QUENCHING OF FLAMES BY SOUND

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ABSTRACT

The fire extinguishing techniques used nowadays are having various drawbacks. The need for new fire extinguishing techniques is very important as fire accidents causes damages. Sound wave could be one of the alternative in extinguishing flames. The acoustic pressure and air velocity produced from a speaker is the fundamental concept used to explain how sound waves put off flames. This paper aims to study and analyze the effect of different frequencies of sound wave on flames and also to study the behavior of acoustic wave propagation in the collimator and surrounding environment. Experiments were then conducted to find the range of frequencies within which fire extinguishes. Three different sources of flames were used with three different state of fuel (solid, liquid and gas). The converged collimator used to increase the air velocity output as compared to an ordinary collimator design. The variation of high and low pressure which is then coupled with high flow air velocity, causes disturbances in air-fuel ratio at the flame boundary, is one of the prime reason leading to flame extinction. In experiment, the frequency range needed suppress the flames was found to be, between 30 to 95 Hz. However, in experiments the flame boundary used was relatively thinner than that of actual fire accident . This experiment focus on extinguishing fires at primary stages.

Keyword: - *Chemical Extinguishers, Putting off Fire, Sound, Space, Acoustic pressure, Air-Fuel Ratio, Temperature Instability*

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1 Introduction

Current extinguishers includes different chemicals and materials, depending upon their area of use. Normally they contains Nitrogen or Carbon dioxide (CO2) under pressure, releasing this pressure on fire will putting off fire. There are many fire fighting agents such as water, potassium bicarbonate, evaporating fluro carbons etc. All these agents have same property of leaving residues behind it. To deal with Fire it is necessary to have complete knowledge about fire and its working in space. Proper mixture of fuel,,oxygen and heating element ignites the fire. As there is no gravity in space, the formed fire will have different shape and properties. Fires are generally identified with its flames but in space fire flames are of semi circle in shape having a blue colour flame which are mostly not visible when they are at lower precision.

There is less chance of detection of fire in space because smoke caused from fire will not be intended towards the smoke detectors . We can extinguish the fire in space though it has such behavior. The first step in starting the fire is that heating element from any source ignites the fuel in presence of oxygen, hence as heating of air molecule starts, these molecule is then works as heating element for another molecule surrounding it and this process continues in the form of convection(the movement of air). It is done naturally on ground and ventilation fans helps in convection in space. We can say that heating elements made fire to spread. Sound could help in removing this heating element or move it apart from fuel.

Through a medium such as gases, liquids and solids, sound propagates in vibration as a typically audible mechanical wave of Pressure and Displacement. Sound is pressure and displacement wave travel in the any medium moving through particles in a random direction, and transferring the pressure from one particle to the another. Sound can be travel in two forms they are

1.) Longitudinal waves : When the displacement of the medium is parallel to the propogation of wave. As because they produce compression and rarefaction when traveling through a medium mechanical longitudinal waves are also called compression waves.

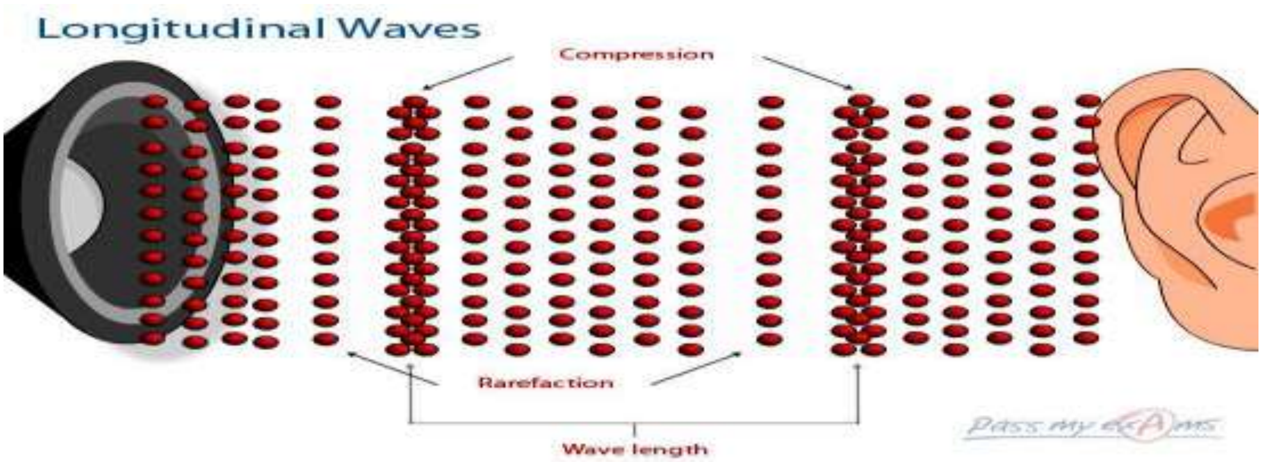

Fig.1.1. Particle movement in longitudinal waves

2.) 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.

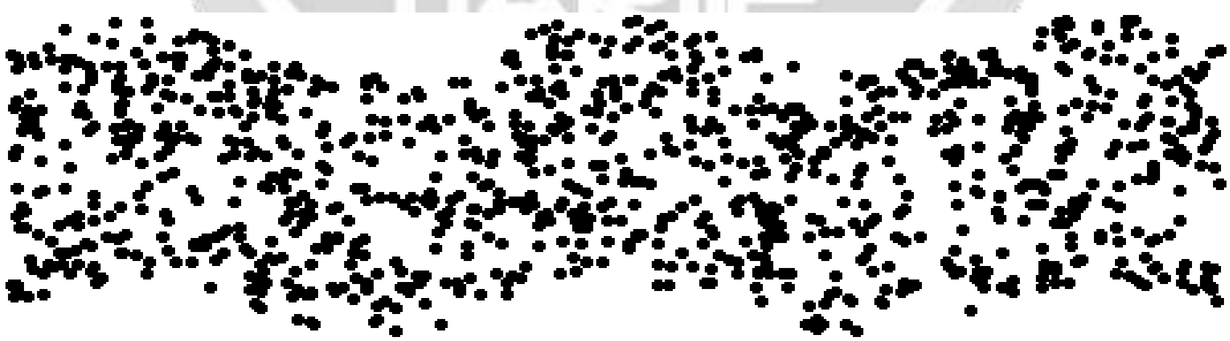

Fig.1.2 Image of transverse wave particles

2. Objectives

1. To identify the frequency range that will be able to suppress an open flame.

2. To analyze the physics behind sound-flame interactions.

3. Problem Statement

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 certain frequency as a fire extinguisher will have advantages as they are not leaving any residues and toxic material behind.

4. BASIC CONCEPTS

4.1 Fire

Fire is the fast exothermic chemical process of combustion, releasing light, heat, and various byproducts. Flame is the visible area of the fire. Fires start when a flammable and/or a combustible material, in combination with a sufficient quantity of an oxidizer like oxygen gas is subjected to a source of heat and is able to withstand a rate of rapid oxidation that produces a chain reaction. This is normally called the fire tetrahedron (Figure 4.1). Fire cannot exist without all of these elements in place and in the right proportions.

Figure 4.1: A flame tetrahedron

4.2 Conventional fire extinguishing techniques

There are four common techniques for putting off fires. The most common practice used to extinguish fire is to cool down the burning material. To extinguish fire involving solid material water is the commonly used as a cooling agent. When water comes in contact with fire it gets vaporized and this helps to cut down the oxygen supply. However, water should be avoided in fires including hot cooking oil or fat as it causes to spread fire. Second thing is to exclude oxygen from the fire. To extinguish a fire oxygen supply can be cut off by the use of Asphyxiating agents.

Foam, which is containing fire extinguishers, can help to isolate the fuel surface from the air and cool down resulting in reducing combustion and being able to resist wind. As because foam is an electrical conductor it should be not used in electrical fires. Other extinguishing agents contains carbon dioxide are ideally used in electric equipment and also sand, which is effective only on small burning areas. One more method for extinguishing a fire is to cut off the fuel supply by switching off the electrical power, isolating the flow of flammable liquids or removing the solid fuel, such as wood or textiles. In woodland fires, a firebreak cut around the fire helps to isolated further fuel. In the case of gas fire, closing the main valve and cutting off the gas supply is the best way of extinguishing the fire. Flame inhibitors are substances that chemically react with the burning material, thus extinguishing the flames.

4.3 Sound wave

Sound is a vibration that propagates as a perceptible mechanical wave of pressure and displacement, through a medium such as air or water. Sound propagates through compressible media such as air, water and solids as longitudinal waves and also as a transverse waves (in solids). The sound waves are generated by a sound source, such as the vibrating diaphragm of a speaker. The sound source creates vibrations in the surrounding medium. As the source continues to vibrate the medium, the vibrations propagate away from the source at the speed of sound, thus forming the sound wave. At a fixed distance from the source, the pressure, velocity, and displacement of the medium vary in time. At an instant in time, the pressure, velocity, and displacement vary in space. The particles of the medium do not travel with the sound wave, the vibrations of particles in the liquid or gas transfer the vibrations, while the mean location of the particles over time does not change. During propagation, waves can be reflected, refracted, or decreased by the medium. The matter that carries the sound is called the medium and sound cannot travel through a vacuum. Sound is transmitted through gases, plasma, and liquids as longitudinal waves. Longitudinal sound waves are waves of alternating pressure deviations from the equilibrium pressure, causing local regions of compression and rarefaction, while transverse waves (in solids) are waves of alternating shear stress at right angle to the direction of propagation. Additionally, sound waves may be viewed simply by parabolic mirrors and objects that produce sound. Sound waves are regularly streamlined to a description in terms of sinusoidal plane waves, which are characterized by these common properties: frequency, wavelength, wave number, amplitude, sound pressure, sound intensity, speed of sound, and direction. Sound that is perceptible by humans has frequencies from about 20 Hz to 20,000 Hz. In air at standard temperature and pressure, the corresponding wavelengths of sound waves range from 17 m to 17 mm.

4.4 Sound-Flame interactions & using sound wave as flame extinguisher

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) and 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 normal flame blow-off characteristics.

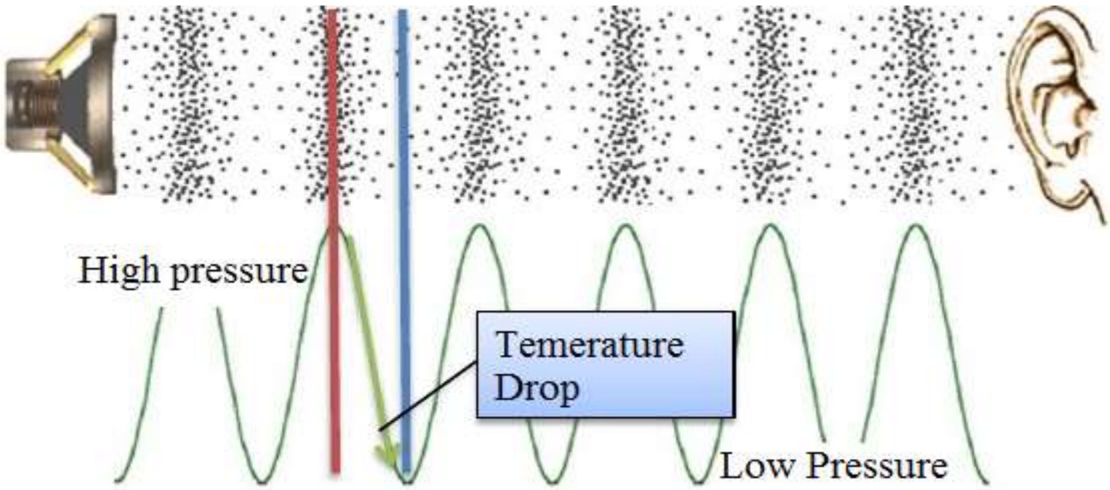

Figure 4.2: The physiology of sound

The main stream analysis for the sound wave effect on the flame is depicted in Figure 4.2. The pressure fluctuations due to the sound wave propagation will cause a significant change in temperature profile near the flame. High pressure to low pressure and vice versa will cause immediate change on the temperature according to the first law of thermodynamic. The combination actions of fluctuating temperature, pressure and air-fuel ratio to the flame will affect the flame behavior under the regulated sound wave environment. Pressure perturbations is known to have influence on the burning rate of a material and cause combustion instabilities, which could eventually lead to flame extinction. High frequency excitation on a reaction will be able to enhance the combustion as well as delaying and perturbing the chemical reaction which depends on the affected bonding for every specific chemical compound on certain frequencies.

5. 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.

The idea of fire being affected by sound was discovered as far back as 1857 when an Irish scientist, John Tyndall, recognized that sound waves could extinguish flames. There were specific frequencies where the flames were extinguished. Frequencies between 0Hz and 10Hz did not effectively extinguish a fire; but frequencies between 30Hz and 60Hz showed promising signs of suppressing a fire. Following this discovery, our proposed design intends to address the need for a new, efficient, light-weight, and innovative approach toward fire suppression.

Combustion is a chemical process in which a substance reacts rapidly with oxygen and gives off heat. The original substance is called the fuel and the source of oxygen is called the oxidizer. The reaction releases the energy as heat and light. In one of our designs, we targeted the suppression of combustion and found that acoustic fields have a significant effect on the process of combustion. This is due to the acoustic oscillations of the heat released from the flame. When acoustic oscillations are combined with the vibrations of heat released from the flame, it alters the transportation process of combustion. It has been studied that frequencies in the 0 Hz to 60Hz range have significant effect on the activity of the flame.

6.1 EQUIPMENT'S REQUIRED

Hardware

1. Speaker
2. Amplifier
3. Collimator (PVC pipe)
4. Power supply unit

Software

Tone Generator software

6.2 Block Diagram:

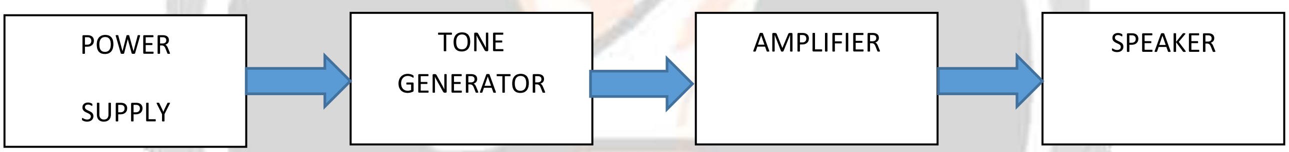

Figure 6.2.1: Block Diagram

7. Conclusion

The idea of extinguishing fire with sound can be a innovative one, however, it is efficient and effective, and can be used in todays world. For instance, installed in every electrical control panel, can be mounted a subwoofer on a dedicated circuit, designed to turn on whenever fire is detected. It can be programmed to alternate the frequency based on the width of the flame. The effectiveness of a certain frequency needs to be in proportion with the width of the flame. With many possible applications, fighting fire with sound is a promising venue, in which sound pressure waves can be used to save an important control center, or an astronauts life.

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