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A Study on the Safeguard of the Person who Suppresses Fire with Sound Fire Extinguisher

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Abstract:

The temperature of the flame is higher than 1000℃ in the field of conflagration and there is a great risk that the person who suppresses fire will be damaged when a conflagration occurs. Therefore, suppression of early conflagration using fire extinguisher is very important. Therefore, as important as the suppression of conflagration is the safeguard of person who suppresses fire. In this paper, we propose a safeguard method for person who suppresses fire using the side sound of Sound Fire Extinguisher, which was studied and developed by the Sori Sound Engineering Research Institute (SSERI). The proposal is to control the flame approaching the person who suppresses fire by controlling the output of the side sound studied for the noise control of Sound Fire Extinguisher. If the sound level of the side sound is more than 90dB, the direction of the portable burner flame and the candlelight are changed. If the sound level is more than 93dB, the direction of the torch lamp flame is changed. Also, the direction of the flame was changed at the relatively low sound level in the main sound beam where the wind velocity was formed. From these experimental results, we confirmed that controlling the output of the side sound can safeguard the person who suppresses fire in actual conflagration field.

Keyword: Conflagration, Person who Suppresses fire, Safeguard, Sound Fire Extinguisher, Flame control

1. INTRODUCTION

We often hear the sad news that firefighters die or become injured in the conflagration field. In korea, firefighter has an average annual death toll of 4.2, and injured person reaches about 100 per year. The firefighter's fire fighting garments last up to about 500℃, but the flame applied to the firefighter is over 1000 ℃. In suppression of conflagration, the most important thing is to rescue a person, and the first priority in relief work is to secure the safety of rescue crew. In the end, safeguard of person who suppresses fire is the first step of lifesaving and conflagration suppression. In fire extinguish facility, besides fire fighting ability for conflagration, ability to safeguard person who suppresses fire is also very important. However, in the conflagration field above 1000℃, person who suppresses fire depends only on fire fighting garment which can withstand up to 500℃. In addition, existing fire extinguishers are only capable of suppressing combustion by using fire extinguishing agents, so there is a high risk that person who suppresses fire will suffer conflagration [1-3].

In this study, we propose a method to safeguard the person who suppresses fire by using the sound component of Sound Fire Extinguisher, which is actively studied by the Sori Sound Engineering Research Institute (SSERI). Sound Fire Extinguisher is a new concept fire extinguish facility that uses sound characteristics to achieve fire extinguish. In this study, Sound Fire Extinguisher proposes a method of suppressing flame access by using side sound that propagates sound energy extensively [4-7]. Chapter 2 explains the flame control principle of sound, and Chapter 3 explains how to safeguard the proposed person who suppresses fire. Chapter 4 explains the experiment and the results, and Chapter 5 concludes.

Fig 1. Sound Fire Extinguisher from SSERI [4]

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2. FLAME CONTROL PRINCIPLE OF SOUND

2.1 Medium Control of Sound

Sound is propagated through medium pressure changes. When sound is generated, the sound is propagated while changing the pressure of the medium at regular intervals. Figure 2 shows an experimental run by Rubens in the early 1900s, in which the magnitude of the flame changes as the frequency changes with changes in air pressure. These experiments show that sound can be used to control the medium. Figure 3 shows a scene of a music record called 'CYMATICS', in which sound influences the flow of fluid through a medium pressure change [8-9].

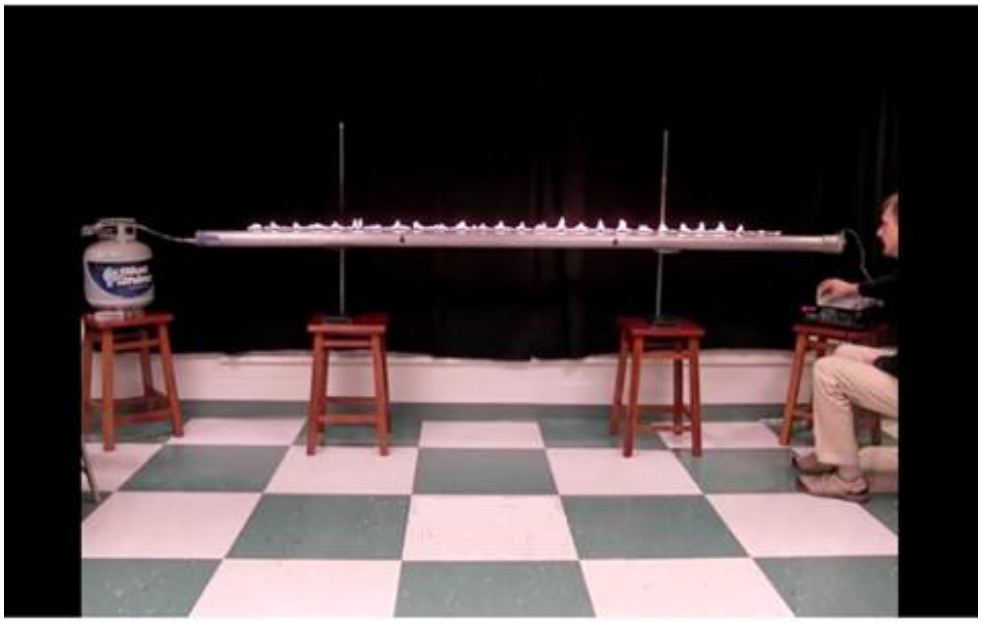

Fig 2. Rubens' Tube [8]

Fig 3. Change of fluid flow by sound [9]

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2.2 Flame Control of Sound

Flame is a mass of heat that combustible (an organism containing carbon) vaporizes and meets with oxygen, rapidly oxidizing. The flame on the path where the sound is propagated causes a change in pressure and volume by the sound as a gas. Flame is also a rapidly oxidizing material, and resonance frequency exists. When we look at several studies, it reacts greatly at frequencies below 100Hz. Since the change in the pressure at which the flame reacts by the sound is equal to the pressure change period of the propagated sound, it can be expressed as Equation (1) [10-11].

$$Y(t) = A' sin(\omega t - k) \quad (1)$$

A' : Amplitude for pressure variation of candlelight medium

In this case, since the resonance of the candlelight with respect to the sound is the same as the direction of change of the sound pressure, the change of the volume of the candlelight is made as shown in Figure 4, and the changed volume can be expressed as Equation (2). According to Equation (3), when the distance from the center of the candlelight to the surface is doubled, the volume increases 2.3 times.

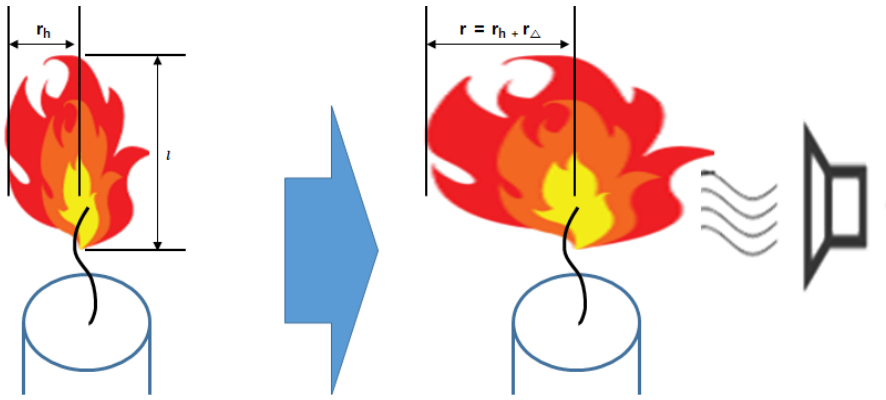

Fig 4. Increase in volume of candlelight by resonance

$$V = \int_0^l (\pi r_h^2 + 2r_\Delta \text{ X } 2r_h) d_h \quad (2)$$

$$if\ r_\Delta = r_h\ then\ V = \int_0^l (\pi r_h^2 + 4r_h^2) d_h = 2.3 \int_0^l \pi r_h^2 d_h \quad (3)$$

By increasing the flame volume 2.3 times, the pressure in the unit volume decreases to 1/2.3 times. And the absolute temperature in the unit volume is also reduced to 1/2.3, according to the Boyle-Charles law of the Equation (4) which shows the correlation between the pressure (P), the volume (V) and the absolute temperature (T) [12].

$$\frac{P_0 V_0}{T_0} = \frac{P_1 V_1}{T_1} \quad (4)$$

In order for combustion to continue, four elements must be provided. The four elements are combustible, oxygen, ignition source (heat), and smooth chain reaction [2]. As the volume of the flame increases instantaneously as shown in Figure 4, the temperature of the flame is lowered to stop the combustion or reduce the rate of combustion. In addition, the decrease in the pressure within the unit volume means the reduction of combustible and oxygen, thereby suppressing the continuation of combustion. In addition, inside the flame away from the surface of the flame, the oxygen supply is shut off, creating an environment where combustion is unlikely to last.

3. PROPOSAL OF METHOD TO SAFEGUARD THE PERSON WHO SUPPRESSES FIRE USING SOUND FIRE EXTINGUISHER

Sound Fire Extinguisher controls the flame by outputting very large low-frequency sounds. Sound Fire Extinguisher requires preparation for low-frequency noise because very large low-frequency sounds can harm person who suppresses fire. SSERI applied the Adaptive Noise Cancellation (ANC) technique to control the low-frequency noise spreading to the rear-side. SSERI uses a special acoustic lens to form the main sound beam to concentrate the sound energy in the flame while outputting the antiphase side sound around the main sound beam to control the noise by dissipating the low frequency noise spreading to the surroundings [13-15].

In this study, we propose a method to safeguard person who suppresses fire from flame by adjusting the level of side sound of Sound Fire Extinguisher. Two or more different sounds interfere with each other instantaneously at the point where they merge, but they proceed in the direction in which they proceed without changing the characteristics by the principle of superposition. Sound Fire Extinguisher's side sound attenuates

loud noises caused by the main sound beam. However, like the main sound beam, it propagates sound energy in the main direction of travel. Therefore, the side sound of the Sound Fire Extinguisher can also control the flame approaching the person who suppresses fire by adjusting the sound level. The side sound requires a level of energy that inhibits access so that flame does not harm the person who suppresses fire, and does not require as much energy to fire. Figure 5 shows how to safeguard the person who suppresses fire using the side sound of the Sound Fire Extinguisher.

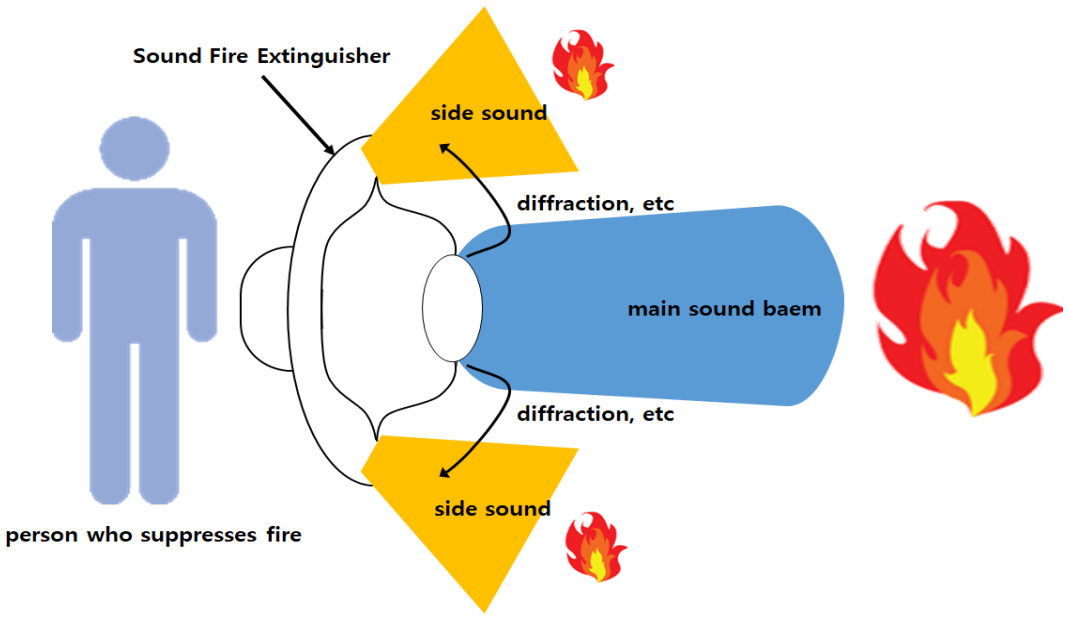

Fig 5. How to safeguard the person who suppresses fire using Sound Fire Extinguisher's side sound

4. EXPERIMENT AND RESULT

In chapter 4, we tried to confirm through experiments that the sound components of the Sound Fire Extinguisher can suppress the flame approach to the person who suppresses fire through the proposed method. The experiment measured the state of flame change when the flame approached the main sound beam and the side sound of the Sound Fire Extinguisher. The experimental method measured the sound level at which the flame changes direction and the sound level at which the flame turns off when the flames of the torch lamp, portable burner and candles with different combustion characteristics were approached to the Sound Fire Extinguisher. In the Sound Fire Extinguisher, a 60 Hz pseudo sinusoidal wave was output as the main sound beam, and the same sound in reverse phase was output as the side sound around it. In the case of the main sound beam, some wind speeds are accompanied by sound energy maintained on the propagate path. Sound level was measured using Acoustilyzer AL1 from NTi Audio. Figure 6 shows the experimental method.

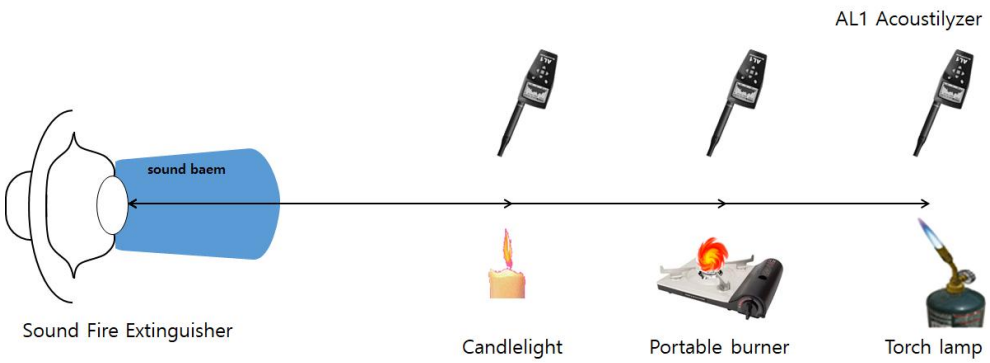

Fig 6. Experimental method

Figure 6 shows that as the flame is approached to the Sound Fire Extinguisher in the main sound beam, the direction of the flame begins to change and then turn off. The side sound also changed the direction of the flame as the flame approached the Sound Fire Extinguisher. However, the output of the sound is distributed rather than the main sound beam, so the flame does not turn off because the sound level is low and the energy is not concentrated. Table 1 shows the result of measuring the sound level that the flame reacts in each situation.

Table 1. Interview summary for the sound of Reed Wind

Type		Torch lamp	Portable burner	Candlelight
Main sound beam	Flame off	95 dB	85 dB	85 dB
	Flame direction change	85 dB	80 dB	80 dB
Side sound	Flame direction change	93 dB	90 dB	90 dB

As a result of the measurement in Table 1, the torch lamp with stronger flame intensity than the portable burner and candlelight reacted when the sound level is high. Also, in the case of the main sound beam focusing the sound, the flame was well reacted at the lower sound level as compared with the side sound beam.

5. CONCLUSION

Fire is an indispensable means of developing human civilization. However, the conflagration caused by fire is devastating to mankind. Firefighters who suppress fire or rescue humans must fulfill their duties in order to secure their safety first. However, in the conflagration field, even if the flame temperature is over 1000℃, protecting the firefighter from the flame is the only fire fighting garment that can withstand up to 500℃. In addition, if person who suppresses fire is exposed to the flame, it may cause personal injury. Therefore, measures to safeguard person who suppresses fire are most important.

In this study, we propose a method to safeguard the person who suppresses fire using the sound component of Sound Fire Extinguisher. The proposed method is to control the output of the side sound which is studied by the noise control technique of Sound Fire Extinguisher to control the flame approaching around person who suppresses fire. In the Sound Fire Extinguisher developed by SSERI, as long as the main sound beam suppresses the flame, the side sound can achieve its intended purpose by outputting energy at a level that suppresses the approach of the flame. As a result of the experiment in chapter 4 with torch lamp, portable burner and candlelight, flame is turned off in the main sound beam, and flame is changed in a certain sound level as distance increases. In case of side sound, the direction of the flame of the portable burner and the candle was changed when the sound level was 90dB or more, and the direction of the flame was changed when the torch lamp was 93dB or more. However, the main sound beam accompanied by the wind speed changed the direction of the flame at a lower sound level than the side sound. As a result of this experiment, we confirmed that the flame approaching the person who suppresses fire in the actual conflagration field can be controlled by increasing the side sound output as the direction of the flame changes in the side sound of the noise canceling level. In addition, side sound can also increase the ability of person who suppresses fire safeguard by forming a sound beam.

In the future, we will continue to improve the side sound output to safeguare the person who suppresses fire in the actual conflagration field.

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