International Journal of New Technology and Research (IJNTR)
ISSN: 2454-4116, Volume-6, Issue-6, June 2020 Pages 17-22

Fire Extinguisher Using Acoustic Waves

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***Abstract*—Fire is a particularly feared hazard. Therefore, a fire extinguisher is very important equipment. Unfortunately, existing fire extinguisher has some drawbacks such as using a chemical compound which is dangerous and it leaves a residue. Current extinguishers contain different kinds of chemicals depending upon their application. Generally, they are pressurized with Nitrogen or Carbon-dioxide (CO2) and when this pressure released on the fire, it extinguishes the fire. There are many such asphyxiating and extinguishing agents like water, potassium bicarbonate, foam etc. All these agents have a common property of leaving by-products behind it. The waste materials generated by these methods can be toxic and harmful. Innovative methods are necessary to minimize the generation of this waste. The need for innovation and modernization in fire extinguishing techniques is extremely necessary. The existing techniques have been created considering only their efficiency in extinguishing fires and not considering the harms they can cause to the environment. Study shows that sound waves could be one of the potential alternatives for extinguishing fires. Acoustic pressure and air velocity produced from a speaker is the fundamental concept used to explain how sound waves put off flames. In this project, we proposed a new method using the sound wave to extinguisher fire. Our method was using a speaker and a converging tube to focus the sound wave to overcome the fire energy and thus put the fire down. The aim is to develop a portable fire extinguisher to study and analyzes the effect of different frequency of a sound wave on flames. Experiments are conducted to find a suitable frequency range to extinguish the flame and to analyze the acoustic-flame interaction.**

***Index Terms*— acoustic flame, acoustic pressure, fire, fire extinguisher, frequency.**

I. INTRODUCTION

Existing fire extinguishers contain different chemicals, depending upon their application. Generally, they are pressurized with Nitrogen or Carbon Dioxide (CO2), when this pressure released on fire will extinguish the fire, as we know there are many such firefighting agents such as water, potassium bicarbonate, evaporating fluorocarbons etc. All these agents have the same property of leaving an unproductive system behind it. To deal with Fire we need to have complete information on fire and its working. The formation of fire requires three elements in a proper mixture they are fuel, oxygen and heating element. There is a chance of extinguishing the fire by sound. If we remove the heating element or move it apart from fuel fire can be extinguished. This particular task is done by sound. In-depth research on sound could help. A mechanical wave of pressure and displacement, through a medium such as gases, liquids and solids. As we underlined above sound is pressure wave and displacement caused in the medium through with particles will move in a random direction, and transferring the pressure from one particle to the other, hence this how sound travel in any medium. Sound can be travel in two forms they are:

A. Longitudinal Waves

Longitudinal waves are waves in which the displacement of the medium is in the same direction as, or the opposite direction to, the direction of travel of the wave. Mechanical longitudinal waves are also called compression waves because they produce compression and rarefaction when traveling through a medium.

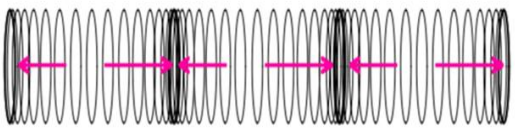

Fig.1.1: Particle movement in longitudinal waves

B. Transverse Wave

A transverse wave is a moving wave that consists of oscillations occurring perpendicular (or right angled) to the direction of energy transfer. If a transverse wave is moving in the positive x-direction, its oscillations are in up and down directions that lie in the y-z plane. Light is an example of a transverse wave. With regard to transverse waves in matter, the displacement of the medium is perpendicular to the direction of propagation of the wave. A ripple in a pond and a wave on a string are easily visualized as transverse waves.

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Fig.1.2: Particle movement in transverse waves

C. Fire

To understand how best to extinguish a fire, there must first be an appreciation of the three elements that make up the 'fire triangle': heat, fuel and oxygen. As fire is primarily a chemical reaction, removing one or more of these three factors will prevent the combustion from taking place.

Fig.1.3: Fire triangle and elements of fire

D. Fire Extinguishing Methods

If the three parts of the 'fire triangle' are kept in mind, extinguishing a small blaze should be a matter of common sense. The principles of fire extinction state that a fire will be put out if one of the three elements is removed, and this can be done using three different approaches. They are Cooling (Cooling the Burning Material), Starving (Removing Fuel from the Fire), Smothering (Excluding Oxygen from the Fire).

Table 1: List of class, method and suitable extinguishers for fire

Class	Source	Method	Suitable Extinguishers
A	Paper Wood	Cooling blanketing	Water type (CO2cartridge type) Water (stored pressure type) Water bucket Sand bucket
B	Petrol	starvation	BCF CO2 Dry chemical power Sand bucket
C	LPG CNG	Smothering starvation	BCF CO2
D	Sodium phosphorus	smothering	Special Type DCF
E	Motors Transformer	Smothering Starvation	CO2 DCP
F/K	Oil	Blanketing	AFFF fire extinguisher

The current method of firefighting has many drawbacks such as toxic to humans and leaves residue (for dry chemical base fire extinguisher) while water base fire extinguishing techniques freezes in cold climates and conduct electricity. Using sound wave with a certain frequency as a fire extinguisher will have advantages as they are not leaving any residues and toxic material behind.

II. Objective

- To overcome the harmful effects of chemical and water fire extinguishers.
- To avoid the toxic effects.
- To avoid pollution and provide reliable operation in low cost.
- It can provide operation with negligible maintenance.

III. Methodology

This experiment will be focusing on the observation in the frequency range of 35–200 Hz (human hearing frequency) in order to confirm the results from previous research. The types of flames that are going to be tested are Solid combustibles including paper, cloth, plastic, metals, or electrical equipment's in order to determine if it is needed to change the frequency to extinguish the flame. A collimator will be used to modify the intensity and direction of the sound wave in the experiments. Collimator will increase the intensity of the sound wave to a single point which will provide better results in suppressing the flame. An acoustic simulation will be executed prior to experimental setup to study the propagation of sound wave (acoustic wave), specifically to study the acoustic pressure and acoustic velocity profiles in the collimator.

Fig.3.1: Methodology of developing a portable fire extinguisher system

A. Design Layout

The development of a fire extinguisher is initiated with the basic design approach as shown in fig.3.3. The key components include frequency generator, power amplifier, subwoofer, power supply, collimator.

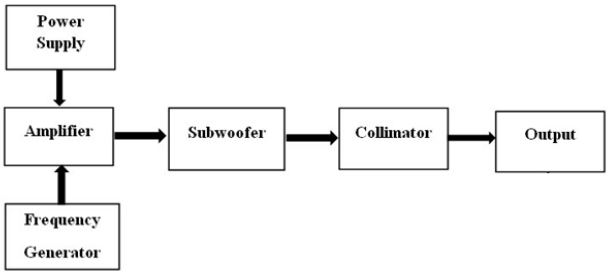

Fig.3.2: Block Diagram of Fire Extinguisher using Acoustic Waves

B. Working Principle

This concept utilized the scientific principle of physics and the engineering aspects of electronics to successfully suppress a flame. Based on the physical aspects of acoustic waves, it is important to understand that acoustic wave patterns are referred to as longitudinal pressure waves –meaning that the waves move in a back and forth vibrating motion in which they are able to agitate air molecules away from the fuel of the flame. Secondly, we hypothesized that the physical aspect of The Ideal Gas Law has an effect on suppressing a flame. The Ideal Gas Law states that Pressure Times Volume is equal to the constants n, the substance of gas and R, the universal gas constant multiplied by temperature (PV= nRT). Therefore, when the pressure waves are being directed at the source of a flame, it will decrease the pressure at the source, which in turn will decrease the temperature of the flame.

3.3 Design

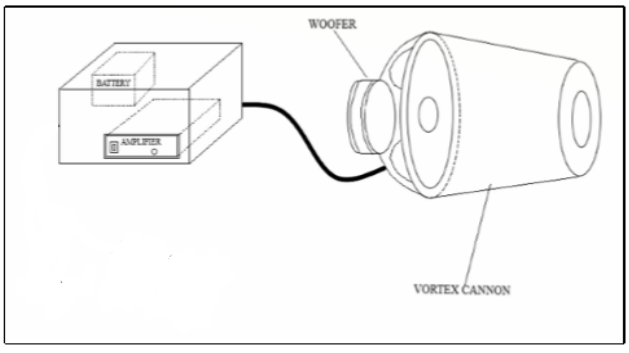

Fig.3.3: Basic design of the device

3.4 Wiring Diagram

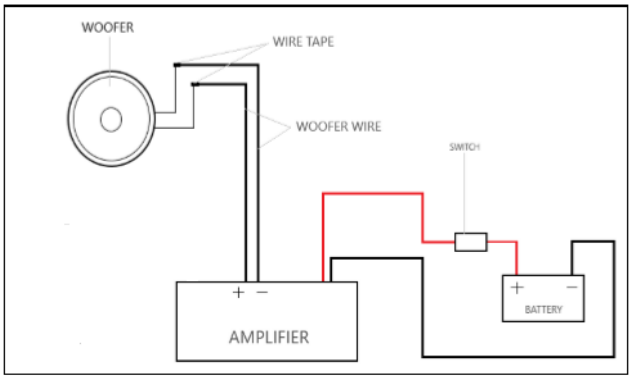

Fig.3.4: Wiring diagram of device

IV. EXPERIMENTS AND RESULTS

A. Optimization of frequency

It was stated that the optimum sound frequency for fire extinction is 60 Hz. According to a sound lens for a sound fire extinguisher, the sound fire extinguisher needs to produce low frequency sound less than 100 Hz. This experiment will be focusing on the observation in the frequency range of 30–100 Hz in order to confirm the results from previous researches [1] [4] [7] [10]. So, the first stage of the experiment is conducted to confirm the frequency found in previous researches. A candle flame was first tested to initiate the experiment. The sound wave was able to extinguish the candle between 48 Hz and 60Hz. An optimum distance, 30cm, is assumed by trial and error method and the candle flame is extinguished by using all the above frequencies and the time needed to extinguish the fire. A graph is plotted by using this data, which is shown in figure.4.1

Table 2: Frequency-time table for three experiments

Frequency (Hz)	Expt.1	Expt.2	Expt.3	Avg. (Time taken in sec.)
48	1.873973	1.968774	1.734569	1.859105
49	1.634783	1.220414	1.567894	1.474363
50	1.100341	1.125721	1.394567	1.206876
51	0.956895	0.938701	1.189546	1.028380
52	0.803614	0.892493	0.938597	0.878234
53	0.692591	0.738588	0.893752	0.774977
54	0.756975	0.823924	0.997587	0.859495
55	0.861255	0.864036	1.012395	0.912562
56	0.963842	0.938701	1.093701	0.998575
57	1.195678	1.192396	1.182321	1.190131
58	1.253793	1.210357	1.204059	1.222736
59	1.298798	1.287314	1.289125	1.291745
60	1.303614	1.293829	1.310456	1.302633

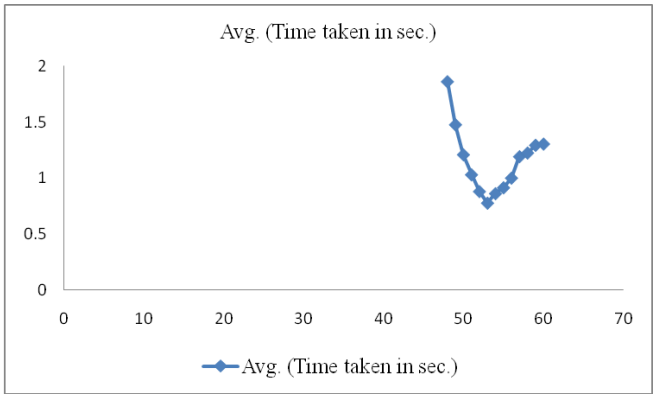

Fig 4.1: Variation of time with frequency

The sound wave was able to extinguish the candle at 53 Hz within 0.774977sec. The figure 4.3 shows the sequence of high-speed images of candle flame leading to flame extinction. It can be seen that the flame boundary resonates (back and forth) with the sound wave. After a certain period of time, the flame boundary slowly thins due to varying high and low pressure, which induces air velocity and causes toward flame extinction.

Fig. 4.2: Sequence images of candle flame extinguishing

B. Effect of time taken on distance

Now, 53Hz is used to test the change of time taken to extinguish the fire with the distance between the vortex tube and flame. Its graph is shown in figure 4.3.

Table 3: Effect of time taken on distance

Distance (cm)	Time Taken (sec.)
10	0.424912
20	0.556813
30	0.723569
40	0.783265
50	0.893569
60	0.938645
70	1.038241
80	1.278459
90	1.438714
100	1.578108

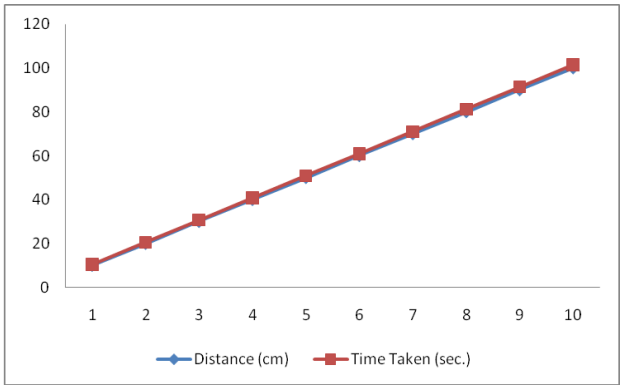

Fig.4.3: Effect of time taken on the distance between the vortex tube and flame

From the graph, it shows that the shape of the curve is linear. So the distance between the vortex tube and flame increases the time taken to extinguish fire also increases.

IV. COST ANALYSIS

Table 4: Cost of components of fire extinguisher

S no.	Item	Cost
1	500 W Amplifier	RS.1600
2	100 W Woofer	RS.850
3	Vortex cannon (Plastic Container)	RS.150
4	12V Battery	RS.850
5	AUX cable	RS.50
6	Aluminum Foil	RS.550
7	Insulation Tape	RS.50
8	Miscellaneous	RS1000
TOTAL		RS.5100

The fire extinguisher that we have made cost around RS.5100. Although there are certain fire extinguishers available for the same and below this price range, fire extinguisher using sound waves is capable of extinguishing fire of classes B and C. Thus by considering these factors, the above-mentioned fire extinguisher is capable of extinguishing different types of fires, also provides a better class of performance while considering other conventional extinguishers of same price categories and so is worth the money.

VI. ADVANTAGES

1. There is no residue compared to chemical fire Extinguisher.
2. Nontoxic to the environment as well as human.
3. It is light in weight.
4. There is no expiration date.
5. There is no refilling date.
6. It can replace chemical as well as a water fire extinguisher.

VII. FUTURE SCOPE

The device can be automated by using any android application in order to control the waves. Mobile phones can also be used as a computing tool for the generation of the waves. These devices will have a receptor medium that is capable of sensing and receiving signals. These devices are configured to operate in full-duplex, whereby they are capable of sending and receiving signals at the same time. Another main scope is this device can be mounted to a moving robot prototype system and the robot is controlled through User Voice Command. The voice input allows a user to interact with the robots which controls the movements of the robot. This Robot can be used in rescue operations during fire accidents where the possibility for servicemen to enter the fire prone areas is very less. The Controller can be interfaced to the Bluetooth module through UART protocol. Based on commands received from Android the motion of robot can be controlled. A booster can be attached to the vehicle to make it a powerful extinguisher. For security purposes, authentication for accessing the robot can also be done. A piston spray can be used which uses the concept of formation of mist as a heat absorbing ability to reduce heat. The vehicle can be mounted with a thermal camera so that auto detecting of heat areas is made possible and live images of the incident can be seen through a wireless camera. GPS enabling can be done so that the vehicle can be controlled from a remote place. This device specifically uses new ways of tackling fires in enclosed spaces, such as aircraft cockpits and ship hold, kitchen, hospitals and shopping malls, Industry, and railways where fires are obviously devastating and incredibly difficult to control. Generally, when fire is caused in an electrical panel circuit, using water is not possible as water conducts electricity, thus using sound waves to extinguish fire is one of its main application.

VIII. CONCLUSION

The idea of extinguishing the fire with sound can be an innovative one, however, it is efficient and effective, and can be used in today's world. Based on the experiment result obtained it can be seen that the sound wave can extinguish flames. The frequency range at which the flame can be suppressed is 53 Hz. However, in these experiments, 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 the concern of safety issues as a larger flame could lead to uncontrollable accidents. Nevertheless, this sound wave-based fire extinguishing could be used to extinguish initial stage fires. With many possible applications, fighting fire with sound is a promising venue. In order to extinguish large area flames acoustically using the current setup, either a larger or more powerful speaker would need to be used. Directly increasing the output power of a speaker will cause signal distortion of the output signal. One can multiplex speakers to achieve extinction of larger flames, however, the practically of such a system comes into question. Hence there is a need for further research investigation to attempt for large fire extinguishers. In the experimental part, different parameters could be used to further explore is study such as using different intensity of sound (by using different speaker power rating), positioning of sound towards the fire source and size of flame (or flame intensity) & varying design of vortex tube. The idea of extinguishing fire with sound is a novel one. A small fire which is left untreated leads to a bigger one. The proposed system will indeed be useful in fighting fire in multilevel information conveyance capabilities so that a bigger disaster can be avoided.

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