Sonic Fire Extinguisher

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Abstract

Fire is necessary for mankind, but it damages people by fire. Depending on the cause of the fire and the material, an appropriate fire extinguishing system should be used. As human civilization develops and societies become more complicated, the response to the fire must also change. It is inappropriate to apply general fire extinguishing facilities in a duct environment connecting elevator, communication line and electric line and connecting the interstices. Sound fire extinguishers can be used as fire extinguishing systems in special spaces such as ducts. In this paper, we compare the sound fire extinguishers with fire extinguishers in a duct environment with obstacles such as elevator or electric wire. As a result of the experiment, it was confirmed that the fire extinguisher of the fire extinguisher was well transmitted to the fireworks even in the structure in which the obstacle was complicated. Also, when the sound extinguisher was turned on, the long lighter did not catch fire. The sound fire extinguisher has fire extinguishing effect and fire extinguishing effect in a duct environment filled with obstacles. The current fire extinguishing comes with various drawbacks. The need for new fire extinguishing techniques is vital as fire accidents cause deaths and injuries. Sound wave could be one of the potential alternatives in putting off flames. The acoustic pressure and air velocity produced from a speaker is the main theory used to explain how sound waves put off flames.

Keywords — Fire, Duct environment, Sound Fire Extinguisher, Fire Extinguishing effect, Flame retardant effect.

I. INTRODUCTION

It is a fact that everyone knows that fire has a great influence on all living spaces in modern society. This kind of fire is necessary for mankind, but it damages people by fire. There are tens of thousands of fires every year in our country, and thousands of people are killed and hundreds of billions of won are damaged every year. Although fire is a necessary necessity for mankind, it can come as a disastrous threat to mankind. There are various

causes of fire and materials that cause fire are also various. Fire extinguishing equipment is usually used for water spraying, foam fire extinguishing, powder fire extinguishing, carbon dioxide extinguishing, and halogen compound extinguishing [1].

However, as human civilization develops and societies become complicated, the response to the fire must also change. As all the buildings become bigger, elevators are installed in the buildings, and communication lines and electric wires are complicatedly installed to accommodate the information communication network in the building [3]. In a duct environment connecting the elevator and the floor and accommodating the communication line and the electric line, it is very inappropriate to apply general fire-fighting equipment [2, 3]. These places can lose their original function due to existing fire extinguishing materials, and there is a great risk of economic loss. The duct environment in which the elevator, communication line and electric wire are housed acts as a path for the fire to spread all over the building due to its structural characteristics when a fire occurs in the building. Especially, the covering of the communication line and the electric wire which are in the pipe ducts and the like is not easily turned off when a fire is formed with a petroleum compound material, and generates poisonous gas which is very poisonous [4, 5, 6].

However, there is no proper fire extinguishing facility to protect the facilities accommodated in the duct environment. In the Institute of Sound Engineering, sound fire extinguishers that suppress fire by using sound have been studied, and they can be used as a suitable fire extinguishing facility for a special space such as a duct environment. Sound fire extinguishers use sound, not digestive materials such as water or medicines, so they can be applied to all spaces and objects that can be economically damaged due to fire. Because sound fire extinguisher has low frequency sound component of 30Hz ~ 60Hz, even if there is obstacle, it has very high diffraction characteristic and can transmit sound extinguishing component well. In addition, the existing fire extinguishing facilities required a very large space and facilities. However, since the sound extinguisher can be installed anywhere as long as the modules and the power source capable of generating sound are supplied, it is easy to install and there is no limit to the space.

A. Aim and Objective

The main aim of this project is to put of the fire using sound waves. To fulfill this this main aim the following objectives are designed:

I. To identify the frequency range that will be able to suppress an open flame.
II. To analyze the physics of sound-flame interactions.

II. RELATED TERMS AND THEORY

A. FIRE

Fires are the accidents which occur most frequently, whose causes are the most diverse. They require intervention methods and techniques adapted to the conditions and needs of each incident. Depending on the type of the fire, meteorological conditions like wind and the

effectiveness of the intervention, material damage can be limited or affect wide areas [5, 6, 7].

Explosions are in a different category. Each type of fire is the object of specific technical prescriptions as regards prevention, intervention and the behavior of the population affected. It is also relevant to note that many fires have a criminal origin and that in times of armed conflict or crisis as well as of indirect wars human intervention also provokes major accidents [8]. A flame tetrahedron is shown in Fig. 1.

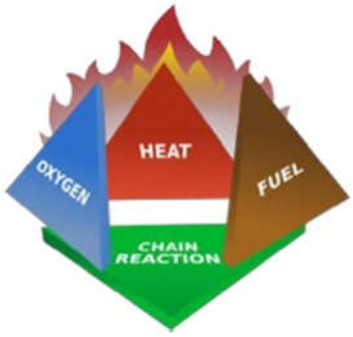

Fig. 1 A flame tetrahedron

B. Conventional Fire Extinguishing Techniques

There are many techniques to stop fire:

- Dry Chemical Fire Extinguisher – Compact and portable designs make these extinguishers best qualified for protection of minor hazards in industrial and commercial settings.
- Wet Chemical Fire Extinguisher – By incorporating a flexible design and effective liquid agent, this extinguishing system quickly reduces flames and cools hot surfaces specifically in food service kitchens.
- Clean Agent Fire Extinguisher – This extinguisher is commonly used in areas with sensitive computer equipment because the discharge dissipates into the atmosphere.
- Class K Fire Extinguisher – With an ability to hold in vapor and steam from a fire, this extinguisher is used in commercial kitchens for grease fires.

The current fire extinguishing comes with various drawbacks. But this new generation fire extinguisher that puts out flames by only playing heavy bass and now, we don't have to rely on water or chemicals anymore [9]. This sonic fire extinguisher can put out a fire with sound waves spread through a mobile subwoofer gun.

C. Sound Wave

Sound wave could be one of the potential alternatives in putting off flames. The acoustic pressure and air velocity produced from a speaker is the main theory used to explain how sound waves put off flames. A simulation of sound wave was carried out to study behavior acoustic wave propagation in the collimator and surrounding environment. Experiments were then conducted to study suitable sound wave frequency range to extinguish flame and to analyze the acoustic-flame interaction through observations from camera. Three different sources of flames were used to with three different state of fuel (solid, liquid and gas) [10].

From the first part of results, using an ordinary collimator, it was found that sound wave can only extinguish gas fuel type flames at 91 Hz. Sound wave was found to be one of the alternatives in creating new method in flame extinguishing technology. There are some aspects of the combustion that can be affected by sound wave. The flame Air-Fuel Ratio at the boundaries which is at the lowest lean limit of the combustion of fuels can be affected by sound wave by changing the velocity of its medium (air) [11]. Furthermore, the changes in air velocity changes will also be able to affect the flow rate of the fuel around the heat source as well as increasing the convective heat transfer of the heat source and reducing the average temperature of the flame. These effects are similar to flame blow-off characteristics.

III. PROJECT DESIGN

Combustion refers to a strong oxidation reaction in which a substance generates a rapid chemical reaction with oxygen to generate heat and light. Three factors are essential for this fire to be generated and maintained, which is called the 'third element of combustion'. The three elements of combustion are defined below, and if none of them is present, they are not burned.

Fuel (combustible material): It is a substance that can be dehydrated in fire, divided into solid fuel, liquid fuel, and gaseous fuel. In addition, the characteristics of burning depend on the composition of the fuel.

Heat (ignition source): In order for the substance to ignite, it must have very high heat, and the amount of heat must be moderate. The size of heat required for combustion is divided into ignition point, flash point, and combustion point. Ignition point: The minimum temperature at which the fuel starts burning.

Flash point: The temperature at which the fuel burns when the fuel is turned on. Burning point: Temperature at which fire continues to drain when fuel is burning.

Oxygen (air): The material must be supplied with oxygen to take heat. Most liquids are difficult to ignite when the oxygen content in the air is reduced to 15% or less.

The block diagram for sonic fire extinguisher is shown in Fig. 2.

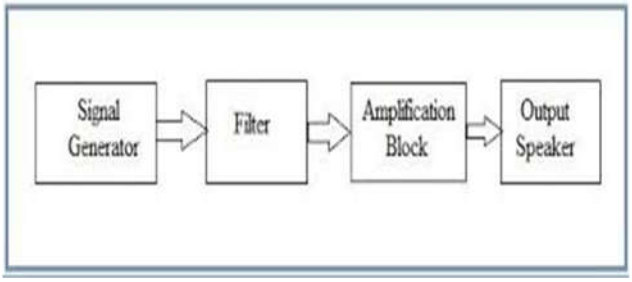

Fig. 2 Block diagram for sonic fire extinguisher

IV. Sound Flame Interaction and Project Fundamental

Sound wave was found to be one of the alternatives in creating new method in flame extinguishing technology. There are some aspects of the combustion that can be affected by sound wave. The flame Air-Fuel Ratio at the boundaries which is at the lowest lean limit of the combustion of fuels can be affected by sound wave by changing the velocity of its medium. Furthermore, the changes in air velocity changes will also be able to affect the flow rate of the fuel around the heat source as well as increasing the convective heat transfer of the heat source and reducing the average temperature of the flame [10]. These effects are similar to flame blow-off characteristics. The physiology of sound is shown in Fig. 3.

Collimator is a device for producing a parallel beam of rays or radiation as shown in Fig. 4. This mainly is due to the converged collimator gives a higher air velocity output as compared to an ordinary collimator design, which was verified through simulation result. The combination of varying high and low pressure and coupled with high flow air velocity, which in then causes disturbances in air-fuel ratio at the flame boundary (leading to thinning of flame boundary), is one of the possible explanation leading to flame extinction [12]. In both experiment, the frequency range needed suppress the flames was found to be, between 90 to 94 Hz. However, in both experiments the flame boundary used was relatively small as compared real fire accidents due to safety consideration. Nevertheless, this sound wave based fire suppression technology could be used to combat early stages of fire accidents.

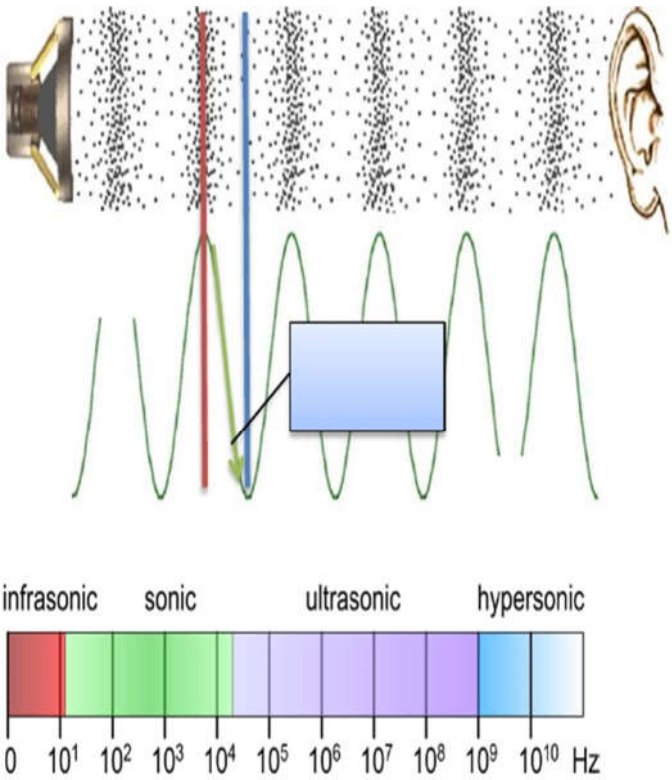

Fig. 3 The physiology of sound

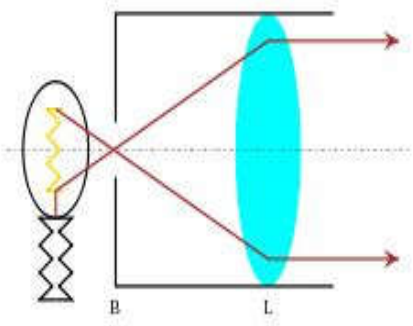

Fig. 4 Collimator

A. Acoustic Fundamental and Governing Equation

Acoustics is the interdisciplinary field that deals with the study of all mechanical waves in gases, liquids, and solids as well as subjects such as vibration, sound, ultrasound and infrasound. The study of acoustics encompasses around the propagation, generation, and reception of vibrations and mechanical waves. There is one fundamental equation that describes sound wave propagation, the acoustic wave equation, but the phenomena that emerge from it are varied and often complex [11, 12].

The fluid momentum (Navier-Stokes) equation and continuity equations are abridged to get the acoustic wave equation via the following assumptions, i.e. the fluid is compressible (density changes due to pressure variations) and there is no mean flow of the fluid [13].

The acoustic wave equation is given by:

$$\nabla\cdot\left(\frac{1}{\rho_0}\nabla p\right)-\frac{1}{\rho_0 c^2}\frac{\partial^2 p}{\partial t^2}+\nabla\cdot\left[\frac{4\mu}{3\rho_0}\nabla\left(\frac{1}{\rho_0 c^2}\frac{\partial p}{\partial t}\right)\right]=-\frac{\partial}{\partial t}\left(\frac{Q}{\rho_0}\right)+\nabla\cdot\left[\frac{4\mu}{3\rho_0}\nabla\left(\frac{Q}{\rho_0}\right)\right] \quad (1)$$

Where:

c = speed of sound $\left(\sqrt{K/\rho_o}\right)$ in fluid medium

ρ_o = mean fluid density

K = bulk modulus of fluid

μ = dynamic viscosity

p = acoustic pressure (= p(x, y, z, t))

Q = mass source in the continuity equation

t = time

B. Hardware Required

- 300 Watt Speakers
- 250 Watt Amplifier
- Collimator
- Power supply unit
- High speed camera

V. FIRE FIGHTING WITH SOUND

While the concept of using sound waves to extinguish flames is not new, previous attempts to realize the principle – including efforts by teams at West Georgia University and the US Defense Advanced Research Projects Agency (DARPA) – had not been successful. Recently, there is a new development towards the use of sonic fire extinguishers making use of sound waves (longitudinal waves) with compressions (high pressure) and rarefactions (low pressure) zones as effective, no-polluting and cost effective firefighting technology [12]. This article presents the principle, working, latest developments and advantages of sonic fire extinguisher. The principle behind the extinguisher is simple: as they are mechanical pressure waves that cause vibrations in the medium in which they travel, sound waves have the potential to manipulate both burning material and the oxygen that surrounds it. If the sound could be used to separate the two, the fire would be starved of oxygen and, accordingly, would be snuffed out. The work could potentially be applied to swarm robotics where the device would be attached to a drone to be used in situations such as large forest fires or urban blazes, thereby improving safety for firefighters [5, 7].

A. Bottlenecks of Technology

One of the problems with sound waves is that they do not cool the fuel so even if we get the fire out, it will rekindle if we don't either take away the fuel or cool it. Further, a possible complication may lie in the heat inherent in larger blazes. As the sonic extinguisher contains no coolant, it may be unable to prevent larger fires from reigniting after the sound is turned off. The project also would have to address different types of fires - solid combustibles such as wood, paper or metals, or electrical equipment - and keep a fire from reigniting.

VI. CONCLUSION

In a building fire, a duct environment containing an elevator, a communication line, or an electric wire can cause a fire to spread all over the building. However, the facilities and lines housed in the duct environment are inadequate to apply the existing fire extinguishing facilities.

It can be observed from the study that how the sound wave propagates inside the collimator based on the acoustic pressure and velocity profile. The pattern of the profile resembles according to the sound wave theory. Next, the design of the exit end of the collimator was varied to study effect on the exit acoustic velocity and pressure. Correspondingly, it can be seen that the exit acoustic velocity of the collimator increases with

smaller diameter, while the acoustic pressure decreases with smaller exit diameter of the collimator. This phenomenon is similar to a flow of fluid in a converged pipe. Based on the experiment result obtained it can be seen that the sound wave can extinguish flames. The frequency range that was able sound wave suppresses the flame is at 92 Hz averagely.

Various theories could be used to explain how sound wave interacts with flame. It was assumed that varying acoustic pressure and air velocity, which leads to disturbances at the flame boundary, could be the explanation on extinction of flame. However, it was observed that, the velocity of air primarily, is the main contribution leading to extinction of the flame. However, the flame boundary created was relativity small as compared size or sound intensity of the speaker and does represent a real fire related accident. This is mainly due to concern of safety issues as larger flame could lead to uncontrollable accidents. Nevertheless, this sound wave based fire extinguishing could be used to extinguish initial stage fires.

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