as follows:

As = S * L ………………… (3.1)

Where:

As = Area coverage per sprinkler. S = Along Branch Lines.

L = length Between Branch Lines

3.2.6.2.2.Maximum Protection Area of Coverage

The maximum allowable protection area of coverage for a sprinkler (As) shall be in accordance with the value indicated in the section foreach type or style of sprinkler.

The maximum area of coverage of any sprinkler shall, table (3.1) explain protection area limitation persprinkler.

3.2.6.3.Sprinkler Spacing

3.2.6.3.1.Maximum Distance between Sprinklers

The maximum distance permitted between sprinklers shall be based on the centerline distance between sprinklers on the branch line or on adjacent branch lines. The maximum distance shall be measured along the slope of the ceiling. The maximum distance permitted between sprinklers shall comply with the value indicated in Tables (3-2)(a ,b ,c) for each type or style of sprinkler.

3.2.6.3.2. Maximum Distance fromWalls

The distance from sprinklers to walls shall not exceed one-half of the allowable maximum distance between sprinklers. The distance from the wall to the sprinkler shall be measured perpendicular to the wall.

3.2.6.3.3. Minimum Distance from Walls

Sprinklersshallbelocatedaminimumof4in.(102mm) from a wall. The distance from the wall to the sprinkler shall be measured perpendicular to the wall.

3.2.6.3.4. Minimum Distance between Sprinklers

A minimum distance shall be maintained between sprinklers to prevent operating sprinklers from wetting adjacent sprinklers and to prevent skipping of sprinklers. Sprinklers shall be spaced not less than 6 ft (1.8 m) on center.

3.2.7.Design Area

The water supply for sprinklers only shall be determined either from the area/density curves of Figure (3-1) where area/density criteria is specified for special occupancy hazards.

When using Figure (3-1), the calculations shall satisfy any single point on the appropriate area/density curve.

3.2.8.Hydraulic Calculation Procedures

3.2.8.1.General

A calculated system for a building, or a calculated addition to a system in an existing sprinklered building, shall supersede the rules in this standard governing pipe schedules, except that all systems shall continue to be limited by area and pipe sizes shall be no less than 1 in. (25.4 mm) nominal for ferrous piping and 3/4 in. (19 mm) nominal for copper tubing or nonmetallic piping listed for fire sprinkler service.

The size of pipe, number of sprinklers per branch line, and number of branch lines per cross main shall otherwise be limited only by the available water supply.

However, sprinkler spacing and all other rules covered in this and other applicable standards shall be observed.

3.2.8.2.Friction Loss Formula

Pipe friction losses shall be determined on the basis of the Hazen- Williams formula, as follows:

$p = (4.52Q^{1.85} / C^{1.85} d^{4.87})$ ..……………… (3.2)

Where

p = frictional resistance in psi per foot of pipe

Q = flow in gpm

C = friction loss coefficient

d = actual internal diameter of pipe in inches

3.2.8.3.Equivalent Pipe Lengths of Valves and Fittings

Table (3-3) shall be used to determine the equivalent length of pipe for fittings and devices unless manufacturer's test data indicate that other factorsareappropriate.Forsaddle-typefittingshavingfrictionlossgreater thanthatshowninTable(3-3),theincreasedfrictionlossshallbeincluded in hydraulic calculations. For internal pipe diameters different from Schedule 40 steel pipe, the equivalent feet shown in the table shall be multiplied by a factor derived from the followingformula:

(Actual inside diameter/Schedule 40 steel pipe inside diameter)=Factor

3.2.9. Schedule for Light Hazard Occupancies

Branch lines shall not exceed eight sprinklers on either side of a cross main. Exception: Where more than eight sprinklers on a branch line are necessary, lines shall be permitted to be increased to nine sprinklers by making the two end lengths 1 in. (25.4 mm) and 11/4 in. (33 mm), respectively, and the sizes thereafter standard.

Ten sprinklers shall be permitted to be placed on a branch line, making the two end lengths 1 in. (25.4 mm) and 11/4 in. (33 mm), respectively, and feeding the tenth sprinkler by a 21/2-in. (64-mm) pipe. Pipe sizes shall be in accordance with Table (3-4).

Each area requiring more sprinklers than the number specifiedfor31/2-in.(89-mm) pipe in table(3-4)and without subdividing partitions (not necessarily fire walls) shall be supplied by mains or risers sized for ordinary hazard occupancies.

3.2.10. Schedule for Ordinary Hazard Occupancies

Branch lines shall not exceed eight sprinklers on either side of a cross main.

Exception: Where more than eight sprinklers on a branch line are necessary, lines shall be permitted to be increased to nine sprinklers by making the two end lengths 1 in. (25.4 mm) and 11/4 in. (33 mm), respectively, and the sizes thereafter standard. Ten sprinklers shall be permitted to be placed on a branch line, making the two end lengths 1 in. (25.4 mm) and 11/4 in. (33 mm), respectively, and feeding the tenth sprinkler by a 21/2-in. (64-mm) pipe.

Pipe sizes shall be in accordance withTable (3-5). Where the distance between sprinklersonthebranchline exceeds 12 ft (3.7 m) or the distance between the branch lines exceeds 12 ft (3.7 m), the number of sprinklers for a given pipe size shall be in accordance with Table (3.5).

3.3. FM-200 Agent

3.3.1. Definition

FM-200 Agent is extinguishing agent. The Fire trace Indirect FM-200 Clean Agent Automatic Fire Extinguisher Unit is UL Listed by Underwriters Laboratories, ULC Listed by Underwriters' Laboratories of Canada, and approved with Factory Mutual research global (FM). These units are designed for total flooding applications, using FM-200 Clean Agent, in accordance NFPA-2001, Standard on Clean Agent Fire Extinguishing Systems.

3.3.2.FM-200 Extinguishing Agent

The extinguishing agent used in firetrace pre-engineered automatic indirect fire suppression units is Heptaneflourpropane, more commonly known as FM-200. FM-200 (1,1,1,2,3,3,3-heptafluoropropane, CF3CHFCF3) is a colorless odorless gas, low in toxicity, electrically non- conductive, leaves no residue, and is an extremely effective fire suppression agent.

FM-200 extinguishes a fire by a combination of chemical and physical mechanisms without affecting the available oxygen. This allows personnel to see and breath, permitting them to safely leave the fire area.

It is an effective Total Flooding extinguishing agent that can be used on many types of fires. It is effective for use on Class A surface fires, Class B flammable liquid fires, and Class C electricalfires.

3.3.2.1. Cleanliness

FM-200 is clean and leaves no residue, thereby minimizing after fire clean up, along with keeping expensive downtime to a minimum. Most materials such as steel ,aluminum, stainless steel ,brass ,as well as plastics, rubber and electronic components are not affected by exposure to FM-200. This agent is also environmentally friendly, having an ozone depletion potential (ODP) of 0.00.

3.3.2.2.Physical Properties of FM-200 (HFC-227ea)

- Chemical Name: Heptafluoropropane (CF3CHFCF3).
- Molecular Weight 170.0
- Boiling Pont (oF) at 14.7psia
- Freezing Point 204 (oF)
- Critical Temperature 214 (oF)
- Critical Pressure 422 (psia)
- Critical Volume 0.0258 (ft3/Ibm)
- Critical Density 38.76 (Ibm/ft3)
- Specific Heat, Liquid (BTU/Ib-oF) at 77oF
- Specific Heat, Vapor (BTU/Lb-oF) at constant 0.185 pressure (1 A.) at 77^{o}F
- Heat of Vaporization (BTU/Ib) at Boiling Point 56.7
- Thermal Conductivity (BTU/h ft) of Liquid at 77oF 0.040 Viscosity, Liquid (Ib/fthr) at 77oF 0.433, Vapor Pressure 66.4 (psi) at 77oF

- And Ozone Depletion Potential 0.00

3.3.2.3. Fill Density

Each Fire trace FM-200 storage cylinder has been designed for a maximum fill density as shown in Table 3-2, and super- pressurized with nitrogen to 150 psig +10, -0 psig at 70^{o}F (10.4 bars gage + 0.7, -0 bars gage at 21^{o}C).

It is important that these values not be exceeded. Fill density and temperature significantly affect the pressure in the storage cylinder. At elevated temperatures the rate of increase in pressure is very sensitive to fill density (Figure 3.2). If the maximum fill density is exceeded; the pressure will increase rapidly with temperature increase so as to present a hazard to personnel and property.

Adherence to the limits on fill density and pressurization levels will prevent excessively high pressures from occurring if the storage cylinder is exposed to elevated temperature. This will also minimize the possibility of an inadvertent discharge of agent through the cylinder pressure relief device, where provided.

It is recommended to not mount the cylinder in direct sunlight if this would create elevated cylinder temperatures.

3.3.3.System Description

The Fire trace FM-200 Automatic Indirect units are available in 3 sizes, namely:

- Model ILP 300: Charged with 3.0 Lbs. ofFM-200
- Model ILP 600: Charged with 6.0 Lbs. of FM-200

- Model ILP 1200: Charged with 12.0 Lbs. of FM-200

These units are designed for use in Total Flooding applications only, where the hazard is normally unoccupied.

The Fire trace indirect units can be used, but are not limited, to protect; electrical and electronic cabinets, telecommunication areas, data Processing areas and cabinets, other high value assets, laboratory fume /exhaust cabinets, pump enclosures, UPS units, flammable chemicals storage cabinets, generator enclosures, transformer cabinets, computer/data storage cabinets, CNC & VMC Machining centers, and many other applications.

FM-200 is a gaseous fire-extinguishing agent that is effective for use on class A – surface type fires, class B – flammable liquid fires, and class C – electrical equipment fires .

FM-200 should not be used where pyrotechnic chemicals containing their own oxygen supply, reactive metals such as lithium, sodium, potassium, magnesium, titanium, zirconium, uranium and plutonium, metal hydrides, or chemicals capable of undergoing auto thermal decomposition, such as certain fire trace FM-200 Automatic Indirect units consists of ; FM-200 Cylinder/Valve assembly, cylinder mounting Bracket, fire trace detector/actuation tubing and fittings (no substitute), discharge nozzles, pressure switch, and discharge tubing and fittings (furnished by others).

Once installed, the Fire trace Automatic Unit becomes a self- contained, self-actuating unit that does not require an external source of power or electricity.

The unit utilizes unique Fire trace flexible tubing that is attached to the top of the cylinder valve. This tubing is pressurized with dry nitrogen to maintain the cylinder valve in the closed position. This tubing is temperature sensitive, and acts as a continuous linear thermal detector that ruptures at approximately 212^{o}F (100^{o}C). Once the detector tubing is ruptured, the cylinder valve automatically opens, allowing the FM-200 agent to flow through the discharge tubing, distributing the extinguishing agent through the nozzle(s) into the protected area.

Upon actuation the pressure switch can be used to indicate discharge, shutdown ventilation, close all openings, shut-off electrical power, etc. as may be required.

3.3.3.1. Operating Pressure

The FM 200 cylinder is super-pressurized with dry nitrogen to 150 psig at 70^{o}F.

3.3.3.2. Operating Temperature Range Limitations

The ambient operating temperature range for all unit components is: 0^{o}F to +130^{o}F (-17.8^{o}C to +54.4^{o}C).

3.3.4. Component Descriptions

3.3.4.1.FM-200 Cylinder/Valve Assemblies

FM-200 is stored in DOT steel cylinders as a liquefied compressed gas, super-pressurized with nitrogen to 150 psig at 70^{o}F (1,034 KPa at 21^{o}C). The cylinder/valve assemblies are available in 3 sizes,namely:

- 3 LB size; filled with 3.0 LBS (1.36 Kg) ofFM-200
- 6 LB size; filled with 6.0 LBS (2.72 Kg) of FM-200
- 12 LB size filled with 12.0 LBS (5.45 Kg) of FM-200

Each cylinder is equipped with a brass valve, a pressure gauge to monitor cylinder pressure ,and a quarter turn ball valve that interfaces with the Fire trace detector tubing. The ball valve must be kept closed at all times when the cylinder is not in service. In addition, the 6 and 12Lb size cylinder valves valve is equipped with a pressure relief (rupture disc) device in compliance with DOT requirements.

Each valve is also equipped with (2) discharge outlet ports. Each outlet port is provided with a safety plug that must be installed in the discharge outlet whenever a cylinder is not in service.

These plugs are safety devices designed to prevent uncontrolled discharge of the cylinder in the event that the valve is accidentally actuated. Table (3-6) describes the 3, 6, and 12 LB cylinder assemblies.

Each cylinder is equipped with a straight siphon tube and can only be mounted in a vertical (upright)position.

The Fire trace FM-200 units are designed for an operating temperature range of 0^{o}F to +130^{o}F. Table (3.8) shows the cylinder gauge, pressure-temperature relationship based on a maximum fill density of 75 Lb/Ft3; and a charging pressure of 150 psig at 70^{o}F.

3.3.4.2. Cylinder Mounting Bracket

A wall mounted painted steel bracket is used to mount the cylinder/valve assembly in a vertical (upright) position. Each bracket is equipped with (2) integral quick-clamp straps.

3.3.4.3 .Fire trace Flexible Detector/Actuation Tubing

The Fire trace tubing is used as a combination linear heat detector andunitactivationdevicetocauseactuationoftheFM-200agentcylinder. The tubing is installed throughout the hazard volume, with one end connected to the top of the FM-200 cylinder valve.

The tubing is pressurized with nitrogen to 150 psig while maintaining the ball valve in the “OFF” position.

An optional pressure gauge or pressure switch can be connected to the other end of the detector tube to monitor unit pressure and/or signal unit actuation etc.

The detector tubing is heat sensitive and in a fire situation is designed to rupture at any point along the tube when the temperature reaches 212^{o}F (100^{o}C).

The rupture of the tube releases the nitrogen pressure causing the FM-200 cylinder valve to actuate, resulting in complete discharge of the FM-200 agent through the nozzles.

3.3.4.4. Discharge Nozzles

Discharge nozzles are used to distribute FM-200 agent uniformly throughout the hazard area. Two size nozzles are available.

The small nozzle is for use with the 3 Lb. size unit only.

The medium size nozzle is for use with the 6 Lb. and 12 Lb size units. The nozzles discharge in a 360^{o} pattern and are designed to be installed at the top of the hazard in the center of the area being protected. The nozzles are brass with female NPT pipe threads.

3.3.4.5. Pressure Switch

A pressure switch is provided as a standard part of the cylinder valve assembly and is connected directly into the pressurized portion of the cylinder valve.

This pressure switch is used to monitor unit pressure, unit actuation and or to energize or de-energize electrically operated equipment. An additional pressure switch is available as an optional item.

This switch is connected at the end of the line of the fire trace detector tubing to provide additional electrical functions as may be required.

Fire trace recommends that all units use a pressure switch coupled with some device to alert personnel in the event of discharge.

3.3.4.6. Recharge Adapters, FM-200 Cylinder

The recharge adapter is installed in one of the cylinder valve discharge ports during the cylinder recharging procedure.

The adapter is used for refilling the cylinder with FM-200 agent.

3.3.4.7. Cylinder Nitrogen Recharge Adapter

The recharge adapter is connected to a fire trace tubing, and the other end of the tubing is attached to the ball valve, located on top of the cylinder valve, during the charging procedure.

The adapter is used to apply nitrogen pressure to internally seat the valve piston, and to super pressurize the FM-200 cylinder with nitrogen.

3.3.4.8. Cylinder Hydrostatic Pressure Test Adapters

These adapters are available for use when a cylinder hydrostatic test is required in order to comply with DOT regulations.

3.3.4.9.FM-200 Warning Nameplate

The warning plate is required to warn personnel not to enter the hazard area during or after discharge.

Warning signs shall be provided in aconspicuous location, at the entrance to the protected areas, or in the case of cabinet protection on the front face of the cabinet.

3.3.5. System Design and Limitation

3.3.5.1. General

The fire trace series of FM-200 Agent pre-engineered automatic indirect units were tested and limits established by fire trace. Units are listed by Underwriters Laboratories Inc and Underwriters' Laboratories of Canada, and approved by Factory Mutual Research Corp.

These units were subjected to numerous performance and fire tests in order to verify their suitability and to establish design limitations for, hazard volume, nozzle area coverage and heights, nozzle placement, discharge time and flow rates, design concentrations & design factors, and Detector tubing placement.

3.3.5.2. Design Procedure

The procedures should be used to design a fire trace model ILP FM-200 pre-engineered automatic unit are conduct a survey and analysis of the hazard to be protected and determine the height, length, and width of the enclosure.

Calculate the volume using table(3-9).

Determine the anticipated minimum and maximum ambient temperatures expected within the enclosure to be protected.

Determine the minimum design concentration required for the hazard using table (3-10-a) and table (3-10-b).

Determine the integrity of the enclosure. Are there any openings that must be closed at the time of agent discharge.

Calculate the quantity of FM-200 agent required to provide the proper design concentration at the minimum anticipated ambient temperature in the hazard enclosure using table (3-11)

Determine the cylinder size required, based on the hazard volume limitations, enclosure size, and quantity of FM-200 agent required.

Calculate the maximum concentration anticipated, based on the total quantity of FM-200 agent being used at the maximum ambient temperature expected within the enclosure.

Table (3-12) (a, b, c) : Maximum Volume That Can Be Protected By 3 Lb. Unit

Determine the location of the FM-200 cylinder. Determine the location and quantity of nozzles required, based on the size and configuration of the enclosure using table (3-13).

• Determine the routing and quantity of discharge pipe (tubing) required. The discharge pipe (tubing) and fitting limitations must not be exceeded using table (3-14).

CHAPTER FOUR

CALCULATIONS AND ANALYSIS

4.1. Calculation of sprinkler system

4.1.1. Classification of Occupancies

The case of the design is a storage building , included number of workshop machines, height of occupancies inside the workshop 1.8 m, and combustibility of contents is moderate to high, so the classification of occupancies is ordinary hazard (Gruop2).

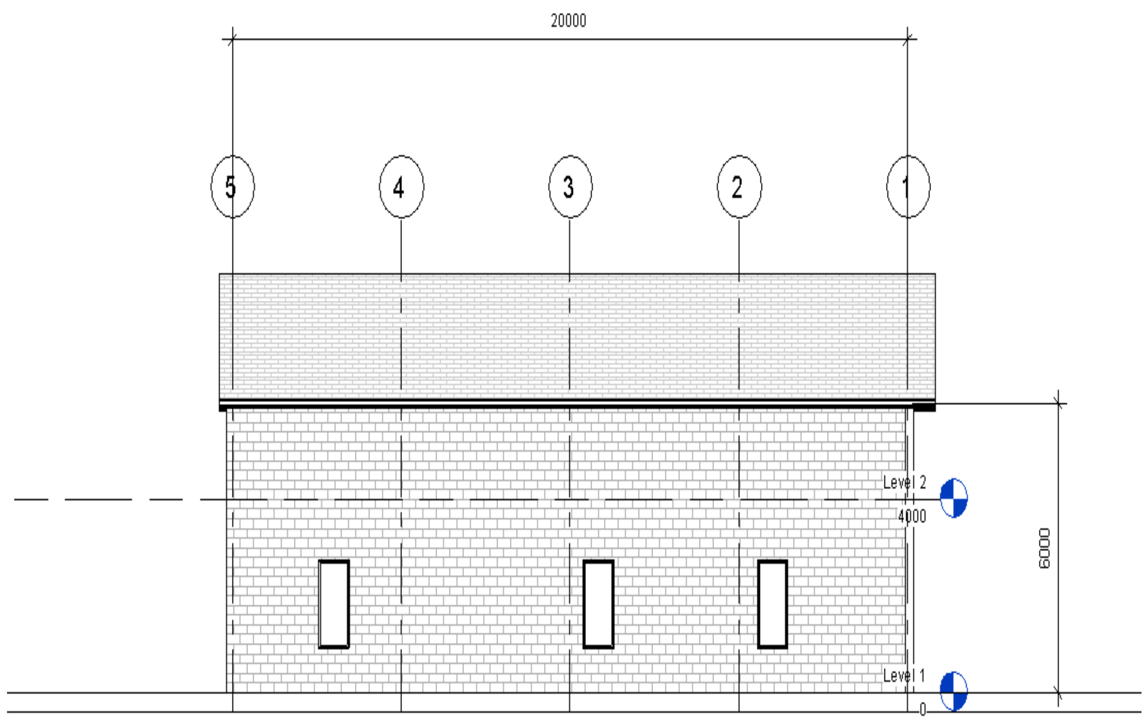


Figure 4-1: Geometric dimension of the storage

4.1.2. Number of Sprinklers, and Spacing between Sprinklers

No. of Sprinkler = Area / Area coverage per Sprinkler

Area=10 *20 = 200 m^2

For ordinary hazard, maximum area coverage per Sprinkler = 12.1 m^2 from table (3-1).

Number of Sprinklers = 200/12.1 ≈ 16

Maximum spacing between sprinkler 15 ft (4.56 m), from table (3.2.a), and the distance from sprinklers to walls shall not exceed one-half of the allowable distance between sprinkler. For these considerations and for distribute the sprinklers to be consentient with the surface area let the number of sprinklers 20.

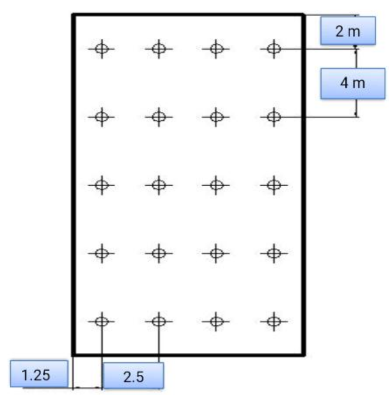


Figure (4-3): Selected Spacing Between Sprinklers

4.1.3. Area Coverage Per Sprinkler (Asp)

Asp = 4*2.50 = 10 m^2

Using table (3-2-a), this value is acceptable (Less than maximum spacing 130 ft^2).

4.1.4. Selection of the Sprinklers Network:

Tree network system can be used for this case, the design calculations using this way is not complex.

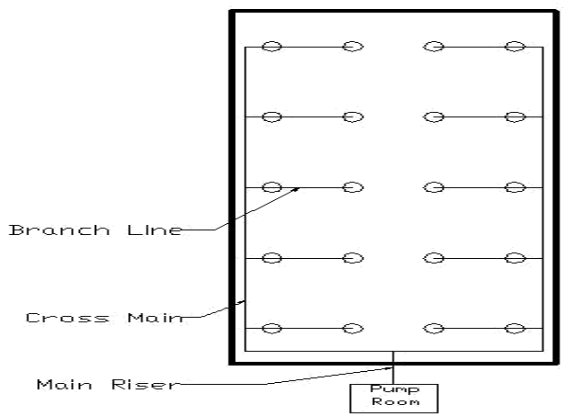


Figure (4-4). Sprinklers Network Using the Tree Network System

4.1.5. Selection of the Pipes Diameters

Ordinary hazard pipe schedule can be used to select the diameters of the pipes depend on the numbers of the sprinklers which the pipe feeds. Using steel pipe, the selected diameters of the pipes can be shown in the figure bellow in accordance with Table (3-5):

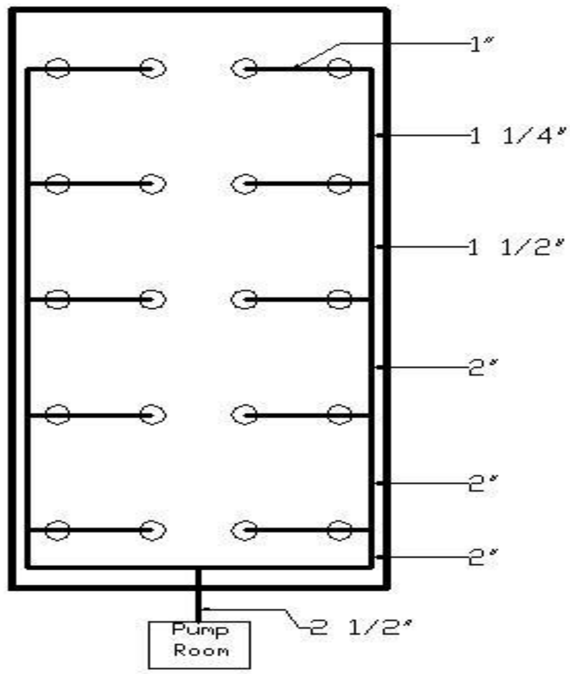


Figure (4-5): Selected Diameters of Pipes

4.1.6. Designing Area

Minimum designing area for ordinary hazard (group2) is 139 m^2 with 0.2 gpm/ft^2 density, as shown in the figure (3-1), these values can be used in this case .

Number of sprinkler in design area = Design area / Area Coverage Per Sprinkler

NO. of sprinklers in design area = 200 / 10 = 20

To create a rectangular Area, let the number of sprinkler is 20 sprinklers.

4.1.7. Calculation of GPM and Pressure

4.1.7.1. Calculation of discharge at the farther sprinkler head (Qst)

Qst = Asp * Dd ……………………….(4.1)

Where:

Asp = Area coverage per sprinkler (ft^2).

Dd = Designing density (gpm / ft^2).

Asp = 10 m^2 = (10 *3.28 *3.28) ft^2

Dd = 0.2 from the chart

Qst = 10 * 3.28 * 3.28 *0.2 = 21.52 gpm

4.1.7.2. Calculation of Pressure at the Farther Sprinkler Head (Pst)

Qst = k √Pst …………………………. (4.2)

Where:

Pst = Pressure at the Farther Sprinkler Head (psi).

k = Nozzle Factor, For standard sprinkler heads the value of nozzle factor is 5.65

Pst = $(Qst/k)^2$

Pst = $(21.52/5.65)^2$ = 14.50 psi

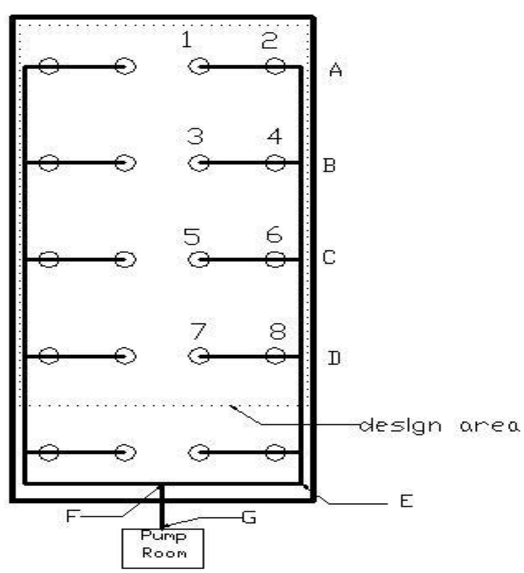


Figure (4-6). Positions of the Sprinklers inside the Design Area

4.1.7.3. Calculation of Pressure and (gpm) at the Sprinkler Head

Number (2):

$P_2 = P_{st}$ + Pressure drop between point 1 and point 2 (P_{drop12})

$P_{drop12} = P * L_{eq12}$ ………. (4.3)

Where:

p = friction losses in the pipe (psi/ft), it can be calculated using equation (3.2):

$$p = 4.52\ Q^{1.85} / C^{1.85}\ D^{4.87}$$

Where:

Q = Volumetric flow rate (gpm)

D = Inside diameter of the pipe (inch)

C = The factor of friction losses, for equivalent schedule 40 steel pipe

C = 120

$P = 4.52 * (21.52)^{1.85} / (120)1.85 * (1.049)^{4.87} = 0.149$ psi/ft

Leq12 = Equivalent length, this value includes the real length of the pipe and the equivalent length of the pieces and the joints throw the pipe, it can be found from the table (3-3).

In the pipe between point 1 and point 2 there are 90 standard elbow, diameter of pipe is 1", let the length between sprinkler and the branch line 1 ft.

Lequ12 = (real length between 1 and 2) + (the length between sprinkler and the branch line) + (equivalent length of the elbow)

Lequ12 = 2.50*3.28 + 1 + 2 = 11.2 ft

Pdrop12 = p * Lequ12 = 0.149 * 11.2 = 1.67 psi

P2 = P1 + Pdrop12 = 14.50 + 1.67 = 16.17 psi

Q2 = 5.65 * √ P2 = 5.65 * √16.17 = 22.72 gpm

4.1.7.4. Calculation of Pressure and (gpm) at point A

QA = Q1 + Q2 = 21.52 + 22.72 = 44.24 gpm

= (real length between 2 and A) + 2 (90^0 long turn elbow with 1 pipe diameter)

Leq2A = 1.25*3.28 + 2 = 6.1 ft

P2A = $(4.52*Q^{1.85})/(C^{1.85}*d^{4.87})$

P2A = $(4.52*44.24^{.85})/(120^{1.85} * 1.049^{4.87})$ = 0.57 psi

Pdrop2A = P2A * Lequ2A = 0.57 * 6.1 = 3.45 psi

PA = Pdrop2A + P2 = 3.45 + 16.17 = 19.64 psi

4.1.7.5. Calculation of Pressure and (gpm) at point B

PB = PA + PdropAB

PdropAB = PAB * LequAB

LequAB = Length between A and B = 4*3.28 = 13.12 ft

PAB = $(4.52*44.24^{1.85})/(120^{1.85} * 1.38^{4.87})$ = 0.149 psi/ft

PdropAB = PAB * LequAB = 0.149 * 13.12 = 1.95 psi

PB = PdropAB + PA = 1.95 + 19.62 = 21.57 psi

In the same way QB = QC = QD = QA because branch lines are similar, but friction losses between these points must be consider, so gpm at these points can be calculate using following equation:

QNew = Q * √(PNew / P) …………. (4.4)

QB = 44.24 * √ (21.57 / 19.62) = 46.39 gpm

4.1.7.6. Calculation of Pressure and (gpm) at point C

QBC = QB + QA = 44.24 + 46.39 = 90.63 gpm

At Qc = 44.24 gpm and Pc = 19.62 psi

PdropBC = PBC * LequBC

PBC = $(4.52*90.63^{1.85})/(120^{1.85} * 1.61^{4.87}) = 0.26$ psi/ft

LequBC = Length between C and B = 4*3.28 = 13.12 ft

PdropBC = 0.26 * 13.12 = 3.47 psi

PC = PB + PdropBC = 21.57 + 3.47 = 25 psi

QC = 44.24 * √ (25 / 17.17) = 49.94 gpm

4.1.7.7. Calculation of Pressure and (gpm) at point D

QCD = QC + QBC = 49.94 + 90.63 = 140.57 gpm

PdropCD = PCD * LequCD

PCD = $(4.52*140.57^{1.85})/(120^{1.85} * 2.067^{4.87}) = 0.18$ psi/ft

LequCD = Length between C and D = 4*3.28 = 13.12 ft

PdropCD = 0.18 * 13.12 = 2.36psi

PD = PC + PdropCD = 25 + 2.36 = 27.36 psi

QD = 44.24 * √ (27.36 / 19.62) = 52.24 gpm

Total GPM at the right side of design area = QD + QCD

Qtotal RIGHT = QD + QCD = 52.24 + 140.57 = 192.18 gpm

Total GPM = Qtotal RIGHT * 2 = 192.18 * 2 = 385.62 gpm

4.1.7.8. Calculation of Pressure at point E

LeqDE = 5*3.28 + 3 (from the table , 90^0 long turn elbow and 2" tube) = 19.4 ft

PdropDE = PDE * LeqDE

PDE = $(4.52*192.81^{1.85})/(120^{1.85} * 2.067^{4.87}) = 0.32$ psi/ft

PdropDE = 0.32 * 19.4 = 6.14 psi

PE = PD + PdropDE = 27.36 + 6.14 = 33.5 psi

4.1.7.9. Calculation of Pressure at point F

PF = PE + PdropEF

LeqEF = 4.555 *3.28 + 10 (Tee flow turned 90^0 and 2" tube)

LeqEF = 24.94 ft

PEF = $(4.52*192.81^{1.85})/(120^{1.85} * 2.067^{4.87}) = 0.32$psi/ft

PdropEF = 0.32 * 24.94 = 7.90 psi

This value is not acceptable, Pdrop must be less than 7 psi. So pipe diameter can be change to be 2.5".

PEF = $(4.52*192.81^{1.85})/(120^{1.85} * 2.469^{4.87}) = 0.13$psi/ft

LeqEF = 4.555 *3.28 + 12 (Tee flow turned 90^0 and 2.5" tube)

LeqEF = 26.94 ft

PdropEF = 0.13 * 26.94 = 3.50 psi (acceptable value)

PF = PE + PdropEF = 33.5 + 3.50 = 37 psi

4.1.7.10. Calculation of Pressure at point G

$P_G = P_F + P_{dropFG} + P_{elevation}$

Pressure Drop by Elevation = H / 10.28

Where: H is the head (meter)

Pelevation = H / 10.28 = 6 /10.28 = 0.58 bar

Pelevation = 0.31 * 14.5 = 4.5 psi

PFG = $(4.52*385.62^{1.85})/(120^{1.85} * 2.469^{4.87}) = 0.48$ psi/ft

The pipe from the out let of the pump (point G) to the point F include; one 90^0 standard elbow, and one butter fly valve, with 2.5" pipe diameter.

Real length between F and G = 6m + 2m (length of the main riser)

Real length between F and G = (6 + 2) * 3.28 = 26.24 ft

LeqFG = 26.24 + 6 +7 = 30.06 ft

PdropFG = PFG * LeqFG = 0.48 * 30.06 = 14.43 psi (not acceptable)

Using 3" pipe diameter:

PFG = $(4.52*385.62^{1.85})/(120^{1.85} * 3.068^{4.87}) = 0.17$ psi/ft

LeqFG = 26.24 + 7 + 10 = 43.24 ft

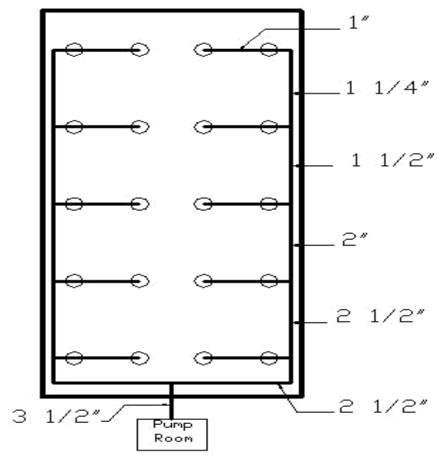
PdropFG = 0.17 * 43.24 = 7.35 psi (acceptable value)

PG = PF + PdropFG + Pelevation = 37 + 7.35 + 4.5 = 48.85 psi

Ppump = 48.85 / 14.5 = 3.37 bar

Qpump = 385.62 * 3.78 = 1457.64 L/min

New values of diameters after the design can be shown in the following figure:



Figure(4.7) :Designed Diameters of Pipes

4.1.8. Tank Capacity

For ordinary hazard time of flow is 75 min

Tank Capacity = Qpump * time of flow

Tank Capacity = 1457.64 * 75 = 109,323 L

4.1.9 Calculation

Using the program of Elite for Firefighting Calculation; general project data, edit pipe data and edit pipe node data can be entered to the program as shown in figures below.

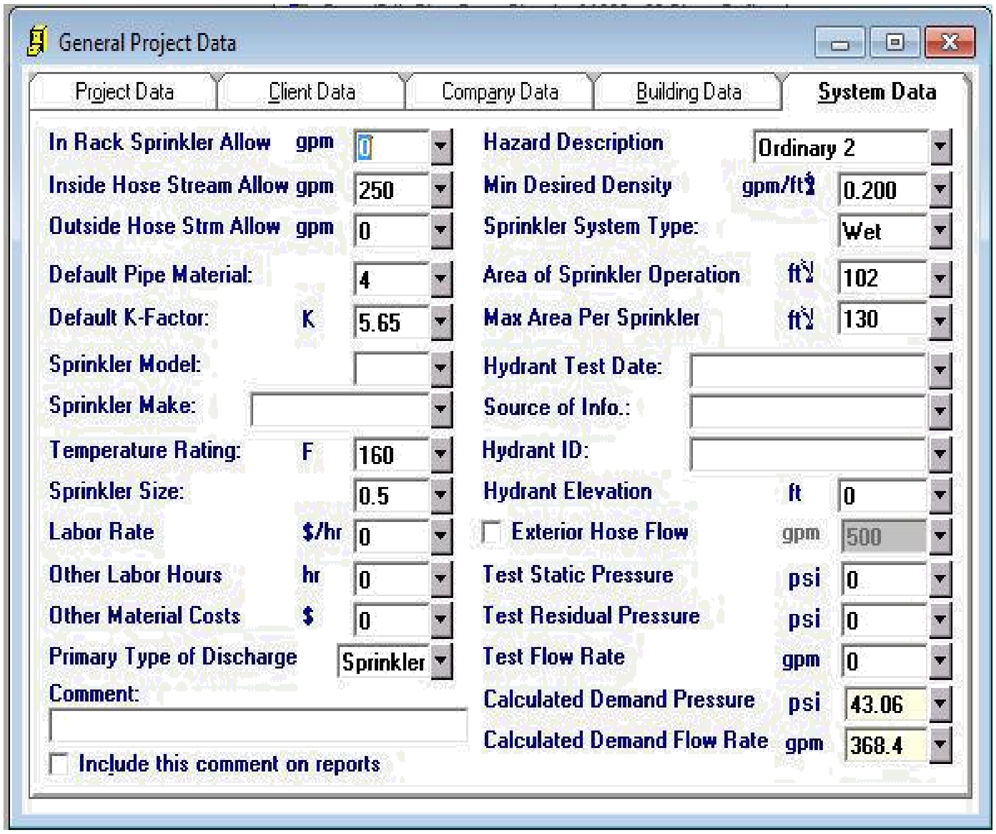


Figure (4-8): General Project Data

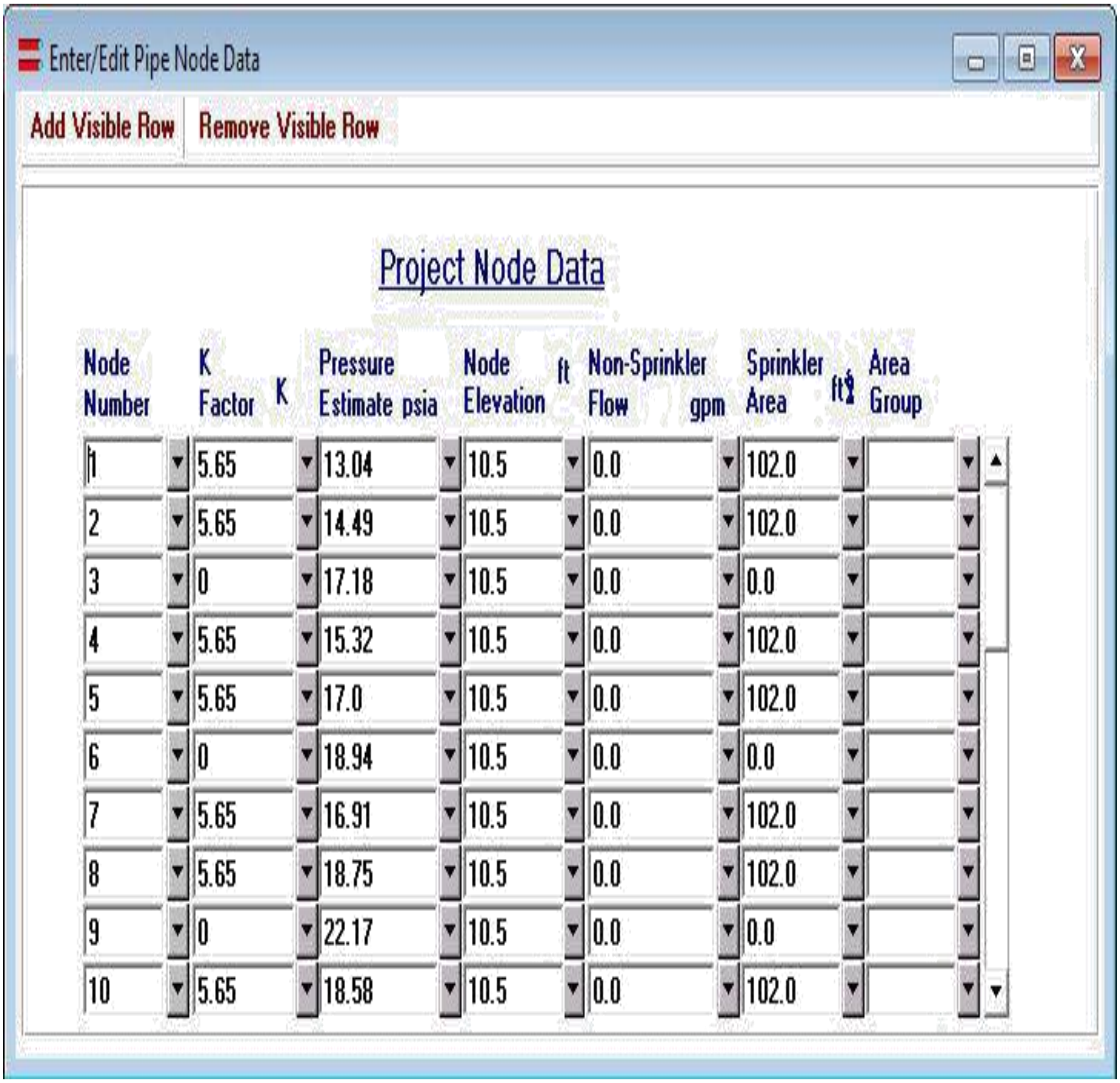


Figure 4-9. Edit Pipe Data

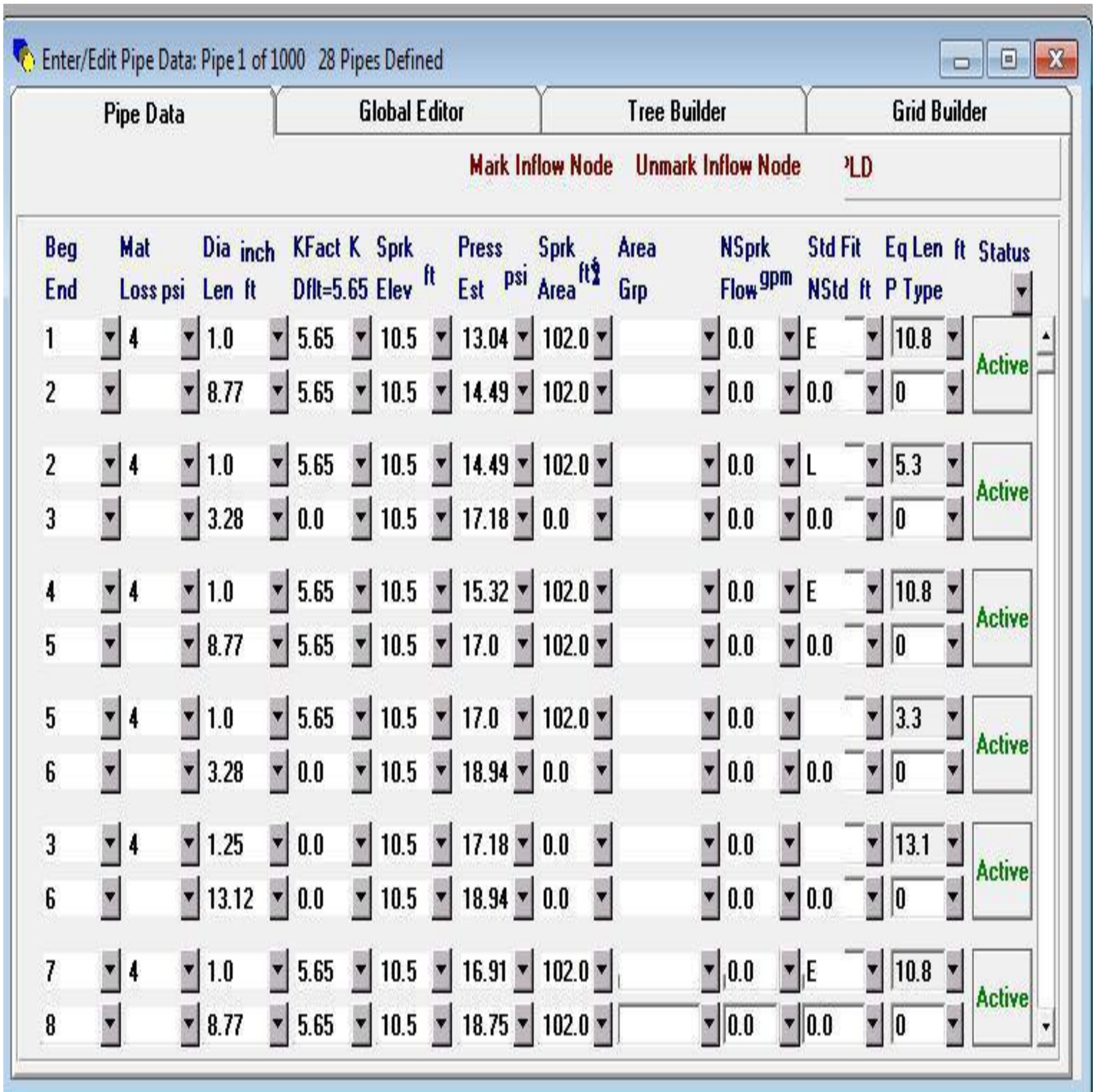


Figure (4-10): Edit Pipe Node Data

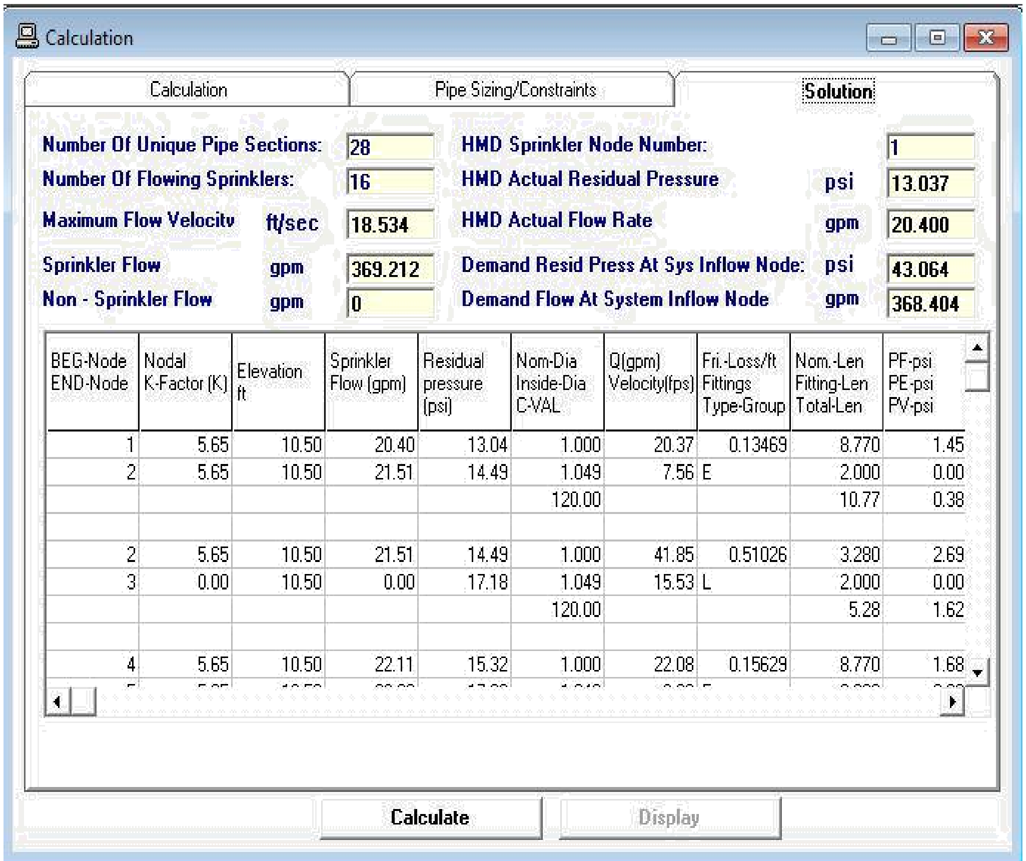


Figure (4-11): Edit Pipe Node Data

4.1.9.1 Calculation Results

Using Elite software application that demonstrates NFPA13 system design, the software results is shown in figure
(4-10).

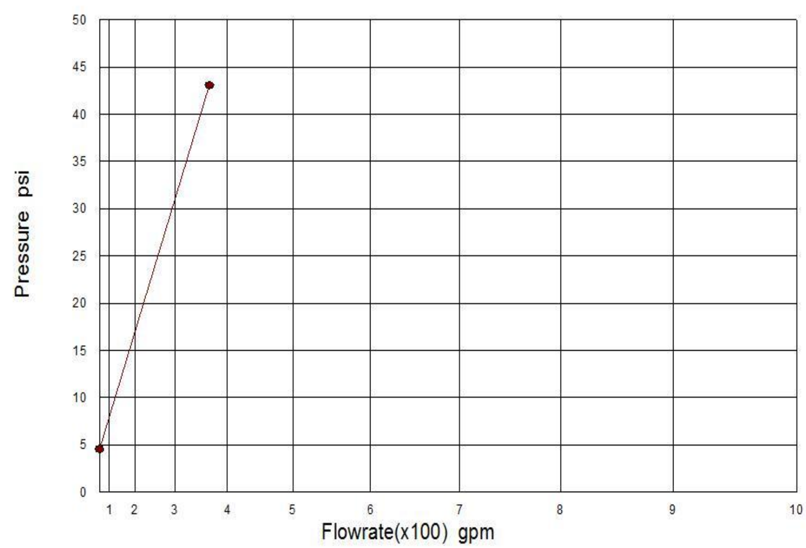


Figure (4.12): Simulation Results of Elite Program

4.2.3 Calculation Results

The results of the simulation is shown in figure (4-14), when the simulation program of plumbing and firefighting calculations used**.** Let the number of nozzles 4.

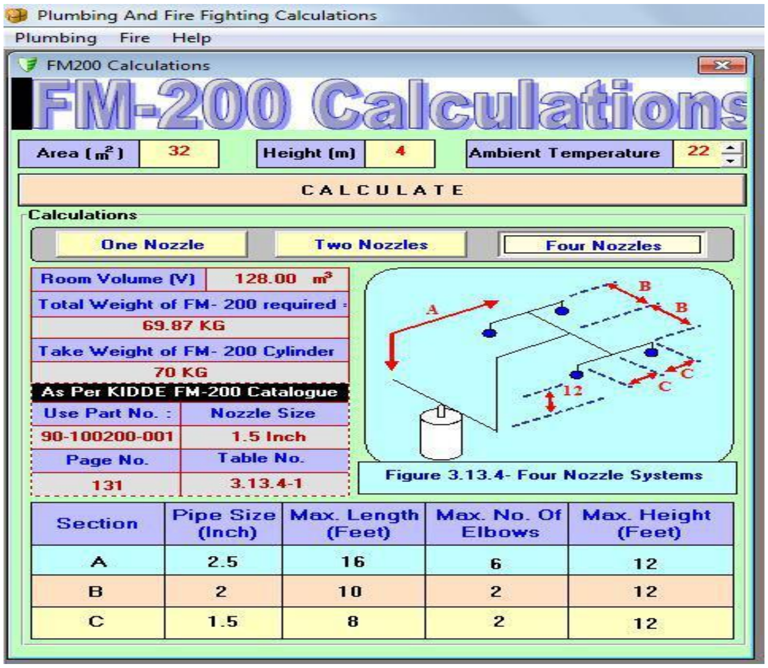


Fig (4-15): The Calculation Results for Fm-200 System

The program shows that

- Room volume is 128 m^2.
- Total weight of Fm-200 required is 69.87 kg.
- One Fm-200 cylinder of 70 kg weight can be used.
- Nozzle size is 1.5 inch.

CHAPTER FIVE

CONCLU SION AND RECOMMENDATION

5.1. Conclusion

This thesis described the appropriate implementation of the firefighting system design parameters using the standards from the NFPA (National Fire Protection Association). In this thesis different two cases selected to apply the accurate design.

First case was storage building for clothes , for this case a complete design of the sprinkler system was done which included; selection of the sprinklers network, selection of the pipes materials and diameters, calculation of GPM and pressure and the tank size.

The program of Elite for firefighting calculation software is used to calculate the mentioned parameters beside the analytical calculation, there are few different between the results in the two ways of calculation for differed fuzziness in each way. Second case was office contain electirical devices, for this case designs of FM-200 Agent System ware done using the simulation program of plumbing and firefighting calculations, each design included total weight and number of cylinders required..

5.2. Recommendation

From the results it recommended that

- From the results obtained by using NFPA in this work we recommend ate to use BS&ISO standard .
- Use firefighting system in storage building and work shop .
- Confidence firefighting system in service building .

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APPENDICES

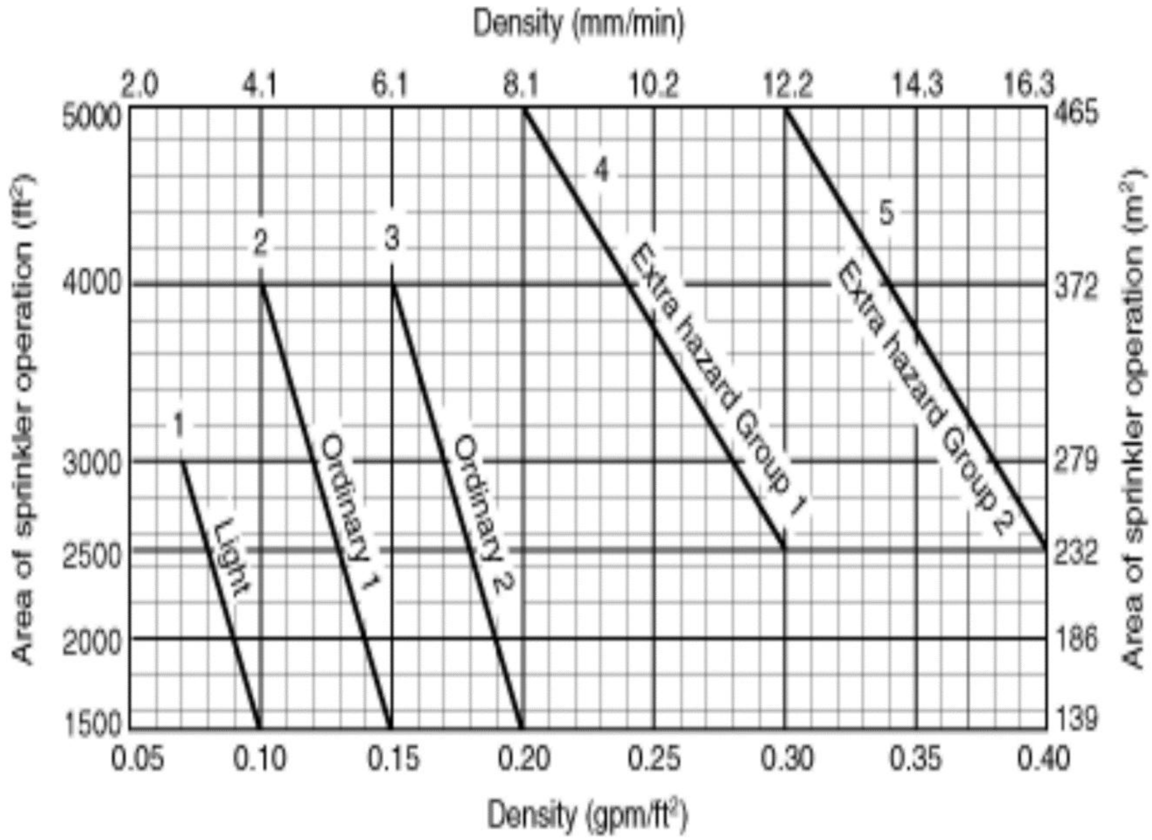


Figure 3-1. Area/Density Curves.

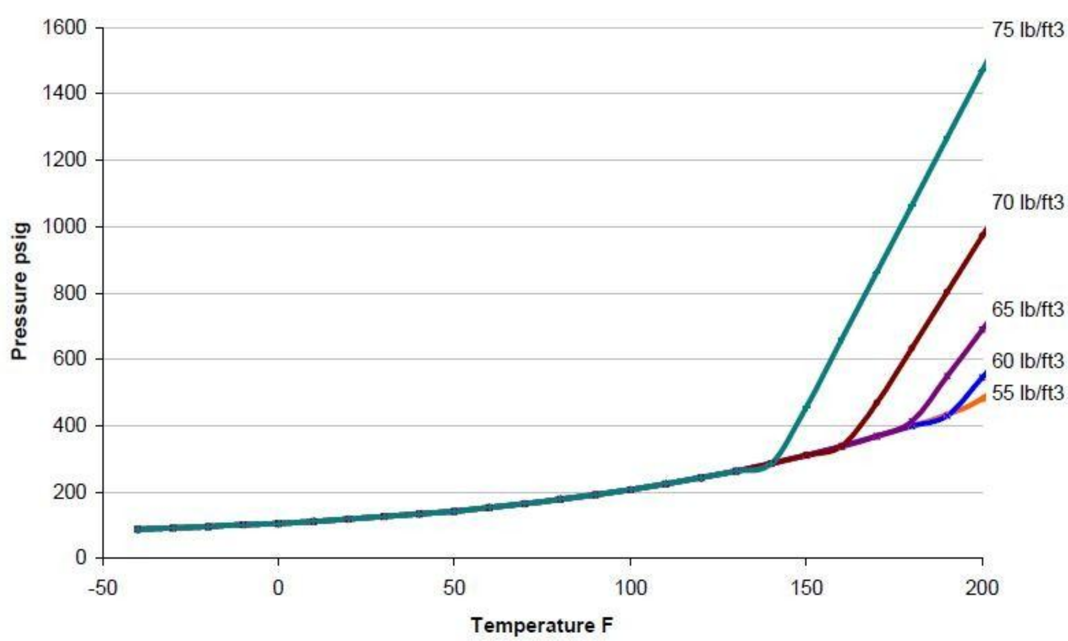
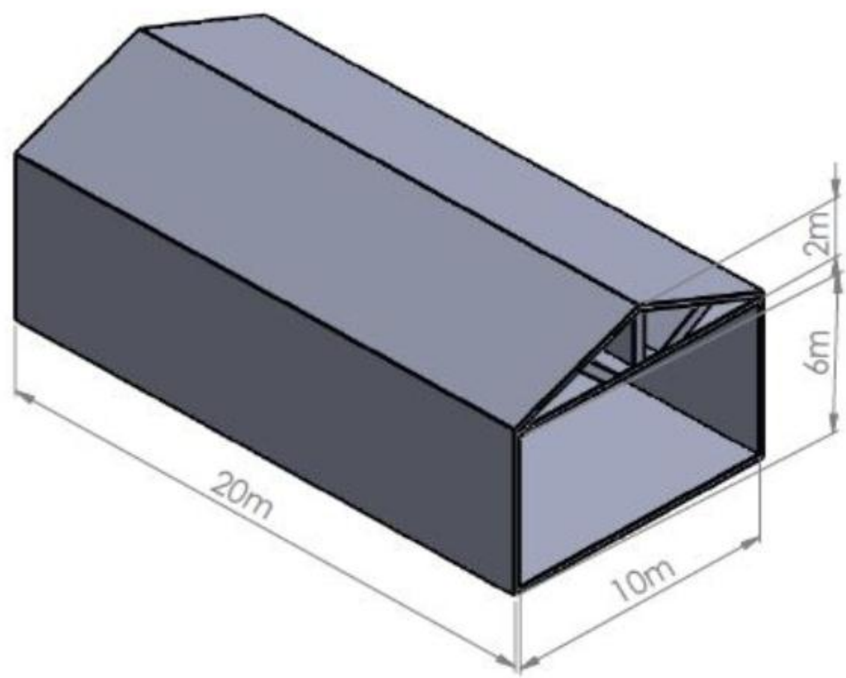


Figure 3-2: Isometric Diagram of FM-200



Figure(4-2): Geometric dimension of the storage

Table 3-1: Protection Area Limitation per Sprinkler

protection Area Limitation per Sprinkler		
Hazard	Area (m²)	Distance between sprinklers (m)
Light Hazard	18.6	6.4
Ordinary Hazard	12.1	6.4
Extra Hazard	9.3	3.7

Table 3-2-a: Protection Areas and Maximum Spacing (Standard Spray Upright/Standard Spray Pendent) for Light Hazard

		Protection Area		Spacing
Construction Type	System Type	ft²	m²	f
All	All	130	12.1	15

Table 3-2-c. Protection Areas and Maximum Spacing (Standard Spray Upright/Standard Spray Pendent) for Extra Hazard

		Protection Area		Spacing
Construction Type	System Type	ft²	m²	f
All	Pipe schedule	90	8.4	12
All	Hydraulically calculated with density ≥ 0.25	100	9.3	12
All	Hydraulically calculated with density above 0.25	130	12.1	15

Table 3-3: Equivalent Schedule 40 Steel Pipe Length

Fittings and Valves	Fittings and Valves Expressed in Equivalent Feet of Pipe													
	1/2"	3/4"	1"	11/4"	11/2"	2"	21/2"	3"	31/2"	4"	5"	6"	8"	10"
40^0 Elbow		1	1	1	2	2	3	3	3	4	5	7	9	11
90^0 Standard	1	2	2	3	4	5	6	7	8	10	12	14	18	22
90^0 Long	0.5	1	2	2	2	3	4	5	5	6	8	9	13	16
Tee or Cross	3	4	5	6	8	10	12	15	17	20	25	30	35	50
Butterfly	.	.	.	.	.	6	7	`10	.	12	9	10	12	19
Gate valve	.	.	.	.	.	1	1	1	1	2	2	3	4	5
Swing check	.	.	5	7	9	11	14	16	19	22	27	32	45	55

Table 3-4: Light Hazard Pipe Schedule

steel		Copper	
1”	2 Sprinkler	1”	2 Sprinkler
1 ¼”	3 Sprinkler	1 ¼”	3 Sprinkler
1 ½”	5 Sprinkler	1 ½”	5 Sprinkler
2”	10 Sprinkler	2”	12 Sprinkler
2 ½”	30 Sprinkler	2 ½”	40 Sprinkler
3”	60 Sprinkler	3”	65 Sprinkler
3 ½”	100 Sprinkler	3 ½”	115 Sprinkler
4”		4”	
For SI Unite 1 in.= 25.4mm			

Table 3-5. Ordinary Hazard Pipe Schedule

steel		Copper	
1"	2 Sprinkler	1"	2 Sprinkler
1 ¼"	3 Sprinkler	1 ¼"	3 Sprinkler
1 ½"	5 Sprinkler	1 ½"	5 Sprinkler
2"	10 Sprinkler	2"	12 Sprinkler
2 ½"	20 Sprinkler	2 ½"	25 Sprinkler
3"	40 Sprinkler	3"	45 Sprinkler
3 ½"	65 Sprinkler	3 ½"	75 Sprinkler
4"	100 Sprinkler	4"	115 Sprinkler
5"	160 Sprinkler	5"	180 Sprinkler
6"	275 Sprinkler	6"	300 Sprinkler
For SI Unite 1 in.= 25.4mm			

Table 3-6: Cylinder Assemblies

Non Size	Assy Part No	Outside Dia.		Overall Height		Internal Volume		FM-200 Agent		Fill Density	
		In.	cm	In.	cm	In^3	Cm^3	Lb.	kg	Lb/ft^3	Kg/m^3
3	100300	3.0	7.62	16.2	41.15	71	1163	3	1.36	73	1169
6	100600	4.25	10.8	17.7	44.96	149	2441	6	2.72	70	1121
12	101200	5.09	12.93	23.0	58.42	300	4916	12	5.44	69	1105

Table(3-7)describes the DOT Specifications used for the manufacture of the FM-200 cylinders.

Nominal Size	DOT Spec	Cylinder Service Pressure psig	DOT Cylinder Test Pressure	
			psig	kpa
3	4B24ET	240	480	3310
6	4B-225	225	450	3103
12	4B-225	225	450	3103

Table 3-8: The Cylinder Gauge, Pressure-Temperature Relationship

Cylinder Pressure			
Temperature		Pressure	
^{0}F	^{0}C	psig	kpa
0	-17.8	91	672
10	-12.2	97	689
20	-6.7	104	717
30	-1.1	111	765
40	4.4	119	820
50	10.0	128	882
60	15.5	139	958
70	21.1	150	1034
80	26.7	163	1124
90	3202	177	1220
100	37.8	192	1324
110	43.3	209	1441
120	48.9	228	1572
130	54.4	249	1717

Table 3-9: Enclosure Size Limitation

Model	FM-200	Maximum Coverage				
		Length (ft)	Width (ft)	Height (ft)	Area (ft^2)	Volume (ft^3)
ILP-300	3.0	6(a)	6(a)	12	36	(b)
ILP-600	6.0	6(a)	6(a)	12	36	(b)
ILP-1200	12.0	6(a)	6(a)	12	36	(b)

Table 3-10-a: The Minimum Safety Factor Required for the Hazard

Hazard Type	Minimum Safety Factor
Class A (surface fires), including plastic materials typically found in electrical/ electronic equipment	1.2
Class B Flammable Liquids	1.3
Class C Electrical	1.2

Table 3-10-b. The Minimum Design Concentration Required

Fuel	Extinguishing Concentration $^0/_0$	Minimum Design Concentration $^0/_0$
Class A (surface fires) Including plastic smaterials typically found in electrical/ electronic equipment	6.23	7.48
Class B Fuels		
Aceton	6.9	10.01
Methanol Ethanol	8.7	12.62
Commercial grade haptane	6.7	9.72
Methanol	10.5	15.23
2-Propanol	7.4	10.74
Toluene	5.2	7.55

Table 3-11: Total Flooding Quantity

Temp. t ^{0}F	Specific Vapor Volume S (ft^3/lb)	FM-200 weight reqmt. per unit volume of protected space, w/v (lb/ft^3) — Design Concentration, C (% by volume)									
		7.48	8	9.72	10	11	12	13	14	15	16
0	1.8850	0.0429	0.0461	0.0571	0.0589	0.0656	0.0723	0.0793	0.0864	0.0936	0.1010
10	1.9264	0.0420	0.0451	0.0559	0.0570	0.0642	0.0708	0.0776	0.0845	0.0916	0.0989
20	1.9736	0.0410	0.0441	0.0546	0.0563	0.0626	0.0691	0.0757	0.0825	0.0894	0.0965
30	2.0210	0.0400	0.0430	0.0533	0.0550	0.0612	0.0675	0.0739	0.0805	0.0873	0.0942
40	2.0678	0.0391	0.0421	0.0521	0.0537	0.0598	0.0659	0.0723	0.0787	0.0853	0.0921
50	2.1146	0.0382	0.0411	0.0509	0.0525	0.0584	0.0645	0.0707	0.0770	0.0835	0.0901
60	2.1612	0.0374	0.0402	0.0498	0.0514	0.0572	0.0631	0.0691	0.0753	0.0817	0.0881
70	2.2075	0.0366	0.0394	0.0488	0.0503	0.0560	0.0618	0.0677	0.0737	0.0799	0.0863
80	2.2538	0.0359	0.0386	0.0478	0.0493	0.0548	0.0605	0.0663	0.0722	0.0783	0.0845
90	2.2994	0.0352	0.0378	0.0468	0.0483	0.0538	0.0593	0.0650	0.0708	0.0767	0.0828
100	2.3452	0.0345	0.0371	0.0459	0.0474	0.0527	0.0581	0.0637	0.0694	0.0752	0.0810
110	2.3912	0.0338	0.0364	0.0450	0.0465	0.0517	0.0570	0.0625	0.0681	0.0738	0.0797
120	2.4366	0.0332	0.0357	0.0442	0.0456	0.0507	0.0560	0.0613	0.0668	0.0724	0.0782
130	2.4820	0.0326	0.0350	0.0434	0.0448	0.0498	0.0549	0.0602	0.0656	0.0711	0.0767

Table 3-12-a: Maximum Volume That Can Be Protected By 3 Lb. Unit

Minimum Anticipated Design Temp. ^{0}F	Maximum Hazard Volume (ft^3) Design Concentration, C (% by volume)									
	7.48	8	9.72	10	11	12	13	14	15	16
0	69	65	52	50	45	41	37	34	32	29
10	71	66	53	52	46	42	38	35	32	30
20	73	68	54	53	47	43	39	36	33	31
30	74	69	56	54	49	44	40	37	34	31
40	76	71	57	55	50	45	41	38	35	32
50	78	72	58	57	51	46	42	38	35	33
60	80	74	60	58	52	47	43	39	36	34
70	81	76	61	59	53	48	44	40	37	34

Table 3-12-b: Maximum Volume That Can Be Protected By 6 Lb. Unit

Minimum Anticipated Design Temp. ^{0}F	Maximum Hazard Volume (ft^3) Design Concentration, C (% by volume)									
	7.48	8	9.72	10	11	12	13	14	15	16
0	139	130	105	101	91	82	75	69	64	59
10	142	133	107	105	93	84	77	71	65	60
20	146	136	109	106	95	86	79	72	67	62
30	149	139	112	109	98	88	81	74	68	63
40	153	142	115	111	100	91	82	76	70	65
50	156	145	117	114	102	93	84	77	71	66
60	160	149	120	116	104	95	86	79	73	68
70	163	152	123	119	107	97	88	81	75	69

Table 3-12-c: Maximum Volume That Can Be Protected By 12 Lb. Unit

Minimum Anticipated Design Temp. °F	Maximum Hazard Volume (ft³) Design Concentration, C (% by volume)									
	7.48	8	9.72	10	11	12	13	14	15	16
0	279	260	210	203	182	165	151	138	128	118
10	285	266	214	210	186	169	154	142	131	121
20	292	272	219	213	191	173	158	145	134	124
30	299	275	225	218	196	177	162	149	137	127
40	306	285	230	223	200	182	165	152	140	130
50	313	291	235	228	205	186	169	155	143	133
60	320	298	240	233	209	190	173	159	146	136
70	327	304	246	238	214	194	177	162	150	139

Table 3-13: Maximum Nozzle Limitation

Unit Size	No. of Cyl. Valve Discharge Ports Used (DP)	Quant. Of Nozzles Per DP	Total Number of Nozzles Per Unit	Max. Area Coverage Per Nozzle	Total Nozzle Area Coverage Per Unit	"D" (Ft)
.	1	1	1	6'x6' (36 Ft^2)	36 Ft^2	4.24
3 Lb	2	1	2	3'x6' (18 Ft^2)	36 Ft^2	3.35
		2	4	3'x3' (9 Ft^2)	36 Ft^2	2.12
6 & 12 Lb.	2	1	2	3'x6' (18 Ft^2)	36 Ft^2	3.35
		2	4	3'x3' (9 Ft^2)	36 Ft^2	2.12

Table 3-14: Maximum Tubing and Fitting Limitation

Unit Size	No. of Cyl. Valve Discharge Ports Used (DP)	Total Nozzles Used	Quant. Of Nozzles Per DP	Max. Length Of Tubing Per DP	Max. No. Of Elbows Per DP	Max. No. Of Tees Per DP
3 Lb.	1	1	1	3 Ft	0	0
	2	2	1	10 Ft	2	0
		4	2	10 Ft	3	1
6 & 12 Lb.	2	2	1	10 Ft	2	0
		4	2	11 Ft	3	1