International Journal of Engineering Research and Technology.
ISSN 0974-3154 Volume 11, Number 10 (2018), pp. 1525-1532

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A Study on the Correlation between Frequency and Eradication Distance of Sound Fire Extinguisher

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ABSTRACT

Modern buildings are becoming taller and larger, and their interior is becoming more complicated. Therefore, a proper firefighting facility is needed for a changing firefighting environment. Sound Fire Extinguisher is a new concept extinguisher that can be applied to a changing firefighting environment to increase extinguishable efficiency. Sound Fire Extinguisher is influenced by the characteristics of sound as much as it suppresses combustion by using characteristics of low frequency sound. In this study, we tried to confirm the correlation between frequency and eradication distance of Sound Fire Extinguisher through experiments. Experimental results show that when the pure tone of 30 ~ 100Hz is transmitted sequentially in a given experimental environment, the sound is decreased when the distance is 50cm apart, but the attenuation pattern of sound is different according to the frequency. At 70 ㎝ distance from the speaker, the attenuation was the lowest at 45Hz sound. At 150 ㎝ distance from the speaker, attenuation was best spread at 60Hz. Sound Fire Extinguisher is expected to maximize the extinguishable efficiency if it chooses the sound component according to the firefighting environment and the distance from the flame.

Keywords: Sound Fire Extinguisher, Sound Component, Frequency, Eradiation Distance, Extinguishable Efficiency

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I. INTRODUCTION

As the development of human civilization accelerates, buildings are becoming taller and larger, and the interior is becoming more complicated. But despite the changing firefighting environment, the development of firefighting policy and firefighting facility is failing. In the high-rise and large-sized buildings, such as the conflagration of Daegu subway station in 2003 and the conflagration of a skyscraper in Dubai in 2017, it is very difficult to prevent and suppress fire by using the existing extinguish facility only. Therefore, a firefighting facility is needed for a changing firefighting environment [1-2].

Soongsil University's Sori Sound Engineering Research Institute is actively studying Sound Fire Extinguisher. Sound Fire Extinguisher is a new concept extinguish facility that can be applied to a changing firefighting environment to enhance extinguishable efficiency. Sound Fire Extinguisher was first released by Defense Advanced Research Project Agency (DARPA) in the United States. At the time of DARPA's release, however, it was only at this level that sound affects extinguish by resonating flame molecules [3-4]. Sori Sound Engineering Research Institute is studying the practical application of Sound Fire Extinguisher to the fire field. Sound Fire Extinguisher uses the principle of suppressing combustion by artificially generating low-frequency sounds and concentrating the sounds on the flame, using various characteristics of sound. So there are a lot of different characteristics depending on the sounds that are generated by the Sound Fire Extinguisher. Sound Fire Extinguisher controls the sound component according to the characteristics of the fire field to suppress the fire. In this way, it is possible to increase the extinguishable efficiency and to prevent the fire. By confirming the various characteristics that appear depending on the sound component supplied by the Sound Fire Extinguisher, Sound Fire Extinguisher will be able to develop various methods that can be applied in the firefighting field. Figure1 is one of the currently studied Sound Fire Extinguisher models [5-9].

Fig 1. Sound Fire Extinguisher

In this study, we tried to confirm how the frequency change of Sound Fire Extinguisher affects the eradiation distance of sound component through experiment. Chapter2 explains the characteristics that appear when sound is transmitted. Chapter3 presents the results of experiments and conclusions in Chapter4.

II. CHARACTERISTICS OF SOUND

Attenuation of Sound: Sound is a wave that propagates along a medium such as air, and the pressure change of the air transmits the energy of sound. The propagation characteristics of sound transmitted by air are mainly spherical propagation characteristics. In wavelength propagated spherically, when the transmitted distance is doubled, the transmitted area increases by a factor of 4, and the transmitted energy has an attenuation characteristic which is reduced to 1/4, which means an attenuation of 6 dB. When a sound is generated in a long line such as a coastline, a railroad, or a highway, sound energy propagates in a cylindrical shape. In this case, when the distance to be transmitted is doubled, the area to be transmitted doubles and the sound attenuates to 3 dB. In addition to the attenuation according to the propagation distance, attenuation characteristics are different according to the state of the air and the frequency of the sound. Generally, as the distance increases, the dB value attenuates linearly. However, as the frequency decreases, the attenuation becomes smaller. This phenomenon is different depending on the humidity and temperature in the air as well as various surrounding conditions. [10].

Propagation Characteristics of Sound: The sound is mostly diffused as it is transmitted. When the diffusion process is performed in one direction, the sound propagates straight, while being reflected, diffracted, and refracted according to the transmitted environment. Sounds are reflections at the interface that changes into a different medium in the course of transmission, or at the interface where density or cross-sectional area changes. When reflection occurs, the reflection and transmission results are different depending on the incidence angle or density difference between media. Also, when sound is propagated, when it encounters different boundaries, the propagation direction is warped by the difference in impedance of different media. This is called diffraction of sound. Another characteristic of the sound is the refraction phenomenon, in which the direction of propagation changes due to the density difference of each medium when the sound is propagated from one medium to another medium. As the density difference becomes larger according to Snell's law, the refraction becomes larger. The propagation characteristics of the sound are greatly affected by the environment in which the sound is transmitted, but they are also affected by the components of the sound waves themselves. Therefore, the sound propagation characteristics are very different depending on the frequency component of the sound emitted from the Sound Fire Extinguisher and the extinguishing environment [10].

Eradiation Characteristics of Sound Fire Extinguisher: Sound Fire Extinguisher uses sound to suppress combustion, so it is influenced by the characteristics of the speaker and the environment in which the sound propagates. The factors that can be considered in the eradiation characteristics of the Sound Fire Extinguisher are the

frequency response of the loudspeaker, the diameter of the loudspeaker (the power of the loudspeaker), the influence of the sound propagating space, the propagation characteristics of the sound, distance from flame, etc,. Considering these factors, we can use Sound Fire Extinguisher very efficiently for fire suppression and prevention if we eradiate sound components appropriate to the flame [5-8]. However, in this paper, we fix all the experimental environment including the volume of sound and change the frequency only, and measure the volume of the sound transmitted by each distance. This confirms only the interrelation between frequency and Sound Fire Extinguisher eradiation distance.

III. EXPERIMENTS AND RESULTS

Experiments were carried out in a university laboratory with a width of 740 mm, a height of 310 mm and a height of 270 mm in order to apply an environment similar to a general firefighting environment. In this experiment, a low frequency sound component of 30Hz ~ 100Hz was transmitted through a low frequency speaker (Britz AMP BR-5100T), and the sound was measured at intervals of 20 cm from 50 cm to 150 cm from the speaker. The instrument that measures the size of the sound is NTI AUDIO's AL1 Acoustilyzer. The measurement mode was set to "FLAT" and the measurement value was set to "SPL" in order to exclude the human auditory characteristics in the measurement of sound and to compare the energy transfer characteristics depending on the distance. The sound component transmitted through the speaker was generated using Audition CC and the Pure tone increased by 5 Hz from 30 Hz to 100 Hz was used. Pure tone for each frequency was generated every 10 seconds, and interval between each transmitted sound was 5 seconds. The change of the sound size according to the distance by frequency was recorded using Samsung Electronics' smartphone Galaxy Note 4. In order to minimize the experimental error, all of the cooling and heating facilities in the laboratory were turned off and all the experimenters were discharged and measured, thereby minimizing the intervention and the influence of the experimenter during the experiment. Figure 2 shows the experimental setup.

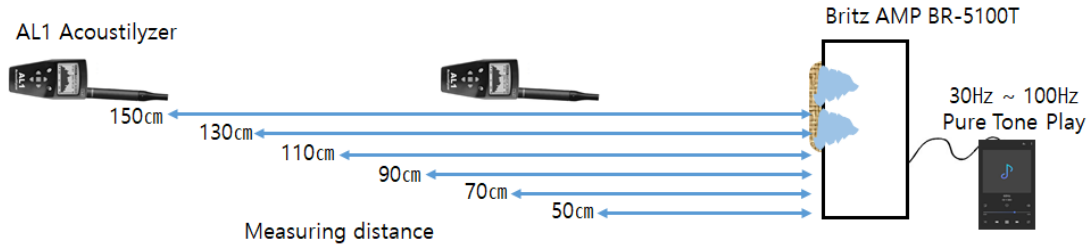

Fig 2. Experiment Environment

In order to confirm the correlation between the frequency and the distance change, the SPL variation according to the distance change was calculated for each frequency in

the actually measured SPL values. The experiment was performed 8 times in total, and Figure 3 is a graph showing the average value of SPL variation from 8 experiments.

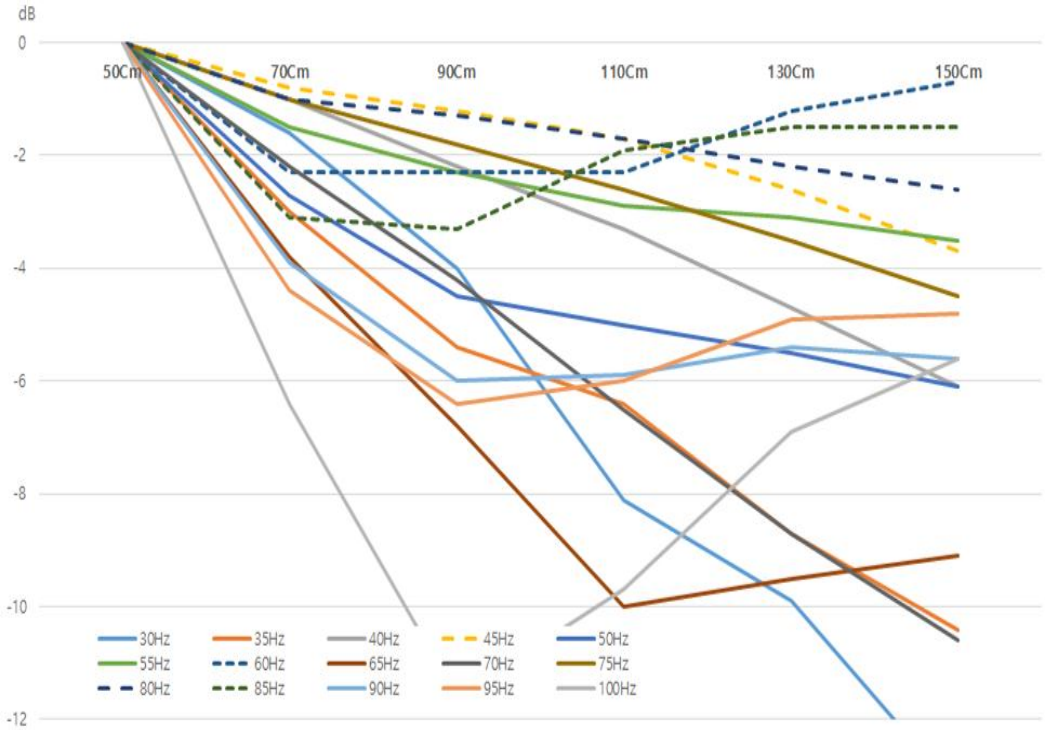

Fig 3. Change in SPL with Distance Change for Each Frequency

In Figure 3, which shows the changed SPL value according to the increasing distance for each frequency, when the distance is 130 ~ 150 cm away from the speaker, the frequency with the least SPL decrease is 60 Hz and then 85 Hz. However, at a distance of 70 cm to 90 cm from the speaker, the frequency with the least SPL reduction was 45 Hz and then 80 Hz.

Figure 4 shows the result of Figure 3 in terms of the SPL value changed according to the frequency changing at each distance. Figure 4 shows that 60Hz attenuation is small at most distances that are eradicated, but attenuation is the least at 130 ~ 150cm, and attenuation at 40Hz, 45Hz, 75Hz, and 80Hz is less at relatively short distances. At 50Hz, 65Hz, 70Hz, 90Hz and above, the attenuation was larger at most distances.

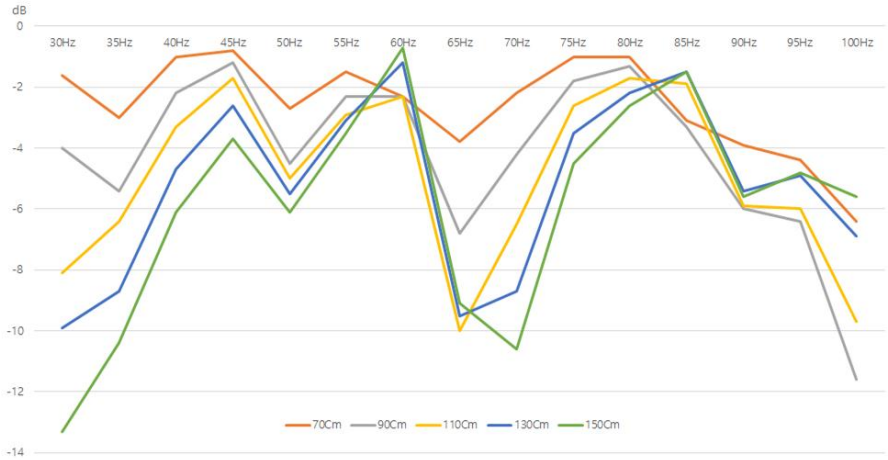

Fig 4. Change in SPL with Frequency Change for Each Distance

Figure 5 shows the results of attenuation at a distance of 150 cm from 8 experimental results. Figure 4 shows that there are some effects of noise around the laboratory in a total of 8 experiments, but the frequency characteristics are generally similar.

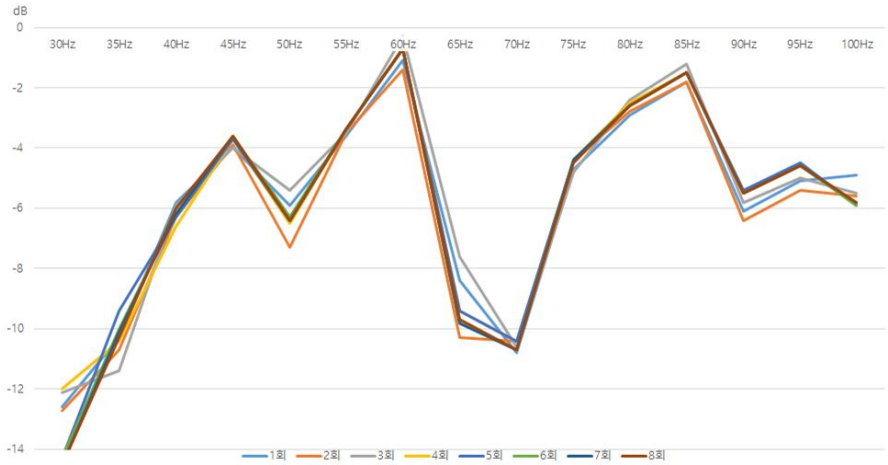

Fig 5. Attenuation by Frequency at Distance of 150cm

These results show that the sound energy is smaller when the distance is longer than the distance of 50 cm as a whole, but the specific frequency region is well propagated because the attenuation of the sound energy is less than that of the other frequency regions. Especially, Sound Fire Extinguisher is expected to have an eradiation distance of 50 ~ 150cm to extinguish or fire. At a distance of 70 cm from the flame, 45 Hz is expected to provide the most smooth sound energy, and at 150 cm distance, 60 Hz is expected to provide the most smooth sound energy.

IV. CONCLUSION

Due to the development of human civilization, the firefighting environment is changing in various and complex ways. Sound Fire Extinguisher is a fire extinguisher that is being adapted for various firefighting environments. Sound Fire Extinguisher generates sound of low frequency and focuses on flame. It uses the principle of suppressing combustion by using various characteristics of sound. So by understanding the sound characteristics of the Sound Fire Extinguisher, we will be able to develop a Sound Fire Extinguisher that is more suitable for an extinguish environment. Since the Sound Fire Extinguisher uses the characteristics of the sound, it can be influenced by various transmission characteristics of sound, response characteristics of speaker, power that speaker can emit (or size of speaker), space characteristic for extinguishing environment, frequency characteristic of sound.

In this paper, by fixing all the environmental factors including the size of the pure tone, and changing only the frequency and sound measurement distance, it is experimentally confirmed that the frequency change in the general firefighting environment affects the eradiation distance of the Sound Fire Extinguisher. Experimental results show that the variation of sound energy delivered by distance is very different for each frequency. In general, the sound energy decreases as the distance increases. However, at 70 ㎝ spacing, the attenuation is the lowest at 45 ㎐ and propagation is well. At 150 ㎝ spacing, the attenuation is the lowest at 60 ㎐ and propagation is well. Of course, a change in the experimental environment may yield somewhat different results. However, it has been confirmed that the eradiation characteristics of the sound component are different depending on the distance in each frequency in a given environment.

Sound Fire Extinguisher has different eradication characteristics depending on frequency components. It is expected that maximizing the extinguishable efficiency by properly selecting sound component of Sound Fire Extinguisher according to firefighting environment.

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