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Senior Design Project Report

Fire Sprinklers Design

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Abstract

A fire sprinkler framework is a dynamic fire assurance technique, comprising of a water supply framework, giving sufficient weight and stream rate to a water circulation-channeling framework, onto which fire sprinklers are associated. Also it is utilized as a part of processing plants and substantial business structures, frameworks for homes and little structures are presently accessible at a practical cost. Fire sprinkler frameworks are broadly utilized around the world, with more than 40 million sprinkler heads fitted every year. In structures totally secured by flame sprinklers alone controlled sprinkler frameworks, more than 96% of flames.

Sprinklers have been being used in the United States since 1874, and were utilized as a part of manufacturing plant applications where fires when the new century rolled over were regularly disastrous as far as both human and property losses. In the US, sprinklers are today required in all new skyscraper and underground structures for the most part 75 feet (23 m) above or beneath flame office get to, where the capacity of firefighters to give sufficient hose streams to flames is restricted. [1]

Sprinklers might be required to be introduced by construction standards, or might be prescribed by insurance agencies to decrease potential property losses or business intrusion. Construction standards in the United States for spots of gathering, by and large more than 100 people, and places with overnight dozing convenience, for example, hotels, nursing homes, residences, and hospitals ordinarily require sprinklers under nearby building regulations, as a state of accepting State and Federal financing.

In this Project, the aim is to develop a simple Fire Sprinkler, where the sprinkler can be tested. The test of the sprinkler is to be by connecting the pipes and the reservoir that contains the water and how the breaking of the chemical tube is happening as if there is a real fire occurring in a building. Further studies will include the calculations of the radius and the area that one sprinkler can handle during a fire case and how many one we have to install in a building to cover the fire as a given flow rate and pressure [2].

Acknowledgments

This work would not have been possible without the support of Prince Mohammad University and the Mechanical Engineering professors whom helped developing the Fire Sprinklers. I am especially indebted to Dr. Aymen Jandoubi and Dr. Nader Nader who have been supportive of my project and who worked actively to provide me with the protected academic time to pursue those goals. I am grateful to all of those with whom I have had the pleasure to work during this and other related projects. Each of the members of ASME PMU Chapter has provided me extensive personal and professional guidance and taught me a great deal about both scientific research and life in general. As my teacher and mentor, he has taught me more than I could ever give him credit for here. He has shown me, by his example, what a good researcher should be. Nobody has been more important to me in the pursuit of this project than the members of my family. I would like to thank my parents, whose love and guidance are with me in whatever I pursue. They are the ultimate role models [3]

List of Acronyms (Symbols) used in the report :

National Fire Protection Association (NFPA)

Early Suppression Fast Response (ESFR)

National Institute for Certification in Engineering Technologies (NICET)

American Society of Mechanical Engineering (ASME)

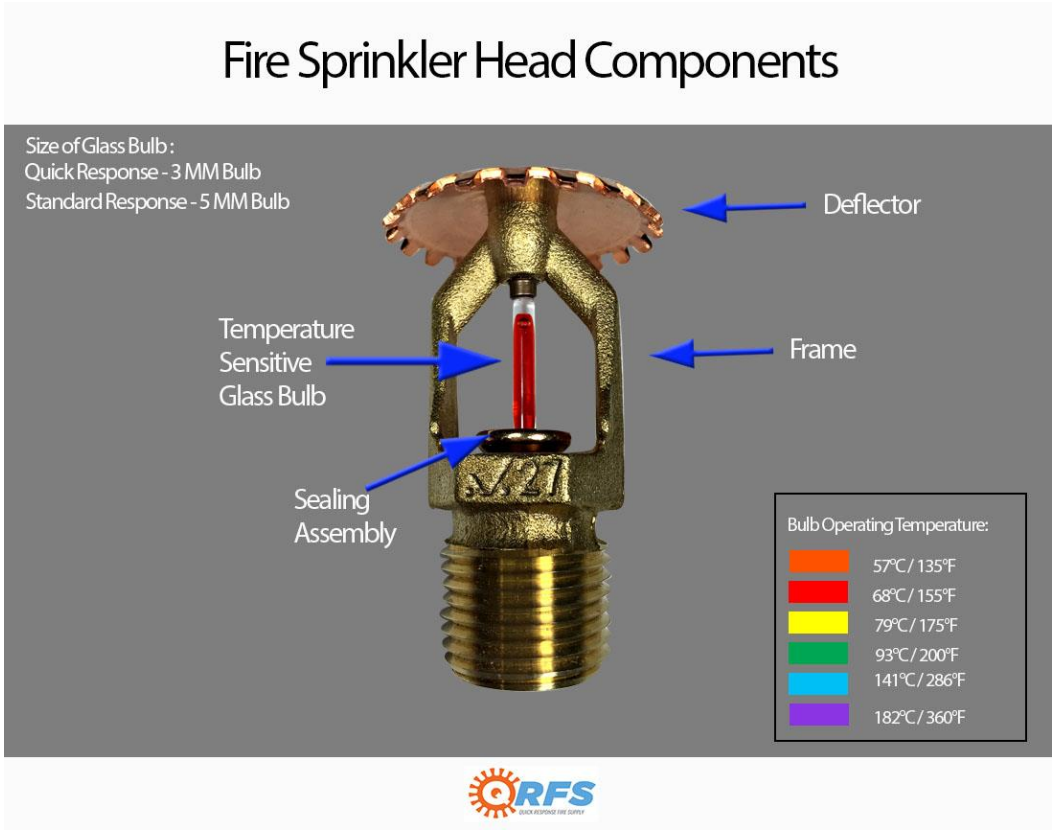
List of Figures:

Temperature		Color of liquid alcohol inside bulb
°C	°F	
57	135	Orange
68	155	Red
79	174	Yellow
93	200	Green
141	286	Blue
182	360	Purple
227 260	440 500	Black

This chart from the fire safety standards indicates the colour of the bulb and the respective operating temperature.

Figure 1

Figure 2



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Chapter 1: Introduction

1.1 Project Definition

This project is intended to design and manufacture a simple Fire Sprinklers, where the fire sprinkler can be inserted and tested. The test fire sprinkler is to be fitted with pipes and connections along with the tube bulb that could be exchangeable for many number of testing in which we can show it many times and change the bulb every time we test. The project is very important to the industries, as through understanding the characteristics of different types of the fire sprinklers so that we could be able to use every one in their specific location and task. This is also very important from the safety prospective as this will lead to a safe social environment to cover many areas such as operation plants, schools, hospitals gas stations and more. The project will show more details about the specifications and dimension and radius of covering the area of the intended to put the fire off of it. Also to show the students how the fire sprinklers working mechanism occurs and how does it really work. Also to demonstrate the different kinds of the distribution flow of the nozzle that could give more efficient and effective result as they could be varied with the environment and the nature of the place or building. For example, school would have different type of fire sprinklers than the chemical industry and so the flow rate and the medium used to put the fire such as Foam, Water and weather it will be wet or dry, as we will see later on [4].

1.2 Project Objectives:

1. Design and construct a Fire Sprinklers to show flow rate and pressure distributing for fire detected in school or hospital or chemical industry using specific type of sprinkles
2. Study the change in different types of the Fire Sprinklers and how they can be more efficient for their designated area and field.
3. Relate different type and medium used in different weather and conditions depending on the environment and needs.
4. Developing fire sprinklers distribution techniques to prevent huge uncontrolled fire to be put off without the need to make firefighters possess more danger and lessen their exposure to fire as much as possible.

1.3 Project Specifications

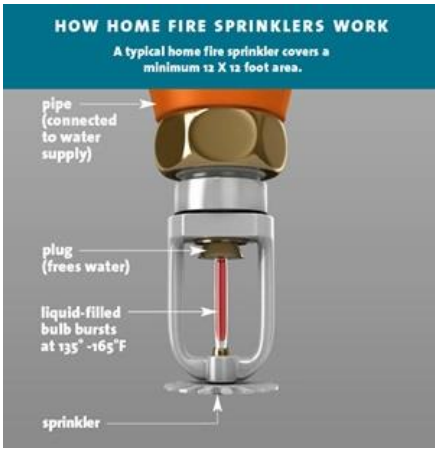


Figure 4

Figure 5

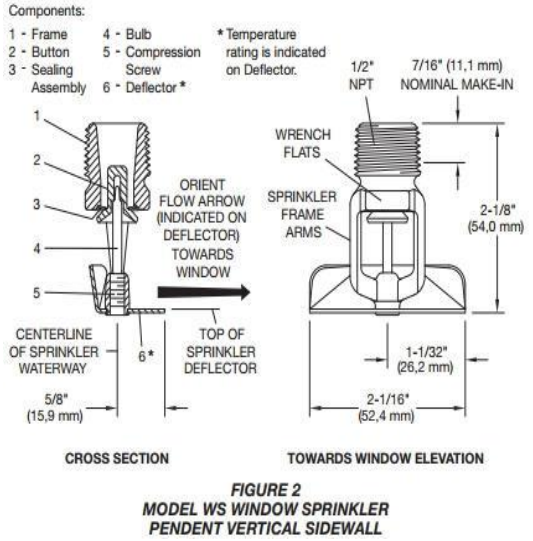


Figure 6

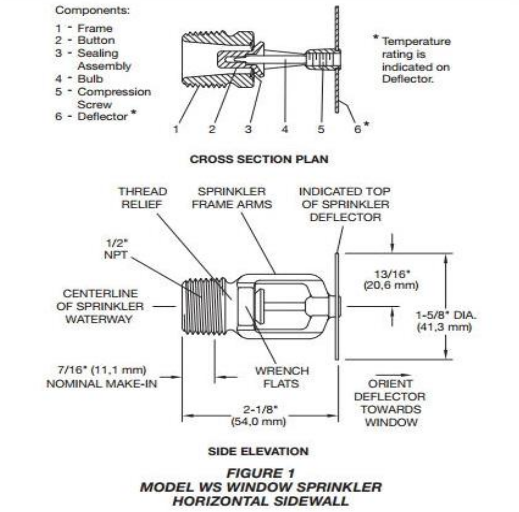


Figure 6

Some of the most important aspect we have to consider is the ceiling height in which it has the means of egress shall have a ceiling height of not less than 7 feet 6 inches (2286 mm). Other things to consider is the number of occupant in the room and it would be calculated and figured upon the table shown below as the standard of NFPA [4].

MAXIMUM FLOOR AREA ALLOWANCES PER OCCUPANT

FUNCTION OF SPACE	OCCUPANT LOAD FACTOR[a]
Accessory storage areas, mechanical equipment room	300 gross
Agricultural building	300 gross
Aircraft hangars	500 gross
Airport terminal Baggage claim Baggage handling Concourse Waiting areas	 20 gross 300 gross 100 gross 15 gross
Assembly Gaming floors (keno, slots, etc.) Exhibit gallery and museum	 11 gross 30 net
Assembly with fixed seats	See Section 1004.4
Assembly without fixed seats Concentrated (chairs only – not fixed) Standing space Unconcentrated (tables and chairs)	 7 net 5 net 15 net
Bowling centers, allow 5 persons for each lane including 15 feet of runway, and for additional areas	7 net
Business areas	100 gross
Business areas	100 gross
Courtrooms – other than fixed seating areas	40 net
Day care	35 net
Dormitories	50 gross
Educational Classroom area Shops and other vocational room areas	 20 net 50 net
Exercise rooms	50 gross
Group H-5 Fabrication and manufacturing areas	200 gross
Industrial areas	100 gross
Institutional areas Inpatient treatment areas Outpatient areas Sleeping areas	 240 gross 100 gross 120 gross
Kitchens, commercial	200 gross
Library Reading rooms Stack area	 50 net 100 gross
Locker rooms	50 gross
Mall buildings – covered and open	See Section 402.8.2 of the *International Building Code*
Mercantile Storage, stock, shipping areas	60 gross 300 gross
Parking garages	200 gross
Residential	200 gross

Table 7

1.4 Applications:

There are many applications that can be differs depending on the type and weather condition of the environment such as gas station in Alaska would use a type called Dry-Pipe System in which the medium will not be subjected to be frozen and at the same time we keep the sprinklers ready to be used. So there are many types of the Fire Sprinklers and on which the applications will be depending on it:

1- Wet Pipe System:

By a wide edge, wet pipe sprinkler frameworks are introduced more frequently than every single other sort of flame sprinkler frameworks. They likewise are the most solid, since they are basic, with the main working segments being the programmed sprinklers and (normally, however not generally) the programmed alert check valve. A programmed water supply gives water under strain to the framework funneling [4].

2- Dry Pipe System:

Dry pipe frameworks are the second most basic sprinkler framework write. Dry pipe frameworks are introduced in spaces in which the surrounding temperature might be sufficiently chilly to solidify the water in a wet pipe framework, rendering the framework inoperable. Dry pipe frameworks are regularly utilized as a part of unheated structures, in parking structures, in outside shelters connected to warmed structures (in which a wet pipe framework would be given), or in refrigerated coolers. In areas utilizing NFPA directions, wet pipe frameworks can't be introduced unless the scope of encompassing temperatures stays over 40 °F (4 °C) [4].

Water is absent in the channeling until the point that the framework works; rather, the funneling is loaded with air at a weight beneath the water supply weight. To keep the bigger water supply weight from rashly constraining water into the channeling, the plan of the dry pipe valve (a particular kind of check valve) brings about a more noteworthy power over the check valve clapper by the utilization of a bigger valve clapper zone presented to the funneling gaseous tension, when contrasted with the higher water weight however littler clapper surface region. When at least one of the programmed sprinkler heads is activated, it opens enabling the air in the channeling to vent from that sprinkler [4].

3- Deluge System:

"Storm" frameworks are frameworks in which all sprinklers associated with the water-funneling framework are open, in that the warmth detecting working component is expelled, or particularly outlined all things considered. These frameworks are utilized for unique dangers where fast fire spread is a worry, as they give a concurrent use of water over the

whole peril. They are in some cases introduced in staff departure ways or building openings to moderate go of flame (e.g. openings in a fire-evaluated divider).

Water is absent in the funneling until the point when the framework works. Since the sprinkler openings are open, the funneling is at climatic weight. To keep the water supply weight from compelling water into the channeling, a "downpour valve" is utilized as a part of the water supply association, which is a mechanically locked valve. It is a non-resetting valve, and remains open once stumbled [4].

Since the warmth detecting components introduce in the programmed sprinklers have been evacuated (bringing about open sprinklers), the downpour valve must be opened as motioned by a fire caution framework. The sort of flame caution starting gadget is chosen for the most part in view of the danger (e.g. pilot sprinklers, smoke indicators, warm locators, or optical fire finders). The start gadget flags the fire caution board, which thus flags the downpour valve to open. Actuation can likewise be manual, contingent upon the framework objectives. Manual initiation is typically by means of an electric or pneumatic fire alert force station, which flags the fire caution board, which thusly flags the storm valve to open.

Task - Activation of a fire caution starting gadget, or a manual force station, flags the fire alert board, which thusly flags the storm valve to open, enabling water to enter the channeling framework. Water streams from all sprinklers at the same time [4].

4- Pre-action System:

Pre-activity sprinkler frameworks are particular for use in areas where incidental enactment is undesired, for example, in exhibition halls with uncommon works of art, original copies, or books; and server farms, for security of PC hardware from unplanned water release. Pre-activity frameworks are half and halves of wet, dry, and downpour frameworks, contingent upon the correct framework objective. There are two principle sub-sorts of pre-activity frameworks: single interlock, and twofold interlock [5]. The task of single interlock frameworks are like dry frameworks aside from that these frameworks require that a "first" fire identification occasion, ordinarily the enactment of a warmth or smoke locator, happens before the "activity" of water presentation into the framework's funneling by opening the pre-activity valve, which is a mechanically locked valve (i.e. like a downpour valve). Along these lines, the framework is basically changed over from a dry framework into a wet framework. The goal is to diminish the bothersome time postponement of water conveyance to sprinklers that is inborn in dry frameworks. Before flame recognition, if the sprinkler works, or the channeling framework builds up a break, loss of gaseous tension

in the funneling will initiate an inconvenience alert. For this situation, the pre-activity valve won't open because of loss of supervisory weight, and water won't enter the channeling [5].

The task of Double interlock frameworks is like downpour frameworks with the exception of that programmed sprinklers are utilized. These frameworks require that both a "former" fire location occasion, commonly the enactment of a warmth or smoke finder, and a programmed sprinkler task happen before the "activity" of water presentation into the framework's funneling. Actuation of either the fire finders alone, or sprinklers alone, without the simultaneous activity of the other, won't enable water to enter the channeling. Since water does not enter the funneling until the point when a sprinkler works, twofold interlock frameworks are considered as dry frameworks as far as water conveyance times, and comparatively require a bigger plan zone.

5- Foam Water Sprinklers System:

A Foam water fire sprinkler framework is an extraordinary application framework, releasing a blend of water and low development froth think, bringing about a froth splash from the sprinkler. These frameworks are normally utilized with exceptional dangers inhabitances related with high test fires, for example, combustible fluids, and airplane terminal storages. Task is as portrayed above, contingent upon the framework write into which the froth is infused [6].

6- Water Spray:

"Water spray" frameworks are operationally indistinguishable to a storm framework, however the channeling and release spout splash designs are intended to secure an exceptionally arranged peril, as a rule being three-dimensional parts or gear. The spouts utilized may not be recorded fire sprinklers, and are generally chosen for a particular splash example to fit in with the three-dimensional nature of the risk. Cases of dangers secured by water splash frameworks are electrical transformers containing oil for cooling or turbo-generator heading. Water splash frameworks can likewise be utilized remotely on the surfaces of tanks containing combustible fluids or gases, (for example, hydrogen). Here the water splash is planned to cool the tank and its substance to forestall tank break/blast and fire spread [7].

7- Water Mist System:

Water mist frameworks are utilized for extraordinary applications in which it is chosen that making a warmth retentive vapor is the essential target. This sort of framework is commonly utilized where water harm might be a worry, or where water supplies are restricted. NFPA 750 characterizes water fog as a water splash with a bead size of "under

1000 microns at the base activity weight of the release spout." The bead size can be controlled by the changing release weight through a spout of a settled hole estimate. By making a fog, an equivalent volume of water will make a bigger aggregate surface zone presented to the fire. The bigger aggregate surface territory better encourages the exchange of warmth, along these lines enabling more water beads to swing to steam all the more rapidly. A water fog, which ingests more warmth than water per unit time, because of uncovered surface territory, will all the more successfully cool the room, in this manner lessening the temperature of the fire. Activity - Water fog frameworks can work with an indistinguishable usefulness from downpour, wet pipe, dry pipe, or pre-activity frameworks. The distinction is that a water fog framework utilizes a packed gas as an atomizing medium, which is pumped through the sprinkler pipe. Rather than compacted gas, a few frameworks utilize a high-weight pump to pressurize the water so it atomizes as it leaves the sprinkler nozzle. Systems can be connected utilizing nearby application technique or aggregate flooding strategy, like Clean Agent Fire Protection Systems.[7]

Chapter 2: Literature Review

2.1 Project background

Sprinkler frameworks are expected to either control the fire or to stifle the fire. Control mode sprinklers are expected to control the warmth discharge rate of the fire to counteract building structure crumple, and pre-wet the encompassing combustibles to avoid fire spread. The fire isn't smothered until the point that the consuming combustibles are depleted or manual extinguishment is affected by firefighters. Concealment mode sprinklers (in the past known as Early Suppression Fast Response (ESFR) sprinklers) are planned to bring about a serious sudden decrease of the warmth discharge rate of the fire, took after rapidly by entire extinguishment, preceding manual intercession. [2]Most sprinkler frameworks introduced today are composed utilizing a territory and thickness approach. In the first place the building use and building substance are broke down to decide the level of flame danger. Typically structures are named light peril, conventional risk gather 1, common danger amass 2, additional risk bunch 1, or additional danger aggregate 2. In the wake of deciding the danger order, a plan territory and thickness can be controlled by referencing tables in the National Fire Protection Association (NFPA) models [3]. The outline territory is a hypothetical zone of the building speaking to the most pessimistic scenario region where a fire could consume. The plan thickness is an estimation of how much water per square foot of floor territory ought to be connected to the outline region. For instance, in an office building delegated light risk, a run of the mill outline zone would be 1,500 square feet (140 m2) and the plan thickness would be 0.1 US gallons for each moment (0.38 l/min) per 1 square foot (0.093 m2) or at least 150 US gallons for each moment (570 l/min) connected over the 1,500-square-foot (140 m2) outline zone. Another illustration would be an assembling office named conventional danger gather 2 where a regular outline zone would be 1,500 square feet (140 m2) and the plan thickness would be 0.2 US gallons for every moment (0.76 l/min) per 1 square foot (0.093 m2) or at least 300 US gallons for each moment (1,100 l/min) connected over the 1,500-square-foot (140 m2) outline zone [3]. After the plan zone and thickness have been resolved, computations are performed to demonstrate that the framework can convey the required measure of water over the required outline territory. These figuring's represent the greater part of the weight that is lost or picked up between the water supply source and the sprinklers that would work in the plan region. This incorporates weight misfortunes because of grinding inside the funneling and misfortunes or increases due to elevation contrasts

between the source and the releasing sprinklers. Once in a while force weight from water speed inside the channeling is likewise computed. Ordinarily these counts are performed utilizing PC programming yet before the coming of PC frameworks these occasionally entangled computations were performed by hand. This expertise of ascertaining sprinkler frameworks by hand is as yet required preparing for a sprinkler framework outline technologist who looks for senior level accreditation from building confirmation associations, for example, the National Institute for Certification in Engineering Technologies (NICET) [3]. Sprinkler frameworks in private structures are winding up more typical as the cost of such frameworks turns out to be more down to earth and the advantages turn out to be more self-evident. Private sprinkler frameworks more often than not fall under a private arrangement isolate from the business orders said above. A business sprinkler framework is intended to shield the structure and the inhabitants from a fire. Most private sprinkler frameworks are principally intended to smother a fire in such an approach to take into consideration the sheltered escape of the building tenants. While these frameworks will regularly additionally shield the structure from significant fire harm, this is an auxiliary thought. In private structures sprinklers are frequently excluded from wardrobes, washrooms, galleries, carports and upper rooms on the grounds that a fire in these zones would not more often than not affect the tenant's escape course [2]. In the event that water harm or water volume is of specific concern, a procedure called Water Mist Fire Suppression might be an option. This innovation has been a work in progress for more than 50 years. It hasn't entered general utilize, however is increasing some acknowledgment on ships and in a couple of private applications. Fog concealment frameworks work by utilizing the warmth of the fire to 'streak' the water fog cloud to steam. This at that point covers the fire. Thusly, fog frameworks have a tendency to be profoundly powerful where there is probably going to be a free-consuming hot fire. Where there is lacking warmth (as in a profound situated fire, for example, will be found in put away paper) no steam will be created and the fog framework won't douse the fire. A few tests have demonstrated that the volume of water expected to smother a fire with such a framework introduced can be significantly not exactly with a traditional sprinkler framework [2]

2.2 Previous Work

As there is the Fire sprinklers design by NFPA, each shut head sprinkler is held shut by either a warmth delicate glass knob or a two-section metal connection held together with fusible composite. The glass globule or connection applies weight to a pipe top which goes

about as a fitting which keeps water from streaming until the point that the surrounding temperature around the sprinkler achieves the outline enactment temperature of the individual sprinkler head. In a standard wet-pipe sprinkler framework, every sprinkler actuates autonomously when the foreordained warmth level is come to. In this way, just sprinklers close to the fire will work, ordinarily only maybe a couple. This expands water weight over the purpose of flame starting point, and limits water harm to the building [8]. A sprinkler actuation will do less water harm than a fire division hose stream, which give around 900 liters/min (250 US gallons/min). An average sprinkler utilized for mechanical assembling inhabitances release around 75-150 liters/min (20-40 US gallons/min). In any case, a run of the mill Early Suppression Fast Response (ESFR) sprinkler at a weight of 50 psi (340 kPa) will release roughly 380 liters for each moment (100 US lady/min). Furthermore, a sprinkler will for the most part initiate inside one to four minutes of the fire's begin, while it commonly takes no less than five minutes for a fire office to enlist an alert and drive to the fire site, and an extra ten minutes to set up hardware and apply hose streams to the fire. This extra time can bring about a substantially bigger fire, requiring considerably more water to stifle. This has been implemented internationally as the standard operation of the fire sprinklers by NFPA which could give it the best credit among other practices among other safety organization [8].

2.3 Comparative Study

1- Verifying Fire Safety Design in Sprinklered Buildings by Fredrik Nystedt from Lund University in Sweden. This report contains a check strategy that could be connected when assessing trail fire security plan in an execution based code condition. The report is concentrated on plan options (i.e. outline options) where fire sprinkler frameworks have an essential part. Three conceivable check techniques are proposed together with the strategy on how they could be connected in outline. The secured techniques are both subjective and quantitative (deterministic and in addition probabilistic). Keeping in mind the end goal to get full advantage of a sprinkler framework establishment, sprinkler execution information is exhibited together with another arrangement of legitimacy criteria in sprinklered structures and sprinklered configuration fires [9].

2- Fire Safety Design Duiflines for Federal Building by George V. Hadjisophocleous and Noureddine Benichou. Which in this study it displays the execution criteria that can be utilized as a part of outlining fire insurance frameworks in structures and the models used to decide if the outline criteria are met by the proposed plans. The models are displayed

alongside their confinements and accessibility. Moreover, the strategies and methods utilized for flame security administration are additionally analyzed [10].

3- A review of sprinkler system effectiveness studies by Kevin Frank which in his paper audits the data presently accessible on sprinkler viability in flames. Two methodologies are by and large taken for assessing sprinkler viability: part based methodologies utilizing a blame tree or comparative strategy and framework based methodologies utilizing fire occurrence information where sprinklers were available. In this paper, sprinkler framework part information and viability gauges from framework-based investigations have been ordered and arranged, with a correlation of the benefits of the two methodologies. Suggestions for utilizing the information for configuration reasons for existing are made, including contemplations for vulnerability and utilizing a half and half framework/part approach for particular sprinkler framework correlations. These suggestions give contribution on the unwavering quality of frameworks in the advancement of execution based fire wellbeing outline techniques [11].

Chapter 3: System Design

Design Constraints and Methodology

The constraints of each manufactured part are listed in table 3.1. The manufactured parts will contain the following parameters, which are; size, geometry, weight, cost, and the effect of the environment on the design.

Table 0.1 *Contains the constraints and details of each manufactured part*

Item	Size	Geometry	Environment	Weight	Cost
Room Pipe	We have chosen the size of the room that can handle two sprinklers as to replicate an actual room size , 4x4 , in a smaller scale. The Dimensions are: 1m x 1m x 2m.	Cubed Rectangular: *Easy to manufacture.	It is applicable to be designed to be regular room with a room temperature 25 degree Celsius .	- NA	-NA
Sprinkler head	The size of the sprinkler head is determined by the application that is used for. The Fire sprinkler head must have the ability to cover the area od the room desired to be equipped with it in which it covers 130-200 Square feet per head. The Dimensions are: Diameter; 34mm length; 74.6mm	Deflector : *Has the ability to distribute the water in circular pattern .	The material of the Fire sprinkler head should not be corrosion resistant to increase the life duration and usually it is painted by chrome.	The weight of the fire sprinkler head is around 60 gs.	The material must be corrosion resistant and easily installed. The Price: 40 SR

Glass Bulb	The size of the glass bulb must be very small to ensure breaking easily and make sure it blocks the water as it resist the pressure applied upon it. The length dimensions are: 24 mm.	Chemical inside the bulb: *Chemical thermally expanding and enables significant improvement in response time	*Can be handled very easy and not hazardous for the body or environment.	The Weight is: 10 grams	The glass bulb costs: 10 SR
Elbow	½ inch size	Circular shape	Easy to control And easy to connect other steal part together	500 gram	4 SR EACH
Seal	The size of the seal in diameter The dimensions are: Diameter: 27mm	Cone Shape	The material of the Seal rubber can be recycled and safe for the environment.	-	The cost of the Seal is usually 5 SR.

3.1.1 Constraints

The Fire sprinkler can be used in places all around the world as along as it can be installed in the roof. The constraints that can affect the overall design of the fire sprinkler are as follows:

I. Environments
II. Economical
III. Manufacturability
IV. Safety
V. Sustainability
VI. Geometrical constraints
VII. Engineering standards

The design constraints above will be taken into consideration in more details. The final design of the Fire Sprinkler will have to take in consideration of the effect that any changes in dimensions will have as a result. The project will apply the engineering standards for future manufacturing to allocate the parts used in the Fire Sprinkler [12].

3.1.1.1 Environments

The environment is a huge factor to take into consideration. The environment can affect the efficiency of the project as a whole. The environments that the project can work at, are places that are too cold and in tropical regions where the water is okay to stay in the pipes. The Fire Sprinkler can be significantly used in closed places that have high occupancy levels where people can be many for example, Gyms, restaurant, offices, etc. The Fire Sprinkler will not be able to always be installed, for example we can't equip a kitchen with it because the water could not put the fire that are is oil base fire, so to be careful to choose the right type of the fire sprinkler [12].

3.1.1.2 Economical

The main benefit of using the Fire Sprinkler is to suppress the fire and reduce the number of people getting hurt by the fire and to reduce the physical loss as much as possible. The constraint that we faced is the amount of water flowing through the pipe is not sufficient to put the fire that can spread as chemical gasoline or fuel can be the cause of the fire as it spread quickly and widely. The more specification and expensive Fire sprinkler and the material inside the pipes we provide to the system the faster and effective the rate of suppressing the fire. The increase in spending money to have the very advanced and up to date fire sprinklers will increase the chance to have better system and put the fire quicker [12]

3.1.1.3 Manufacturability

The system can be manufactured very easily due to the availability of the material and way of manufacturing that is by Modeling in which we can have many pieces of fire sprinklers easily. In addition, the chemical tubes could be differs in manufacturability because the type of the chemical can be hard to obtain and placing the chemical inside the tube could be very difficult if the integrity is bad for that fire sprinkler. This because every temperature standard has specific color of the tubes in the bulb that have some constrains to manufacture. The main constraint that we face during the manufacturing of the fire sprinkler is the deflector head because it need to be designed carefully to cover up the room and if bent during transportation could lead to unpleasant result if operates [13]

3.1.1.4 Safety

Safety is always a main concern where the lives of people who are using the fire sprinkler have to take into consideration. The main one is the corrosion of the piece in which it will

reduce its efficiency and it might not work at all. The other thing is that to when there is some maintenance in the building, which the fire sprinkler system could be shut off, and then forgetting to out the system back online which might lead to disastrous results. So to solve that, there were a standard developed to recover this and reduce the time of the interruption of the system brought by NFPA. Also if the system is inappropriate for the hazardous in which the wrong type is installed in the wrong place for example if we are a very cold area we shall go for a Dry System not to make the water inside the pipe be frozen and leading to failure of the fire sprinkler system. Another thing to mention is that the fire sprinkler is not intended to be used many times; means that one fire sprinkler can handle only one fire a time. So we have o make sure that the fire sprinklers are changed and replaced if fire had happened to ensure the functionality of the system [12]

3.1.1.5 Sustainability

The expensive and well-manufactured fire sprinkler will hopefully have a greater endurance compared to the cheap and low integrity fire sprinklers system. Where it will last longer and the functionality is faster and the maintenance is less and the reality is higher than the one with less specification and cheap standards. The better made fire sprinkler will only need annual checking and sometimes once every two years, but the cheap manufactured one can have a semiannual checking and may be subject to many interruption systems which is not acceptable if the place is critical and crowded with people [13].

3.1.1.6 Engineering Standards

The engineering standards will be applied on parts and materials that are being used on the project. The parts that will contain the standards is only the fire sprinkler head and its relevant. The pump will be using the standard IEC 60034-1 from the international electro-technical commission. The pipes will be using the ASME standards codes to determine the calculations for the forces that are being applied on the pipes; this will consist of calculation [12].

3.1.2 Design Methodology

Before starting to build our project and manufacture the parts we focused on some important points. The following are our important points that we focused on:

- Economical.

- Easy to manufacture.
- Practical.
- Applicable.

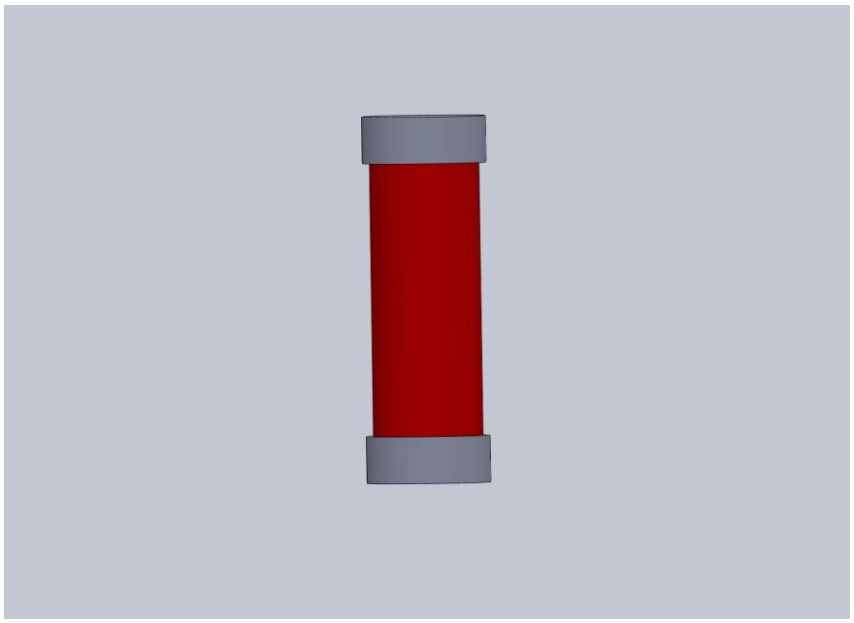
These points are important for us to build and manufacture our project in practical way. After we took these points into consideration we start build and manufacture the project's parts [14].

3.1.2.1 Glass bulb

The glass bulb has a liquid with a specific color such as red, green, blue white, purple, and every color indicates a different or a specific temperature that it reacts or the glass bulb breaks when high temperature is detected

The Figure 3.1 represents the follows;

- Width: 5mm
- Length: 10mm



- Height: 24mm
- Thickness: 10mm

Figure 3.1

3.1.2.2 Seal

The seal is an important part that hold the glass bulb and it is controlling the water discharge through the pipes and has a bigger dimeter than the glass bulb, the glass bulb and the seal are very related to each other, as soon as the glass bulb indicates the heat transfer to it and breaks, the seal will be released from the sprinkler causing the water fluid to flow from pipes to the sprinkler head [15].

Figure 1.2 Solidworks drawing of the seal

3.1.2.3 Sprinkler head

It is the main and important part in the fire sprinkler system, it is the component of a fire sprinkler that discharges water fluid when the effected of a fire or high temperature have been detected as such as a predetermined temperate have exceeded [14].

Figure 0.3 Solidworks drawing of sprinkler head

Engineering Standards

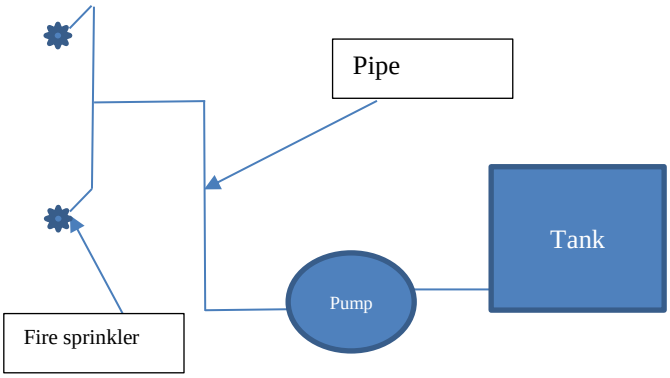
For all the components used in this project, engineering standards had to be followed. This section will briefly describe them. The engineering standards will be applied on parts and materials used on the project. The parts that will contain the standards are the seal, glass bulb, sprinkler head and the deflector. The sprinkler will be using the standard EN 12845. The glass bulb will be using the NFPA13 codes to calculate at what temperatures will the glass reacts and breaks; this will consist of calculating the temperature. The seal is the standard NFPA13 and is a rubber seal that can control discharge of water through the pipe [11]

Table 0.2 *Engineering standards*

Components	**Engineering Standard**
Glass bulb	NFPA13
Seal	NFPA13
Sprinkler head	EN 12845

Theory and Theoretical Calculation

3.1.3 Velocity calculation



$$Q=0.0004995\ m3/s$$

$$\mathrm{A} = 0.0001267\ \mathrm{m2}$$

$$v = \frac{Q}{A} = \frac{0.0004995}{0.0001267} = 3.94\ m/s$$

$$Re = \frac{\rho v D}{\mu} = \frac{1000 \times 3.94 \times 0.0127}{0.0008891} = 56279.38\ Turbulant$$

$$\frac{1}{\sqrt{f}} = -1.8\log\left[\frac{6.9}{Re} + \left(\frac{\epsilon/_D}{3.7}\right)^{1.11}\right]$$

$$\frac{1}{\sqrt{f}} = -1.8\log\left[\frac{6.9}{56279.38} + \left(\frac{\frac{0.002 \times 10^{-3}}{0.0127}}{3.7}\right)^{1.11}\right]$$

$$\frac{1}{\sqrt{f}} = 6.95 \gg f \approx 0.020668$$

$$hl_{Total} = \frac{0.020668(2.5)}{0.0127} + 0.5 + 3(0.9) + h_{plastic\ pipe}$$

$$z = \frac{v^2}{2g} \gg v = \sqrt{2gz}$$

$$v = \sqrt{2 \times 9.81 \times 0.5} = 3.13\ m/s$$

$$Re = \frac{\rho v D}{\mu} = \frac{1000 \times 3.13 \times 0.0127}{0.0008891} = 44739.1\ \ Turbulant$$

$$\frac{1}{\sqrt{f}} = -1.8\log\left(\frac{6.9}{44739.1} + 0\right)$$

$$f_{plastic} = 0.02124$$

$$h_l, total = h_{stainless\ steel} + h_{plastic} + h_{minor}$$

$$h_l = \frac{0.020668(2.5)}{0.0127} + \frac{0.02124(2)}{0.0127} + 0.5 + 2(0.9) + 1.05$$

$$h_l = 10.76\ m$$

$$\frac{p_1}{\rho g} + \frac{{v_1}^2}{2g} + z_1 + h_{pump} = \frac{p_2}{\rho g} + \frac{{v_2}^2}{2g} + z_2 + h_l$$

$$h_{pump} = \frac{{v_2}^2}{2g} + z_2 + h_l$$

$$h_{pump} = \frac{{v_2}^2}{2g} + 1m + 10.76m$$

$$39.9 = \frac{{v_2}^2}{2 \times 9.81} + 1 + 10.76$$

$$v^2 = (2 \times 9.81) \times 28.14$$

$$v^2 = 552.11 \gg v = \sqrt{552.11}$$

$$v = 23.5\ m/s$$

Where:

V: Velocity of flow.

h_l: Head loss.

f: Friction factor.

h_m: Minor friction.

Z: height of pipe.

g: Gravity.

$\rho\ of\ water = 1000\ {}^{kg}/_{m^3}$

$$A\ of\ pipe = \frac{\pi * D^2}{4}$$

The velocity of water for pipe's diameter:

$when\ D = 0.0127m$

Table 0.3 *Calculation of water velocity*

Diameter D [mm]	0.0127 m
Velocity u [m/s]	23.5 m/s

Product Subsystems and selection of Components

3.1.4 Sprinkler head

Figure 3.4.1

Is an active fire sprinkler protection method, consisting of water supply system, providing adequate pressure and flow rate to a water distribution piping system, and the sprinkler should be a long life material and service high humidity and not corroded easily and has a long life even if it didn't work or functioned for years [11].

3.1.5 Glass bulb

It is the glass color that indicates at what temperature the sprinkler will work and function and every color indicates a specific temperature and reacts with it such as shown in the figure 3.4.2 below.

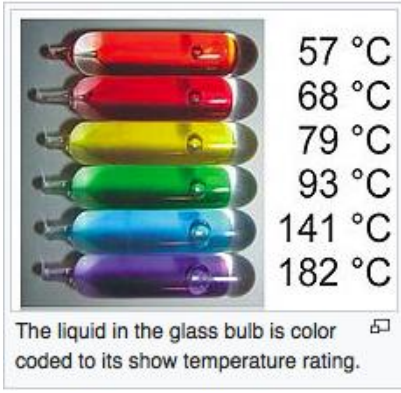


Figure 3.4.2

3.1.6 Seal

Is the rubber part that holds and connect the glass bulb and control the discharge of fluid water from the pipes and it works as soon as the glass bulb breaks due to detected temperature.

Manufacturing and assembly (Implementation)

3.1.7 Sprinkler system (assembly)

Consisting of metal sprinkler head, seal, glass bulb and gives us a fire sprinkler system. This will carry the main load as it deliver and distribute the flow equally through the rounded pieces that looks like flower petals. the screwing mechanism is to connect it to the pipes and have the mean of portable and be easy to change because they are going under quarterly of annual checking if they get rusted or corroded or damaged. They have to be decently cheap and handy so they provide many chances of the environment to make it safer and good to live in under the extreme heat circumstances like in GCC countries.

Figure 3.5.

3.1.8 Glass bulb

This glass bulb indicates at which temperature the sprinkler will activate at a detected heat temperature [11]. This heat is varies from one color to another in which each one have a different responding temperatures that cracks on.

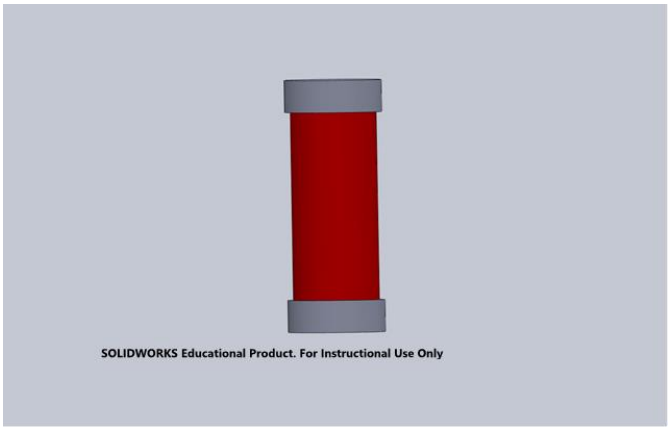


Figure 3.5.2

3.1.9 Seal

This seal holds the water pressure by holding the glass bulb and as soon as the glass bulb reacts and breaks due to heat it will release the water to the sprinkler head.

Figure 3.5.3

Chapter 4: System Testing and Analysis

4.1 Experimental Setup, Sensors and data acquisition system

1- Connect the pipe to tank.

2- Connect the pipe from the tank to the pump.

3- Connect the elbow to the pipe to T joint.

4- Install the fire sprinkler on the pipe.

5- Apply heat to the fire sprinklers.

6- Record the results [16]

4.1.1 Image of the setup and the locations of the sensors:

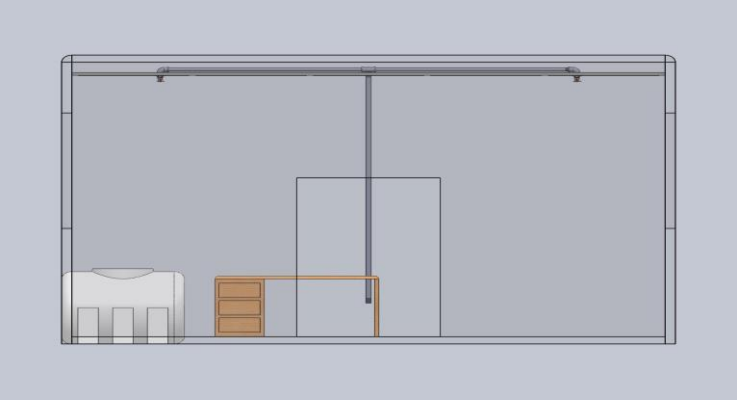


Figure 4.1.1

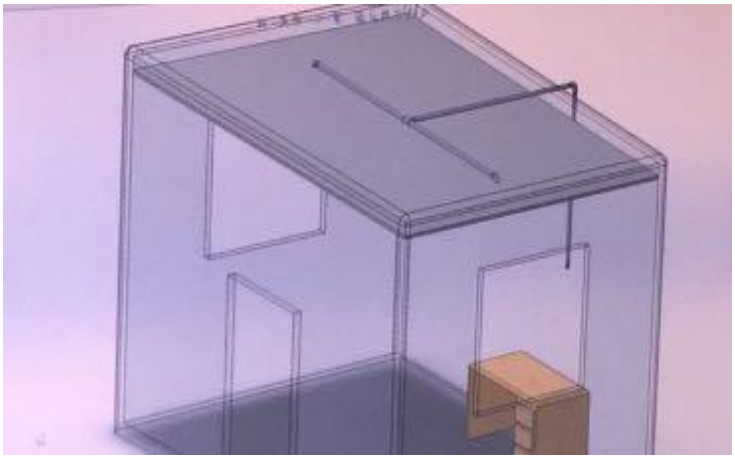


Figure 4.1.2

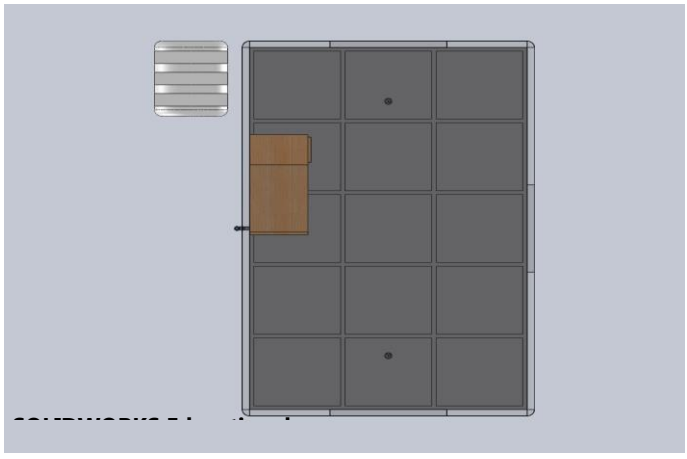


Figure 4.1.3

4.1.2 Specification of the sensor:

- Width: 5mm
- Length: 10mm
- Height: 24mm
- Thickness: 10mm
- Break temperature at 68°

4.1.3 Testing parameters:

A procedure used to determine the status of a system as intended by conducting periodic physical checks such as water flow tests, and fire pump tests. These tests follow up on the original acceptance test at intervals specified in the appropriate chapter of NFPA 25 [16].

4.2 Results, Analysis and Discussion

Figure 4.1.3

Figure 4.1.4

Fire sprinkler experiment results:

Temperature	statues
54°	didn’t break
58°	didn’t break
62°	didn’t break
66°	didn’t break
69°	break

Table 4.2. Fire sprinkler break temperature.

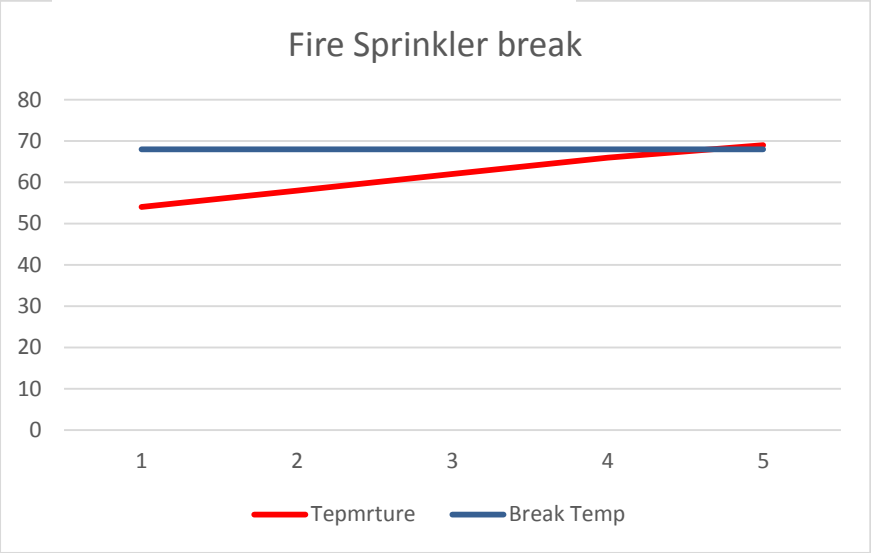


Figure 4.2. Fire sprinkler break temperature experiment.

4.2.1 Discussion:

The goal of this experiment is to show the when sprinkler will break based on temperature on each type. Upon the experiment that we have done on the fire sprinkler on Wet Pipe System, [16] the temperature break on 69°. As the red bulb standard will break at the temperature of 68 degree Celsius we have only one degree as the difference between the standard and the experimental in which could be considered as human error. The most important factor that have been found theoretically is the velocity in which it have been found to be 23.5 m/s and the experimental measurement we found using the pressure gauge is 23.1 m/s. the velocity we found experimentally has some minor losses in which they are represented in the 90 degree elbows and the Tee Joints that have the KL= 0.9 and KL=1.05 respectively. Constructing the project without the help of pump was our first plant to check whether the system will run properly or not. Obviously, it have found to be running poor

without the pump ; so in order to compensate the minor /major losses through the pipes we should add the pump to get the expected results in which the fire sprinklers will work accordingly and operate within the acceptable limit and afford the sufficient flow and velocity to extinguish the fire. In most cases, there will be a desperate need to the pump because there are the fire sprinkler will not work and have the completed radius of fire water in order to put the fire off . If we stay on the same elevation in which we lifted the tank 3 meters the flow will not be distributed in full radius of 8 meters square, so the pump is essential to get the proper flow and pressure to put the fire off. In another words, the fire should have very reliable pressure and flowrate to protect the souls and prevent the loss. So the pump compensated the loss in the friction and elevation constrains in which if we want to get the same pressure without the pump we must elevate the tank almost 3 times its original place which is almost not practical and not safe to be practiced for college demonstration and illustration. The easy and suitable way to bring the demo to school and share with others and find and observe the different variations in parameters is to bring the pump and start to calculate and measure and have the standard met.

Also as we were doing the survey in PMU, we have found some misconstruction of the fire sprinkler system in some of the mechanical engineering classes where the sprinklers are covered by plastic protection. This plastic protection is what they used to protect the glass of the fire sprinkler to break during the shipping and transportation, but they did not remove the plastic cover while installing thinking that it is part of the fire sprinkler. This may lead to a tremendous loss and disaster in which the sprinkler will not work as the plastic cover is on it and the heat will not touch the glass to break up and release the water. So that is one of the most important standard in which it should be known and be familiar with. Along with the possibility of the fire to happen in which the department is full of the laboratory materials and heat experiments and many coils that are used for test and to be experimented. So as to make this clear we have continue our journey to survey for more of misconstruction of the fire sprinklers and we found only 4 rooms in the ground floor of PMU’s engineering classes.

Chapter 5: Project Management

5.1 Project Plan

In this project we worked as team and we make a time plan for each task. We followed our time plan to the end of the project. Here in the table 5.1 its describe our time plan what we did clearly.

Table 0.4 Duration of the tasks

No.	Tasks		Start Date	Finish Date	Duration
1	Introduction		February 1, 18	February 4, 18	4 Days
2	Literature Review	Project background	February 10, 18	February24 , 18	14 Days
		Previous Work			
		Comparative Study			
3	System Design	Design constraints	February 25, 18	March 10, 18	14 Days
		Design Methodology			
		Product Subsystems and Components			
		Implementation			
4	System Testing and Analysis	Subsystem1	April 1, 18	April 30, 18	30 Days
		Subsystem2			
		Overall Results Analysis and Discussion			
5	Manufacturing	Solidworks model	February 1, 18	February 6, 17	6 Days
		Room			
6	Test the system	Sprinkler	March31, 18	April 3, 17	4 Days
		Pump			
7	Writing, corrections and presentation		February 1, 18	April 17, 18	76 Days

5.2 Contribution of Team

Here we divided the work between the team members by the leader and supervisor. The distribution is based on the strength and knowledge of each person according to the task. In the table 5.2 below shows who assigned to each task.

Table 0.5 Tasks distribution

No.	Assigned	Contribution	Load percentage
1	Introduction	All	100%
2	Literature Review	Ibrahim AlSulaiman+ Mhd AlHarfi + Mhd Alissa	100%
3	System Design	Ibrahim Alsulaiman+ Mhd AlHarfi+ Ibrahim Mutambak	100%
4	System Testing and Analysis	All	100%
5	Project Management	Mhd Alissa+Mhd Alharfi + Ibrahim Alsuliaman	100%
6	Project Analsis	Ibrahim AlSulaiman+ Majid AlShammari+ Ibrahim Mutambak	100%
7	Conclusion	Majid AlShammari+ Ibrahim AlSulaiman	

5.3 Project Execution Monitoring

During the work we worked in the different places some of them usually and some once or few. In the table 5.3 below shows the time for each Place.

Table 0.6 Table of activities

Time	Activities
Weekly meeting	With group members
Meeting every three weeks	With advisor
April 2, 2018	Midterm presentation
April 1 2018	Test the system
May 3 2018	Final presentation

a. Challenging and Decision Making

When we worked on the project there was some challenges and problems we faced like:

1- Three of us are employee

2- Design problem

5.3.1 Three of us are employee

The challenge here is the employees two of them in Jubail and the other one in Alkhafji. Also all of them are married and they have a kids and it was problem to choose suitable time in the middle of the week so the solution was to make a group in the Skype and we make a group video call.

5.3.2 Design problems

At the beginning we could not identify what is the diameter of the pipe the will be suitable to deliver the water flow rate or velocity that we maintain we made the pipe at incline angle to increase the velocity and to cover a certain distance but to bad we didn’t so we used a pump to increase the velocity of the water through the pipe to the sprinkler and it worked and we reached the distance we desired to reach.

5.4 Project Bill of Materials and Budget

In this part table 5.4 he will describe the materials costs

Table 0.7 List of material and their cost

Materials		Cost (SR)
Pipe		400 SR
Elbow		25 SR
Pump		700 SR
Tank		183 SR
Temperature Gun		300 SR
Room		800 SR
Roof		58 SR
Sprinkler	Sprinkler head	40 SR
	Glass Bulb	10 SR
	Seal	5 SR
Total		2,521 SR

These materials are very important to completed the experiment and run the fire sprinkler for testing. The pipes, elbows and joints are connected together to make the proper shape that will hold the fire water within and deliver it via the pump to reach to the fire sprinkler head. These pipes and elbows have some minor losses in which the water will not deliver 100% to the head of the sprinkler, so we brought a pump to compensate these losses and run the fire water through the pipes efficiently. As this material has been purchased to meet our goals of testing and experimenting the fire sprinklers , we have used the gun temperature to measure the heat within the fire sprinkler as it is subjected to the fire. We want to check and test the temperature of the glass in which it breaks and we really had found that it breaks on 69 degree Celsius. Also the pump as we mentioned is a very important element to carry and compensate the losses occurred in the pipes and elbows and maintain the pressure and velocity to last tip of the fire sprinkler. These apparatus are very essential to get the experiment completed and succeeded to achieve the desired goals.

Chapter 6: Project Analysis

6.1 Life Long Learning

During our project's life we had learned and improve many skills, knowledge, and experiences. We had gained and taught all of these things from working in a group, limitation of time, and communications. Each one of these things taught us different skills, knowledge, and experiences. I will divide the most important learning that we had gained during our project's life into four parts and I will explain each of them

6.1.1 Improve our Skills in Some Software Tools

We had to use many software tools during our project, such as Solidworks, Microsoft Word, and Microsoft PowerPoint. All of these software tools are not new for us, but we had used them in a more professional way. We learned many things in these software tools that we had not learned them before.

6.1.2 Time Management Skill

Time management skill is one of the important skills that we learned though our project's life. When we want to achieve some specific objective and goals at the specific time we have to manage our time and distribute the tasks for each member to end them at specific time. While we worked on the project we faced many tasks that assigned for us to do them at specific time. This challenge gave us a great skill and experience to manage our time. To manage our time, we built our GRANTTS chart that includes all the tasks and the subtasks that we have to achieve them through the project's life. GRANTTS chart is one of the most useful tools that help us to know when we should start and when we should end each task.

6.1.3 Problem Solving

While we worked on the project we faced many problems that we solved eventually. These problems gave us good knowledge, skills, and experience of how to solve the problems. We had faced many problems during our project's life that we solved them skillfully such as purchasing right materials and tools, finding a machinist, and importing from abroad. Actually, this skill helped us to know how to solve the problem that we will face in the future skillfully.

6.2 Impact of Engineering Solutions

Our project achieved great impact on the society, environment, and economy. We will explain the impact of each of them in details.

6.2.1 Society

When we come to the society it is the most important source that we have to care about it. Our target is to provide a good impact on the society to can present our project in good way. Our project can be used in houses to save from fire in the living spaces. If the fire is spreading fast it will lead to very disastrous circumstances and high loss in souls and money. So our project can suppress the fire and provide more saving for ourselves and our money and property. Also, we can use the project at industries and all indoor affiliates where the fire possibility of occurring is high. Moreover, the other impact on the society is that we can use the project to suppress the fire in all the closed areas such as gyms, kitchens, restaurant and all the places that can possibly trapped around walls.

6.2.2 Environment

We will explain the impacts that our project achieved on the environment. As we all know high fire caused a lot of loss of souls and assets such as people can die from burning and suffocation, some kind of fire should be treated with the proper agent no all time we use water. So our project will give good reduce on these losses and provide safe area under universal fire protection standards.

6.2.3 Economy

When it comes to the impacts that our project achieved on the economy, our project is a simple example of an efficient economic fire sprinkler. Our project has a pump, so it will increase the pressure of the fluid applied on the intended area properly and not exceeding the amount of water needed. So we don’t go for too much water neither for less water to put the fire down. The amount of energy we consume for putting the fire is very small compared to other operating systems that might consume too much energy to put the fire and cost too much. Also, our project needs less maintenance compared to other fire sprinklers that used dry system and heaters to keep the water unfrozen.

Contemporary Issues Addressed

When start talk about the issues that are facing our GCC countries and Saudi Arabia, we will talk about how fire sprinklers should be used properly standards shall be followed in

order to reduce the enormous loss. When summer is beginning, the fire is tending to happen frequently due to the very high temperature that can be reached in the summer. As we know, the temperature might reach to more than 50 degrees Celsius and this could lead to fire if the fuel and oxygen are available. So we have to follow strictly the standards in which protection should be ready to suppress any type of fire under the extreme circumstances. Sometimes the building doesn't follow the standards and might get the fire to happen but we need to follow the standard strictly and seriously. This result in massive lost if not handled very fast and efficient and that is why we need to follow the standard in which the fire sprinklers should be distributed in the building as standard and ensure that the maintenance is done for all the part of the system as to reduce the lost if fire occurred.

Chapter 7: Conclusions and Future Recommendations

Conclusions:

Safety is always a main concern where the lives of people who are using the fire sprinkler have to take into consideration. The main one is the corrosion of the piece in which it will reduce its efficiency and it might not work at all. The other thing is that to when there is some maintenance in the building, which the fire sprinkler system could be shut off, and then forgetting to out the system back online which might lead to disastrous results. So to solve that, there were a standard developed to recover this and reduce the time of the interruption of the system brought by NFPA. Also if the system is inappropriate for the hazardous in which the wrong type is installed in the wrong place for example if we are a very cold area we shall go for a Dry System not to make the water inside the pipe be frozen and leading to failure of the fire sprinkler system. Another thing to mention is that the fire sprinkler is not intended to be used many times; means that one fire sprinkler can handle only one fire a time. So we have o make sure that the fire sprinklers are changed and replaced if fire had happened to ensure the functionality of the system. And after testing the Fire Sprinkler we have achieved the following:

1. Successfully designed and construct a Fire Sprinklers to show flow rate and pressure distributing for fire detected in school or hospital or chemical industry using specific type of sprinkles
2. We studied the change in different types of the Fire Sprinklers and how they can be more efficient for their designated area and field.
3. We chose the right type and medium used in specific weather and conditions .
4. Developing fire sprinklers distribution techniques to prevent huge uncontrolled fire to be put off without the need to make firefighters possess more danger and lessen their exposure to fire as much as possible.

Future Recommendations

Mainly we have found that in some cases we can get benefit of the fire water when it gets out of the fire sprinkler. To clear that , if the water released from the fire sprinkler it carries a pressure and flow rate. This pressure that is developed could be used in another application in which emergency light can run on a motor that runs on the rotational power developed from the fire sprinkler rotating heads. Due to the fire occurred in the building all electricity will shut off and one way to light the building is by the power developed from the fire sprinkler movement. Also another thing that we recommend is that the standard should be strictly

followed in all the buildings in the country to ensure the safe distribution of the fire sprinklers in the buildings and be safer. As we have found the extreme weather in Saudi Arabia in the summer session the temperature reaches 50s degree Celsius and the possibility of the houses to burn is high. This because of the contents in the houses of gas cylinders and heat developed by the appliances and other devices which can lead to fire . So we recommend to strictly have the fire sprinklers system to be installed in every house in Saudi Arabia , in which the system is not very cost and will provide a protection of the human souls. Also as we found in PMU there are some classes that have the wrong installation of the fire sprinklers in which they will not operate .Clearly , the case we found at PMU that the for sprinkler glasses are covered by a plastic cover that protect the glass from breaking due to the shipping and transportation. These pieces have not been removed and the fire sprinkler will not operate if the plastic cover did not removed.

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