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# A Study on Sound Beam Formation of Sound Fire Extinguisher

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**Abstract:**

A new fire fighting technology is needed because of the changed fire fighting environment. Sound Fire Extinguisher is a new technology that suppresses conflagration by using the characteristics of sound and can be an alternative to the changed fire fighting environment. The Sori Sound Engineering Research Institute (SSERI) applied a special acoustic lens to the Sound Fire Extinguisher to focus the sound energy. In this paper, we investigate the characteristics of a sound beam formed by a special acoustic lens and how efficiently a sound beam transmits sound energy through experiments. While the wind velocity of the sound beam was measured, when the reverse phase sound was supplied to the sound beam, the wind speed was lost and the sound level was reduced by about 20 dB. This confirms that the velocity of the sound beam is a measure of the movement of the medium at regular intervals with very large pressure changes. As a result of measuring the sound level on the transmission path, it was attenuated by 4 dB to 30 cm, which is three times the distance from 10 cm, and sound energy was effectively transmitted from the Sound Fire Extinguisher to 40 cm. As a result of this experiment, we confirmed that a special acoustic lens of Sound Fire Extinguisher concentrates the sound energy by spouting the resonant sound as a surface source type sound beam, and effectively transmits it to the flame.

**Keyword:** Fire Fighting Environment, Sound Fire Extinguisher, Special Acoustic Lens, Sound Beam, Sound Energy

## 1. INTRODUCTION

As buildings become skyscraperized, larger, and complex, conflagration can lead to large conflagration. Despite these changes in the fire fighting environment, the extinguish method to date remains in use of chemical reactions by fire extinguishing agents. A new extinguish method is needed to overcome the change of fire fighting environment [1-3].

Sound Fire Extinguisher has been actively researched as an alternative to overcome the changing fire fighting environment. Sound Fire Extinguisher is a fire extinguisher that suppresses the conflagration by using sound characteristics. It is expected to be a new fire fighting technology that can overcome the limitation of existing fire extinguisher that depends only on chemical reaction. Sound Fire Extinguisher was first released by US Defense Advanced Research Projects Agency (DARPA) and George Mason University students. The Sound Fire Extinguisher, which they released for the first time, is hard to use in the fire fighting field because the sound energy spreads all the way and does not deliver enough energy to the flames [4-6].


**Fig 1.** Sound Fire Extinguisher from DARPA[4]

In the Sori Sound Engineering Research Institute (SSERI), a special acoustic lens was applied to improve the disadvantages of the previously released Sound Fire Extinguisher to focus sound energy forward. A special acoustic lens developed by SSERI collects and resonates the sound and changes the direction of the resonance sound energy to the front. The sound beam that occurs during the process of centralizing the sound energy forms a wind velocity due to the transmission of a very large sound energy [7-9].

**Fig 2.** Sound Fire Extinguisher from SSERI

In this study, we tried to verify the characteristics of a sound beam with wind velocity due to a special acoustic lens. Chapter 2 covers the basic theory, and Chapter 3 describes the sound fire extinguisher's sound beam with wind velocity. Chapter 4 covers experiments and results, and Chapter 5 concludes with conclusions.

## 2. BASIC THEORY

### 2.1 Progression type of sound

Sound is a longitudinal wave transmitted by changing the pressure of the medium in a progressive direction. Therefore, it is accompanied by the movement of the medium particles by changing the density of the medium in the direction in which the sound propagates. This phenomenon can be said to be a periodic change in the velocity at which the medium particles move with a change in the density of the medium, which is somewhat different from the one in which the medium simply moves due to the pressure difference [10].

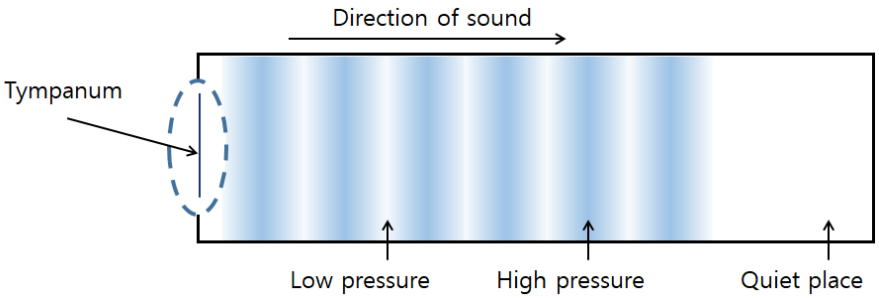


**Fig 3.** Principles and progress of sound generation [10]

As shown in Figure 3, the progression type of the sound can be expressed as Equation (1) because the sound is transmitted by periodically changing the density of the medium [10].

$$Y(\mathrm{x}, t) = A\sin(\omega t - kx) \tag{1}$$

### 2.2 Surface source

A sound source is called a surface source when the sound source is spread over a wide plane. A surface source progresses in a hemispheric manner on the surface in countless numbers of sounds of the same phase. The energy reaching the sound receiving point (P) at a distance r from the surface source can be obtained by integrating the energy of a large number of transmitted sounds. The distance attenuation for a circular surface source with diameter D is given by Equation (2), and the distance attenuation for a circular surface source is shown in Figure 4 [11].

Distance attenuation of circular surface source

$$= 10\log\left(ln\left|1+\left(\frac{D}{2r}\right)^2\right|\right)\ (\mathrm{dB}) \tag{2}$$

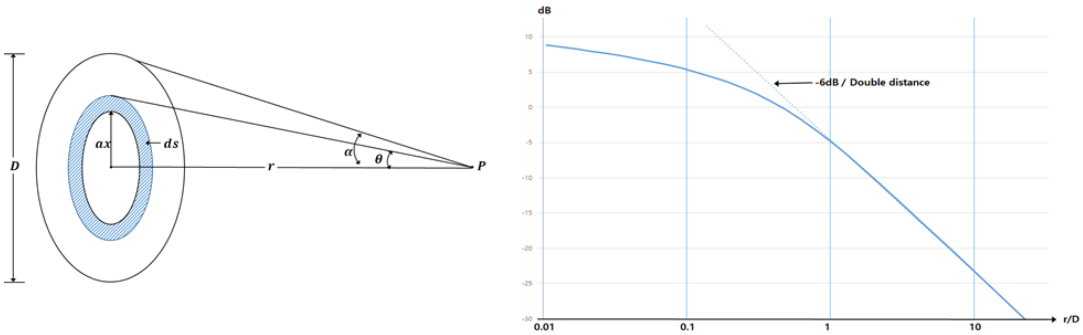


**Fig 4.** Distance attenuation of surface source [11]

As shown in Fig. 4, the distance attenuation near the surface source is small, and after propagating to some extent, it decreases by 6dB for every 2 times distance like the point source.

### 2.3 Pascal's principle

Pascal's principle is that if you apply a force to a fluid filled in a closed space, the pressure (P) acting on each side of the closed space is the same. According to Pascal's principle, the pressure applied in the fluid is transferred to the whole area (A) through the fluid at the same pressure. Pascal's principle can be

explained by the pressing of various parts of the toothpaste, with the toothpaste coming out. This principle is applied to hydraulic devices which can act as a large force F2 due to the transfer of less force F1. Figure 5 is a diagram illustrating Pascal's principle. Equation (3) shows the relation of the pressure transferred according to area [12].

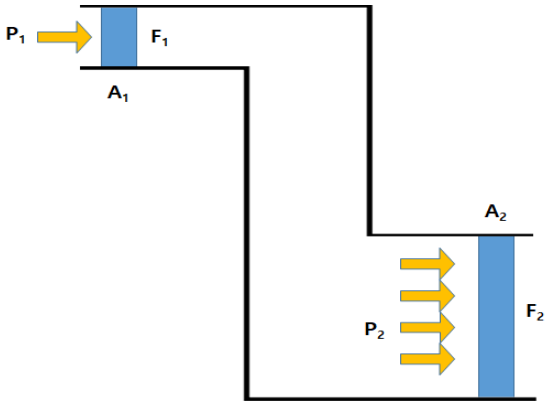


**Fig 5.** Pascal's principle [12]

$$P_1 = P_2 \rightarrow \frac{F_1}{A_1} = \frac{F_2}{A_2} \rightarrow F_2 = F_1 \frac{A_2}{A_1} \quad (3)$$

### 2.4 Destructive interference of sound

The sound is transmitted by the principle of superposition without changing the size and characteristics of the sound. However, a composite wave occurs at the point where two or more sounds meet. At this time, when the same sound in the reverse phase is composite, destructive interference occurs in which the sound is reduced in size. The destructive interference for the same sound in the reverse phase is expressed as Equation (4) [13].

$$Y(t) = A_1 \sin(\omega t - k) + A_2 \sin(\omega t + \pi - k) = (A_1 - A_2) \sin(\omega t - k) \quad (4)$$

## 3. SOUND FIRE EXTINGUISHER'S SOUND BEAM

Sound Fire Extinguisher's a special acoustic lens collects the sound from all directions into one place and resonates greatly. Resonance in a confined space with a special acoustic lens and cone propagates a very large periodic pressure to a spherical shape. At this time, the pressure generated in the closed space is transferred at the same magnitude of pressure to the narrow power outlet according to Pascal's principle [12]. In this process, the sound energy transmitted from the resonance point (A) to the all directions is changed to the front plane of the energy direction through the power outlet (B) of a special acoustic lens. A sound level of 117 dB was achieved when there was no special acoustic lens, while the sound level spouted to the front due to a special acoustic lens was 121 dB. It can be seen that the pressure increased 1.6 times. The pressure transferred to the surface (B) in one direction accelerates the movement of the medium particles and forms a wind velocity of 8 to 10 m/s just before a special acoustic lens. Figure 6 shows the formation of the sound beam of a Sound Fire Extinguisher with wind velocity.

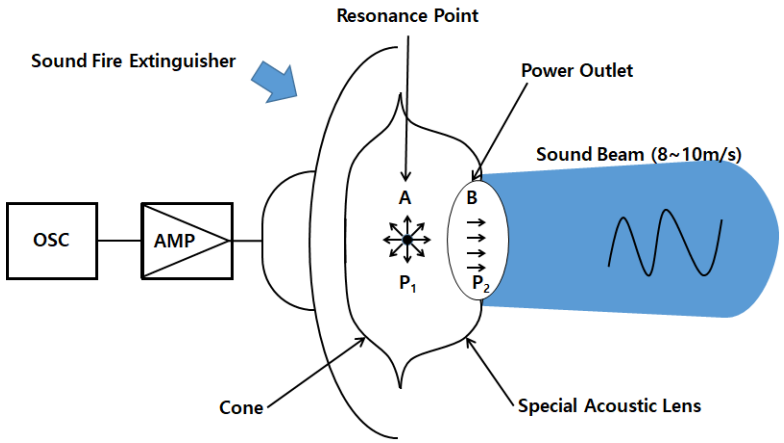


**Fig 6.** Sound Fire Extinguisher's sound beam formation

## 4. EXPERIMENTS AND RESULTS

In Chapter 4, we confirmed the characteristics of the Sound Fire Extinguisher's sound beam and confirmed how efficient the sound energy transmitted the formed sound beam through experiments. The experimental method was to measure the change of the sound level and the wind velocity by supplying the sound phase of the reverse phase to the sound beam. We also measured the change of the sound level every 10 cm on the pathway of the formed sound beam. The sound component

applied to the Sound Fire Extinguisher was 60 Hz pure tone and the sound level was measured using NTi Audio's Acoustilyzer AL1 and the wind velocity was measured using an Anemometer GM816. Figure 7 shows the difference between sound level and wind velocity when a reverse phase sound is applied to the Sound Fire Extinguisher's sound beam. And, Figure 8 shows the measurement of the transfer characteristic according to the separation distance from the Sound Fire Extinguisher.

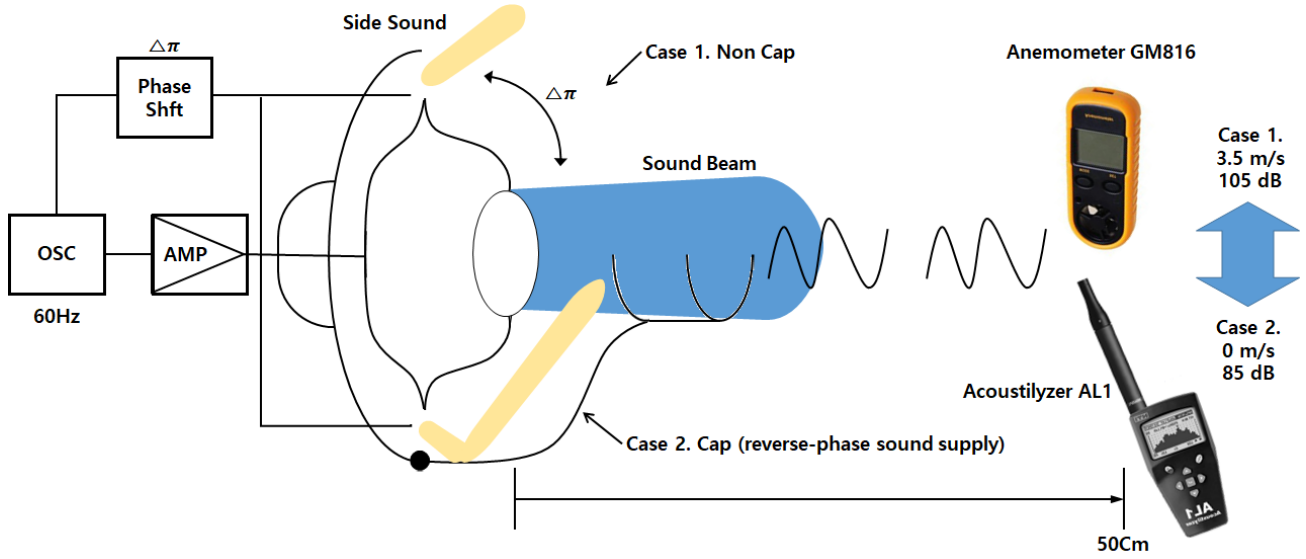


**Fig 7.** Comparison of wind velocity and sound level according to supply of reverse phase sound component

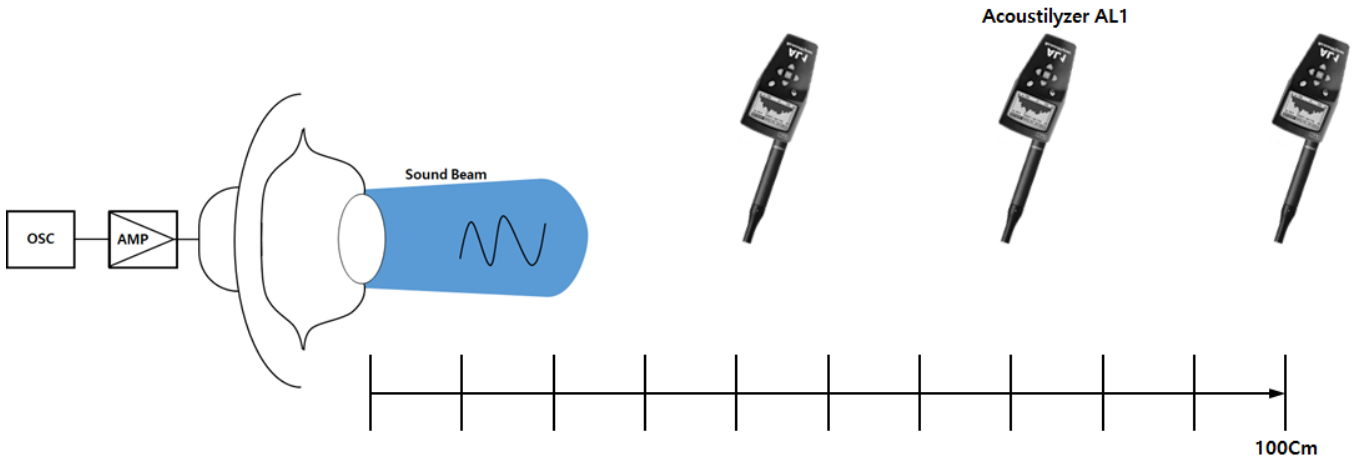


**Fig 8.** Measure sound level by distance

Figure 7 shows that the sound level was 105dB at a wind velocity of 3.5m/s at a distance of 50cm from the Sound Fire Extinguisher. On the other hand, when the sound of reverse phase was supplied by covering the cap, the wind velocity was 0m/s, and the sound level was 85dB at a distance of 50cm. When the sound of the reverse phase is heard, the sound level and wind velocity are reduced by destructive interference. These results show that the wind velocities formed by the Sound Fire Extinguisher are formed by the rapid movement of air particles at a constant period due to a very large pressure change momentarily.

Table 1 shows the sound level of each distance on the path of Sound Fire Extinguisher's sound beam according to the experiment in Figure 8. Table 1 shows that the average sound level is 119 dB when the transmission distance is 10 cm. It decreases by 4 dB when the distance is 30 cm, which is 3 times the distance, and 7 dB when the distance is 40 cm when the distance is 4 times. These results show that the attenuation amount is significantly smaller than that of the conventional point source which propagates to the spherical shape by 6dB every 2 times distance.

**Table 1.** Sound level measurement on pathway

| Transmission distance(cm) | 1'st (dB) | 2'nd (dB) | 3'rd (dB) | 4'th (dB) | Average(dB) |
|---|---|---|---|---|---|
| 10 | 118 | 127 | 120 | 112 | 119 |
| 20 | 118 | 125 | 117 | 110 | 118 |
| 30 | 115 | 122 | 113 | 110 | 115 |
| 40 | 112 | 118 | 110 | 108 | 112 |
| 50 | 107 | 112 | 106 | 101 | 107 |
| 60 | 100 | 108 | 100 | 94 | 101 |
| 70 | 94 | 103 | 90 | 90 | 94 |
| 80 | 90 | 97 | 87 | 89 | 91 |
| 90 | 87 | 93 | 85 | 88 | 88 |
| 100 | 85 | 90 | 85 | 88 | 87 |

Figure 9 compares the attenuation amount by the distance expected from the point source and the attenuation amount of Table 1. As a result, the sound beam of the Sound Fire Extinguisher has relatively low attenuation up to 50 cm, but its attenuation increases from 60 cm. It can be seen that these characteristics follow the characteristics of the surface source. Therefore, Sound Fire Extinguisher can say that the sound beam is formed up to 30cm which is less than 5dB, and attenuation to about 40cm is minimized, so that the sound energy is transmitted well.

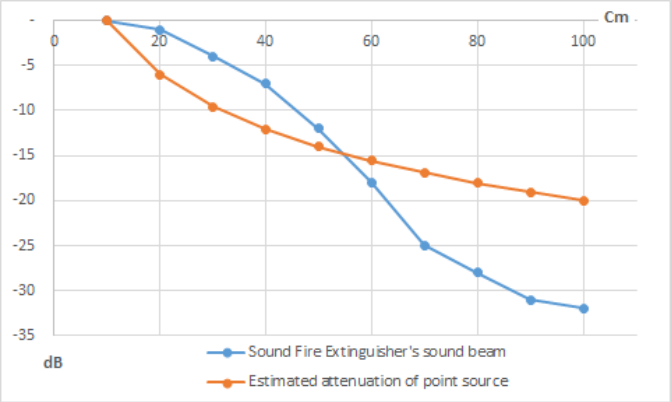


**Fig 9.** Comparison of attenuation by distance

## 5. CONCLUSION

It can not be overcome to overcome the fire fighting environment which was changed only by existing extinguish method which depends only on chemical reaction of fire extinguish agents. Sound Fire Extinguisher, which uses sound characteristics, can be an alternative to overcome a changed fire fighting environment. SSERI has improved its focus on sound energy in flames by applying a special acoustic lens to the existing Sound Fire Extinguisher released by DARPA and George Mason University students.

In this study, we tried to confirm the wind velocity and transfer characteristic of Sound Fire Extinguisher's sound beam formed by a special acoustic lens through experiments. As a result of the experiment in Chapter 4, when the sound of the reverse phase is supplied to the Sound Fire Extinguisher's sound beam, the sound level as well as the wind velocity are greatly reduced. Therefore, the wind velocity of the sound beam is not simply the air passing quickly, but the transmission phenomenon of the sound that periodically changes the pressure of the medium. In addition, as a result of checking attenuation amount according to transmission distance, sound propagation type is changed from point source to surface source and spouted to a sound beam, thereby minimizing attenuation to about 40cm and smoothly transmitting sound energy to flame.

Sound Fire Extinguisher can maximize efficiency by appropriately using sound characteristics. We are actively studying the sound characteristics of Sound Fire Extinguisher and hope that Sound Fire Extinguisher will work in the fire fighting field as soon as possible.

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