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ASSESSMENT OF FIRE SPRINKLER SYSTEM OPERATIONS AT POWERMECH PROJECT LIMITED

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ABSTRACT:

Fire sprinkler systems are essential fire protection mechanisms involving a water supply and distribution system connected to sprinklers. They are widely used in commercial buildings, factories, and increasingly in residential structures due to affordability. Each year, over 40 million sprinkler heads are installed globally, and systems that exclusively utilize sprinklers can suppress over 96% of fires. Sprinklers have been standard in the U.S. since 1874, particularly in industrial settings prone to devastating fires. Current regulations mandate their installation in new skyscrapers and basements over 75 feet where firefighter access is limited. Building codes require sprinklers in assembly occupancies exceeding 100 people and facilities like hotels and hospitals to qualify for funding. This project aims to create a simple fire sprinkler test setup, simulating real fire conditions to assess performance, radius, coverage area, and the necessary number of sprinklers for effective fire control, based on flow rate and pressure requirements.

KEYWORDS: Fire sprinkler systems, fire suppression, fire safety regulations, sprinkler installation, flow rate, water pressure requirements, coverage area.

INTRODUCTION

This project aims to design and manufacture an adjustable fire sprinkler system capable of being tested with interchangeable tube bulbs, allowing for numerous evaluations. The importance of the project lies in understanding the distinct characteristics of various fire sprinkler types for their effective application in specific environments, enhancing safety across multiple settings such as industrial plants, schools, and hospitals. Key aspects include demonstrating the specifications, dimensions, and effective area coverage of the sprinklers, alongside educating students on their operational mechanisms and various nozzle flow distributions. The project objectives encompass constructing a fire sprinkler system tailored for different environments, studying the efficiency of various sprinkler types, adapting mediums like foam or water based on conditions, and innovating distribution techniques to minimize firefighter exposure to hazards. Detailed specifications are also a focus of the project, emphasizing tailored applications for distinct settings like schools versus chemical industries.

LITERATURE REVIEW

Automatic fire sprinkler systems have become one of the most effective fire protection technologies used in industrial, commercial, and residential buildings. According to National Fire Protection Association, sprinkler systems significantly reduce fire damage and improve occupant safety. Research by Hall Jr., John R. (2013) reported that sprinkler-only systems successfully controlled more than 96% of structure fires, demonstrating their reliability in emergency fire situations.

The hydraulic performance of sprinkler systems is a critical factor in ensuring effective fire suppression. Brock, Pat D. (2000) explained that proper water supply analysis, pressure calculations, and flow distribution are essential for maintaining adequate sprinkler operation during fire incidents. Similarly, Hickey, Harry (1980) emphasized the importance of hydraulic principles in designing efficient fire protection systems capable of delivering sufficient water discharge.

Studies by Wass, Harold S. (2000) further highlighted the relationship between sprinkler spacing, pressure requirements, and coverage area. The author discussed how hydraulic calculations directly affect sprinkler efficiency and overall fire control performance. These findings are important in designing experimental sprinkler setups for evaluating discharge radius and operational effectiveness.

Historical developments also contributed to the advancement of modern sprinkler technology. According to Associated Fire Protection (n.d.) and Wormald (1923), automatic sprinkler systems evolved rapidly during the industrial revolution due to increasing fire hazards in factories and warehouses. Grant (1996) noted that the establishment of the National Fire

Protection Association played a major role in standardizing fire safety regulations and sprinkler installation guidelines.

Recent fire safety standards require sprinkler installations in high-risk structures such as skyscrapers, hospitals, hotels, and assembly occupancies. Industrial Fire Sprinklers (2013) explained that modern building codes mandate sprinkler protection in areas where firefighter accessibility is limited. These regulations have increased the demand for efficient and affordable sprinkler systems worldwide.

The present project focuses on developing a simple fire sprinkler test setup to simulate real fire conditions and evaluate sprinkler performance. Parameters such as flow rate, pressure, spray radius, and coverage area are analyzed to determine the number of sprinklers required for effective fire suppression. The study contributes to understanding practical sprinkler operation and improving fire protection system design.

PROJECT OBJECTIVES:

1. Design and build a fire sprinkler system that uses a certain type of sprinkler to display the flow rate and pressure distribution for a fire detected in a hospital, school, or chemical plant.

2. Examine how various fire sprinkler types have changed and how they can be more effective for the field and area they are intended for.

3. Describe how various types and media are employed in various weather and situations based on the needs and surroundings.

4. Creating methods for distributing fire sprinklers to put out large, uncontrolled fires without putting firefighters in greater risk and reducing their exposure to flames as much as feasible.

SYSTEM DESIGN

Design Constraints and Methodology

The design and assessment of the fire sprinkler system were carried out under several operational and practical constraints to ensure realistic evaluation and safe experimentation.

Water Supply Limitation: The sprinkler system performance depends greatly on the availability of sufficient water supply, pressure, and flow rate. Limited storage capacity and pump discharge pressure restricted the operating duration and spray coverage during testing.

Pressure and Flow Requirements: Maintaining adequate hydraulic pressure throughout the pipeline network was a major constraint. Pressure losses due to pipe friction, bends, valves, and elevation differences affected sprinkler discharge efficiency.

Sprinkler Coverage Area: Each sprinkler head has a limited discharge radius and coverage area. Proper spacing between sprinklers had to be maintained to avoid dry spots and ensure uniform water distribution.

Environmental Conditions: Wind velocity, ambient temperature, humidity, and surrounding airflow influenced water spray patterns and reduced the effectiveness of sprinkler discharge during open-area testing.

Safety Constraints: Real fire testing involves high temperatures and smoke hazards. Therefore, controlled fire sources and limited combustible materials were used to ensure operator safety and prevent accidental fire spread.

Equipment Availability: The project was developed using locally available pipes, fittings, pumps, valves, and sprinkler heads. Budget limitations restricted the use of advanced automated monitoring systems.

Compliance with Fire Safety Standards: The system design had to satisfy standard fire protection guidelines and building safety regulations related to sprinkler spacing, pressure rating, and installation practices.

The document discusses the critical factors influencing the effectiveness of fire sprinkler systems across various environments and manufacturing considerations, emphasizing the importance of safety, sustainability, and adherence to engineering standards.

Environments: The environmental context greatly affects project efficiency, with fire sprinklers suitable for high-occupancy areas like gyms and restaurants. However, specific conditions limit their installation; for instance, kitchens cannot use traditional sprinklers due to oil-based fire hazards. The effectiveness of the sprinkler system is also tied to the water supply, with rapid-spreading fires caused by flammable liquids emphasizing the need for advanced sprinkler technology. Higher investment in sophisticated systems correlates with improved fire suppression capabilities.

Manufacturability: The manufacturing process for fire sprinklers is straightforward due to material availability, yet challenges arise with chemical tubes that may be difficult to produce and fill, particularly under strict temperature-related standards. A critical manufacturing constraint is the deflector head's design, which must ensure adequate coverage and maintain integrity during transport.

Safety: The document highlights safety concerns related to system failure, particularly due to corrosion or maintenance lapses that may lead to operational shutdowns. Standards developed by NFPA aim to mitigate such risks, emphasizing the need for an appropriate sprinkler type for specific environments, such as dry systems in cold areas to prevent freezing. Fire sprinklers are not intended for multiple uses and must be replaced after activation to ensure continued functionality.

Sustainability: High-quality fire sprinklers provide greater durability and efficiency over cheaper alternatives, requiring less frequent maintenance and offering reliable performance, which is crucial in densely populated areas. In contrast, lower-quality systems may lead to more frequent interruptions, making them unsuitable for critical environments.

Engineering Standards: The text specifies that engineering standards will govern the components utilized in the fire sprinkler system, focusing on the sprinkler heads and relevant parts. The pump will adhere to IEC 60034-1 standards, while ASME codes will guide the calculations for the forces acting on the pipes, ensuring a compliant and effective system.

Engineering Standards

The engineering standards that apply to the project's components are described in this section. The glass bulb, sprinkler head, deflector, and seal are important parts. While the glass bulb uses NFPA 13 regulations to establish its reaction and breaking temperatures, requiring temperature calculations, the sprinkler system complies with the EN 12845 standard. Furthermore, the rubber seal complies with NFPA 13 requirements, which govern the regulation of water discharge through the piping system.

Table 1 ***Engineering standards.***

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

PRODUCT SUBSYSTEMS AND SELECTION OF COMPONENTS

Sprinkler head

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.

Glass bulb

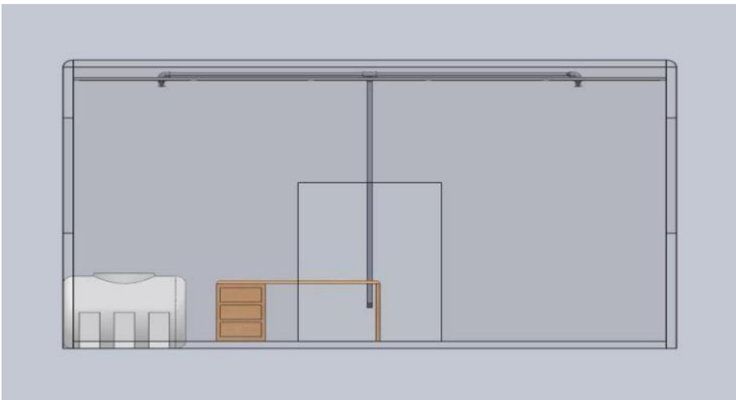
It is the glass color that indicates at what temperature the sprinkler will work and function and every color indicate a specific temperature and reacts with it such as shown in the figure below.

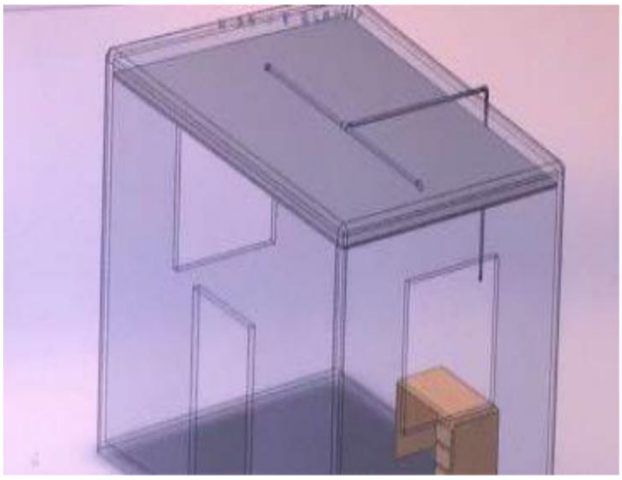
Figure 1.

SYSTEM TESTING AND ANALYSIS

Experimental Setup, Sensors and data acquisition system

- Connect the pipe to tank.
- Connect the pipe from the tank to the pump.
- Connect the elbow to the pipe to T joint.
- Install the fire sprinkler on the pipe.
- Apply heat to the fire sprinklers.
- Record the results





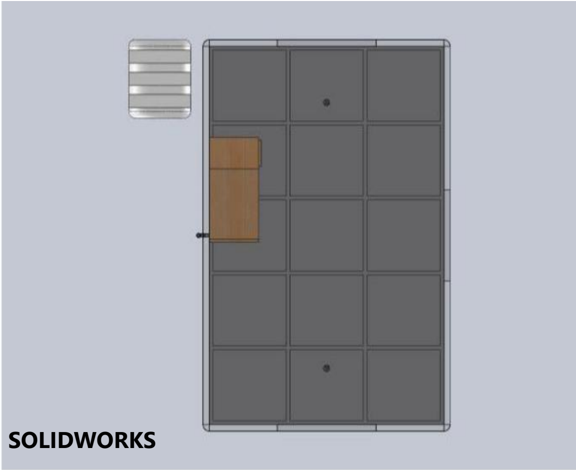


Figure 2-3-4.

Specification of the sensor:

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

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.

RESULTS, ANALYSIS AND DISCUSSION

The experiment aimed to determine when different types of fire sprinklers will break based on temperature. In a test involving the Wet Pipe System, the break point was observed at 69°C, closely aligning with the standard red bulb break temperature of 68°C. Theoretically, the critical factor affecting performance was found to be the velocity of water, recorded at 23.5 m/s theoretically and 23.1 m/s experimentally, with minor losses due to 90-degree elbows and Tee Joints. Initially, the project was constructed without a pump, resulting in inadequate performance; thus, a pump is deemed essential to compensate for losses in flow and pressure, ensuring the fire sprinklers function effectively within safety limits.

Without the pump, achieving the necessary pressure and flow rate for effective fire control is impractical, as elevating the water tank to compensate would be unsafe for demonstrations. Surveys indicated misconstructions within the PMU engineering classes, such as fire sprinklers being covered by plastic protective coverings. These covers, intended to protect the glass during transportation, were left in place during installation, obstructing the glass from breaking under heat and rendering the sprinklers ineffective.

This oversight poses a significant risk, particularly in an environment with numerous laboratory materials and heat experiments. A follow-up survey identified only four rooms on the ground floor of the PMU engineering classes with such misconstructions. The findings highlight the necessity for awareness and adherence to standards regarding fire sprinkler installation to prevent catastrophic failures during a fire incident.

CONCLUSIONS AND FUTURE RECOMMENDATIONS

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 to 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, it was observed that the fire sprinkler system can provide additional benefits apart from fire suppression. When water is discharged from the sprinkler heads, it carries considerable pressure and flow rate. The rotational movement produced by the sprinkler heads due to water discharge can be utilized for secondary applications. One possible application is the generation of mechanical power to operate a small motor connected to emergency lighting systems.

During fire incidents, the main electrical supply of a building is often shut down for safety purposes, resulting in loss of lighting inside the structure. The rotational energy developed from the sprinkler movement can therefore be converted into electrical energy to power emergency lights and improve visibility for occupants and rescue personnel during evacuation.

Furthermore, it is recommended that fire safety standards and regulations should be implemented more strictly in all commercial, industrial, and residential buildings. Proper installation, regular inspection, maintenance, and testing of fire sprinkler systems are essential to ensure reliable operation during emergencies. Strict adherence to fire protection standards can significantly reduce fire damage, protect human life, and improve overall building safety.

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