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Experimental Investigation on Water Mist Fire Suppression System

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Abstract

Fire hazards have been an issue in industrial as well as commercial sectors for years. Fire suppression systems equipped with water mist spray techniques are implemented in these buildings to avoid or prevent these property damages and human health hazards. But this water mist suppression system is less effective when collateral damage is considered. If we can reduce the fire suppression time, we will be able to decrease the loss. In order to enhance the performance of the fire suppression system, a new additive can be added to the system. So, this experiment deals with the calculation and comparison of fire suppression time of water mist and the mixture. A calculated proportion of the organic solvent mixture is added along with water mist. As we increase the proportion, the fire suppression time of the pool fire rapidly declines and then slightly increases at some point. Our aim is to find the point at which the fire suppression time is minimum for different organic mixtures. From this experiment, we can compare the fire suppression time of different organic solvents mixed with water mist.

Keywords*: - Fire suppression, Water mist suppression, Organic solvents.*

INTRODUCTION

Nowadays, fire hazards have been causing greater damage to human health and collateral damage. At present, infrastructure has implemented fire suppression systems having different types of fire suppressants. These hazardous fire damages are commonly observed in areas where people gather, such as theatre, shopping mall, hospitals, institutions, offices

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etc. We have been using conventional fire suppression systems with glass bulb type sprinkler employed in water mist fire suppression system. But, water as a fire suppressant has some clinical disadvantage, such as its corrosive nature and tendency to cause collateral damage. So we are introducing some modification to this conventional fire suppression system to reduce the fire suppression time. Our project titled "EXPERIMENTAL INVESTIGATION ON WATER MIST FIRE SUPPRESSION SYSTEM" focuses on reducing these hazardous fire effects by reducing the fire suppression time. We aim to acquire these results through an experimental investigation. We are performing the experiment using different water solvent mixtures. We plan to compare the reduction in fire suppression time using an experimental setup consisting of Air compressor, Control valve, Storage tank etc. Through this experimental study, we will be able to prevent inevitable devastation caused by fire.

OBJECTIVES OF THE WORK

- To increase the rate of fire suppression
- To reduce the health hazards caused due to fire
- To reduce collateral damage caused due to fire
- To prevent corrosion and property damage caused by water droplets when used as 100% water.

METHODOLOGIES

- Selection of different concentration of the water-organic solvent mixture
- Cost estimation
- Setting up of experimental apparatus
- Finding results through experiments

EXPERIMENTAL SETUP

The experiments can be conducted at any type of setup which is feasible and with the best geometry that resembles a hall. This experiment will be conducted on a 2m x 2m x 2m cubical chamber with an opening on one side. The main components are Air compressor, Solvent Water mist chamber, Control valve, Nozzle Interconnecting pipes. The experimental setup is completely enclosed with cast iron material. The whole bottom area will be used to produce fire. A tube carrying the fire suppressant will be passing through and enters the cube. A nozzle will be fitted to the end of the tube with nozzle facing downwards. The water mist solvent mixture from the respective chambers is directed to the nozzle using the air compressor. The flow is adjusted using a control valve. There is an external setup for

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the supply of the fire suppressants. The external setup will be having mainly 2 chambers, one for water and the other for the organic solvent that will mix with the water. Both the chambers will be connected to the air compressor that will provide enough pressure for the water to be sprayed. The actuation of the nozzle will be through a mercury tube which breaks, when the temperature goes high, allowing. See below **figure 1 and 2**.

Experiment to be conducted

The experiment will be conducted on a 2m x 2m x 2m cube with nozzles placed inside it at the necessary location. The bottom area will be filled with the fuel to be used, and fire will be set up when the temperature inside the cube goes beyond a preset value, the mercury tube breaks. The fire suppressant used will flow through the valve and then to the nozzle.

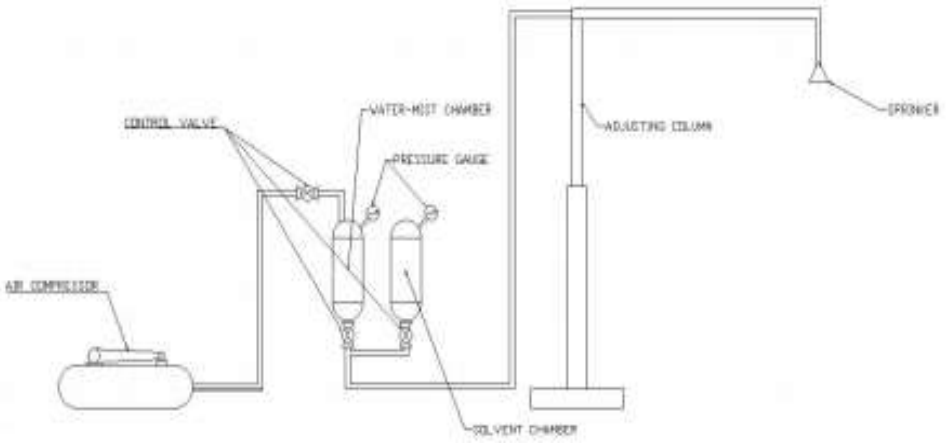

Figure 1: External part of experimental setup

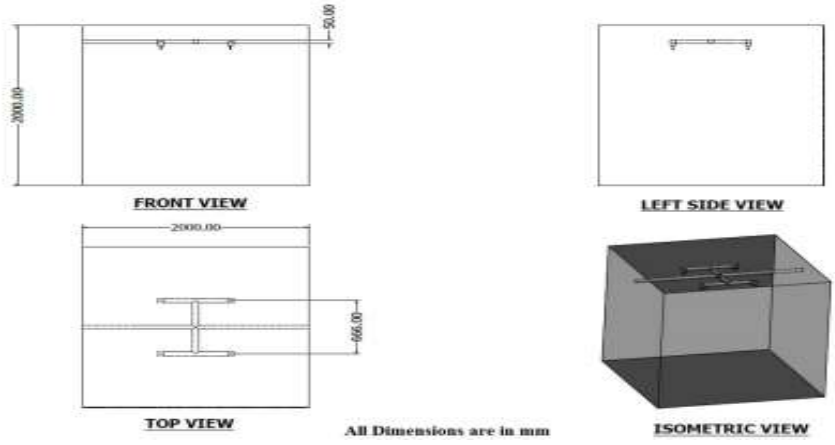

Figure 2: Experimental setup

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Due to the high pressure of water, the water hits at the nozzle tip, thus having a spray type action. This mixture will extinguish the fire. A high definition camera will record this process. Later, time will be calculated after examining the video at a slow speed. The time taken by the fire suppressant to extinguish the fire is noted down. First, the experiment will be conducted using pure water as a fire suppressant. The time for the water mist to extinguish the fire is measured using a stopwatch. Also, the volume of water needed is also found out. Then the water will be mixed with organic solvents at different proportions. Then the experiment will be conducted using a mixture of water and organic solvent. The time measurement obtained during all the experiments will be compared.

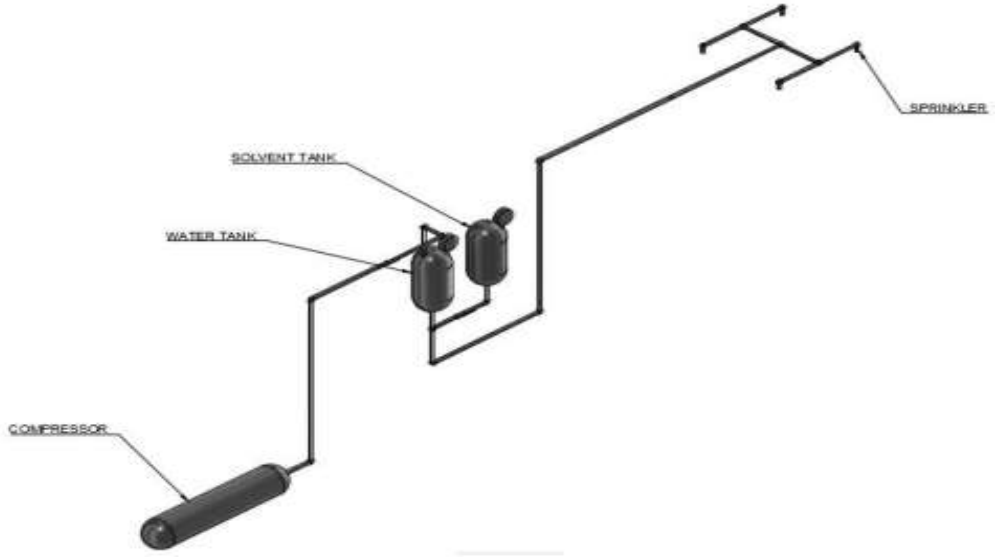

Figure 3: Full Experimental Setup

Cost Estimation

Table: 1

MATERIAL	COST (in Rs)	QUANTITY	TOTAL COST (in Rs)
Sprinkler	165 per piece	4 nos	660
Butanol	390 (500 ml)		
1,4 Dioxane	1047 (1 ltr)		
Dimethyl Sulfoxide	690 (500 ml)		
Tank	400 per piece	2 nos	800
Metal Sheet	62 per kg	63 kg	3900
Glass Sheet	45 per sq ft	43 Sq ft	1935

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Selection of Solvent

A list of solvents was collected and was categorized as extremely flammable, highly flammable, flammable and Non Flammable. This categorization was done based on their flashpoint. Since the experiment is to extinguish the fire, solvents with extremely flammable properties were not considered.

Non-water-soluble solvents were also avoided since a mixture of both should be used for the experiment. Another factor of concern was the health issues that these solvents cause. From the remaining list of solvents, solvents that cause serious health issues like respiratory issues, dizziness etc., were avoided.

Finally, 3 solvents with minimum health issues and with good availability were finalized. The selected solvents are:

1) Butanol
2) 1,4 Dioxane
3) Dimethyl Sulfoxide

Design Variables

Including organic solvents, this experiment is conducted using 5 design variables. The design variables used include fuel, solvent, the concentration of solvent, pressure and number of nozzles.

Each of the 5 variables has 3 levels. The details regarding the design variables and their levels are shown in **table 2** below.

Design of Experiment

Using Taguchi Orthogonal Array, a set of experiments were formulated. 27 experiments were listed that has the best combinations of the variables used. The formulated sets of experiments are shown in **table 3** below.

Table: 2

VARIABLES	LEVEL 1	LEVEL 2	LEVEL 3
FUEL	WOOD	CLOTHES	PAPER
SOLVENT	BUTANOL	1,4 DIOXANE	DIMETHYL SULFOXIDE
% OF SOLVENT	1	5	10
PRESSURE OF WATER (in MPa)	4	6	8
NUMBER OF NOZZLES	2	3	4

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Table: 3

Sl No	Fuel	Solvent	% Of Solvent	Pressure of Water	No of Nozzles
1	Wood	Butanol	1	6	2
2	Wood	Butanol	1	6	3
3	Wood	Butanol	1	6	4
4	Wood	1,4 Dioxane	5	8	2
5	Wood	1,4 Dioxane	5	8	3
6	Wood	1,4 Dioxane	5	8	4
7	Wood	Dimethyl Sulfoxide	10	10	2
8	Wood	Dimethyl Sulfoxide	10	10	3
9	Wood	Dimethyl Sulfoxide	10	10	4
10	Clothes	Butanol	5	10	2
11	Clothes	Butanol	5	10	3
12	Clothes	Butanol	5	10	4
13	Clothes	1,4 Dioxane	10	6	2
14	Clothes	1,4 Dioxane	10	6	3
15	Clothes	1,4 Dioxane	10	6	4
16	Clothes	Dimethyl Sulfoxide	1	8	2
17	Clothes	Dimethyl Sulfoxide	1	8	3
18	Clothes	Dimethyl Sulfoxide	1	8	4
19	Paper	Butanol	10	8	2
20	Paper	Butanol	10	8	3
21	Paper	Butanol	10	8	4
22	Paper	1,4 Dioxane	1	10	2
23	Paper	1,4 Dioxane	1	10	3
24	Paper	1,4 Dioxane	1	10	4
25	Paper	Dimethyl Sulfoxide	5	6	2
26	Paper	Dimethyl Sulfoxide	5	6	3
27	Paper	Dimethyl Sulfoxide	5	6	4

EXPECTED RESULTS

This experiment is mainly conducted to protect human health and reduce collateral damages. From a scientific study we have performed, for a floor area of 2m X 2m ignited with class A fire, a heat of 261.43 MJ will be released. By calculating the sprinkler pressure and coefficient of discharge, we approximated the discharge per sprinkler as 0.184 l/s.

From the below values, both the boiling point and specific heat of water is less than the above-mentioned solvents. So we approximately conclude that the fire suppression rate will increase while using the mixture. Expected values of fire suppression time are given in the table below.

Table: 4

Sl No	Solvent	Boiling point	Specific heat	Expected time
1	Water	100°C	75.2 J/mol K	20 sec
2	Butanol	117.7°C	174.26 J/mol K	1s - 2s faster
3	1,4 Dioxane	101°C	149 J/mol K	2.5s - 3.5s faster
4	Dimethyl Sulfoxide	189°C	153 J/mol K	3s - 4s faster

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CONCLUSION

The project is meant to be an efficient and effective replacement to conventional fire suppression systems. Traditional methods might not be much expensive as a single unit, but on a large scale, it is a bit expensive. Compared to it, experimentally, a better cost-efficient system on a large scale will be found out after the experiment. We have discussed about the problem and found out its effects on society, conventional solution etc. We discussed about the social relevance of our project and formulated methodologies and objectives. As per discussion conducted by the group members with proper resource persons and by referring to the related articles, the expected outcome will be a faster way to extinguish a fire during a sudden outbreak where the fire needs to be extinguished before human interaction.

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