# THE STUDY ON SOUND REDUCTION IN WINDOW TYPE OF VARIABLE-VOLUME RESONANT SILENCERS

Wen-Sung CHU
*Ph. D. Candidate, Department of Architecture, National Cheng Kung University, Tainan, Taiwan*
*wensung.chu@gmail.com*

Rong-Ping LAI
*Professor, Department of Architecture, National Cheng Kung University, Tainan, Taiwan*
*lairp@mail.ncku.edu.tw*

## Summary

The study focuses on sound insulation and takes into account the ventilation effects, the objective is to develop silencers systems that will reduce noise transmission whilst allowing Airflow into the indoor.

This study based on Helmholtz resonators theory are applied to the optimal design of resonant absorption silencer, By changing the length of the resonant volume, a variable volume resonant Silencers was designed. This maximum noise reduction frequency is in fact the resonance frequency, and depends on the size of the resonant volume.

The result confirms that different resonant volumes will change the resonance frequency. The bigger the volume, the lower the frequency, and on the contrary, the smaller the volume, the higher the frequency, the result indicates that the influence of resonant volume on Insertion loss varies with length of the resonant chamber. Clearly, Insertion loss of resonant absorption silencer increases with length of the resonant chamber, 140 centimeter long air duct have the values over 15 dB by noise reduction.

According to this concept, a Silencers can be designed to confine a wanted all frequency noise without largely changing the original exhaust air duct. To confirm the design model, one may conduct further experiments on integration of silencers system and window system in the future.

**Keywords:** Windows, Variable-Volume Resonant Silencers, Sound insulation, noise reduction

## 1 Introduction

### 1.1 Printed and electronic version

Sound environment is getting worse due to highly intensive development in cities. Noise from road traffic and other sources has a substantial and growing detrimental impact on the urban environment. Most buildings install a single window, windows of buildings in noisy environments often need to be sealed, causes the problems of sound insulation and ventilation. The acoustic insulation of buildings shows many problems if related to the transparent openings, due to their low noise insulation properties, the airflow openings are at the same time very important when considering the indoor air quality.

Traditionally, A relatively simple method is to seal the windows and use a silencer-type element to allow natural ventilation. The element may be located within the window aperture, or be placed in the opaque part of the envelope, but use of fibrous materials in some systems may be a cause for concern on health grounds due to the potential hazard of fragments of fibre contaminating the air, and other contaminants being held in the fibre matrix, and released under certain conditions. In addition, conventional acoustic treatments with relatively rough surfaces tend to increase airflow resistance in the ventilator system. Finally, most of these systems only consider the requirement for minimum air exchange, and the need for occupant comfort, by means of airflow and requiring much greater opening area especially in summer, has not been sufficiently recognised.

In this research, an alternative passive method was explored, was to create a ventilation path and using variable-volume resonant silencers absorbers along the path created to reduce noise. Due to the use of variable-volume resonant materials, there is far more freedom when designing the system. aimed sound insulation performance of micro-perforated silencers and to develop high sound-insulated performance micro-perforated silencers. Moreover, ventilation performance by focusing on the need to achieve occupant comfort by means of air movement, although the requirement for air exchange was also taken into account.

## 2 Materials/Methods

A Helmholtz resonator consists of a neck and a cavity volume. The volume of air in the neck is analogous to a mass on a spring and the body volume of Helmholtz resonator is analogous to a spring of defined spring constant. The resonant frequency is:

$$f_r = \frac{c}{2\pi}\sqrt{\frac{S}{V(t+\delta)}} \tag{1}$$

The length L' is the effective length, and is not equal to the actual length L. The effective length L' should be utilized in order to enhance accuracy, when the resonant frequency in Helmholtz resonator is evaluated. The additional length is employed at each end of the neck, because the acoustic length of the neck is longer than the physical length of neck. This additional length is affected by two factors. First of all, the effective length L' depends on whether both ends are flanged or unflanged. An added length, which is equal to 0.85 R, is added to the actual length L, when the end that terminates within the cavity volume has a flange. Also, the extra length, which has a value of 0.6 R, is added to an original length L, when the end that opens into the atmosphere, has no flange. So the effective length L' is L' = L + O.85 R + O.6 R, where the radius R is related to crosssectional area of the neck. For the present experiment, an equivalent, circular opening should be calculated in order to evaluate the radius R, because the shape of crosssectional area of the neck is rectangular.

Consequently, for Helmholtz resonator absorbers it is not necessary to provide extra acoustic resistance using porous materials. Helmholtz resonator or membrane mounted at distance from a rigid wall makes a resonance system. Comparisons between calculation and measurement with various configurations of Helmholtz resonator absorbers have shown a very good performance. In this research, an alternative passive method was explored. The core idea, as illustrated in Figure 1 and Figure 2, The silencers is a box-shaped structure whose outdoor and indoor sides are equipped, respectively, with an inlet and outlet gate, create a ventilation path and the duct walls have a Helmholtz resonator profile by acoustic absorbing material, the natural ventilation openings offer a little resistance to noise passage, so different noise reduction techniques have to be considered, minimizing airflow path resistance, air may flow through the duct while noise is absorbed on the duct walls.

In Table 1, the cross-sectional area of the neck is equal to 1452 $cm^3$, and the volume of the Helmholtz resonator is adjusted from 30 $cm^3$ to 3 $cm^3$ by moving the position of a piston inside the resonator

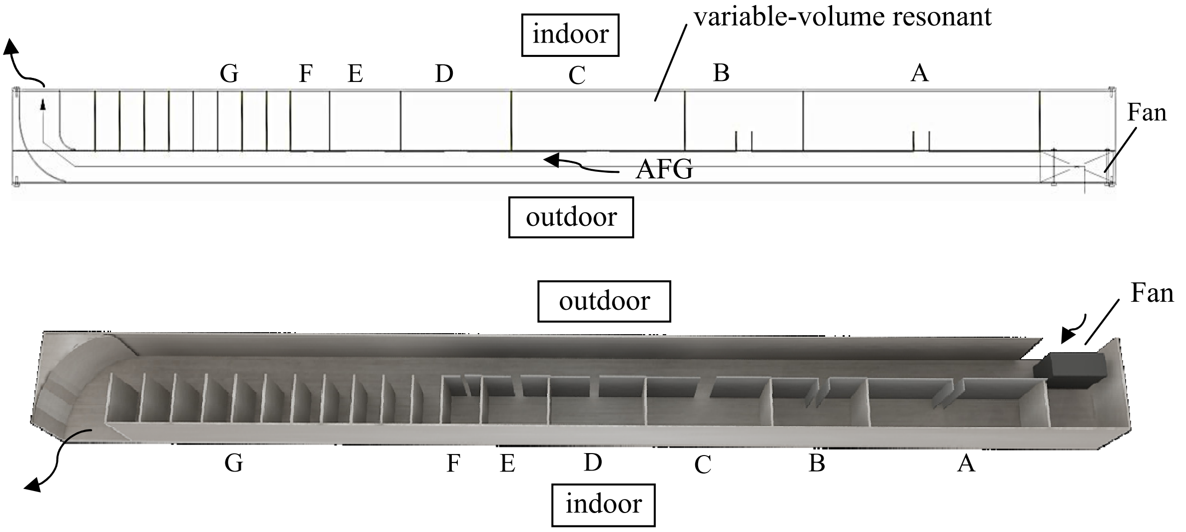



*Fig. 1* *Generic/basic configurations of the variable-volume resonant silencers system. The resonance frequency are A:232.9 Hz; B:329.4 Hz; C:399.8 Hz; D:501.2 Hz; E:630.2 Hz; F:807 Hz and G:1082.8 Hz.*

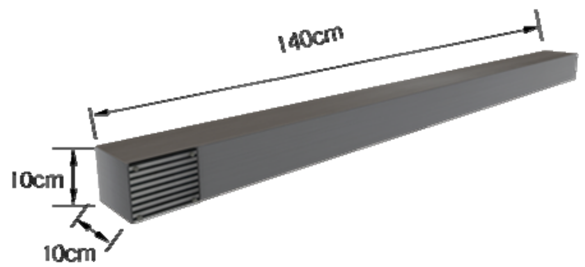
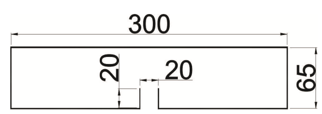
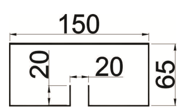
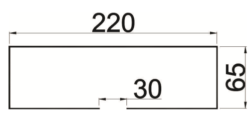
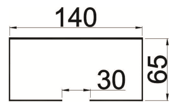
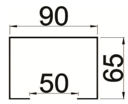
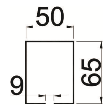
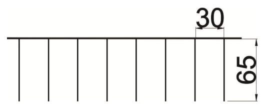



*Fig. 2* *An exterior of a 3D model.*

*Tab. 1* *Conclusions of resonant frequency*

| Sample No. | Resonant frequency | Dimension |
|---|---|---|
| TYPE.A | 232.9 Hz |   |
| TYPE.B | 329.4 Hz |   |
| TYPE.C | 399.8 Hz |   |

| Sample No. | Resonant frequency | Dimension |
|---|---|---|
| TYPE.D | 501.2 Hz |  |
| TYPE.E | 630.2 Hz |  |
| TYPE.F | 807.0 Hz |  |
| TYPE.G | 1082.8 Hz |  |

## 3 Experimental facilities

All measurements specimens at the acoustics laboratory in Department of Architecture, National Cheng Kung University. The shape and the volume of the Lab test room are in agreement with the constraints of ISO 140/1. The sound insulation performance of silencers of tested was installed on a filler wall, which divides the emitting and the receiving room. Test room map and filler wall sections are sketched in Fig. 3. $R_w$ measurements were performed according to ISO 15186-1 procedure, and $R_w$ calculation were performed according to ISO 717-1, sound transmission by the standard of sound intensity and noise reduction (IL), The sound transmission loss was determined by:

$$TL = (L_P)_{avgi} - (L_I)_{avgt} - 6dB \tag{2}$$

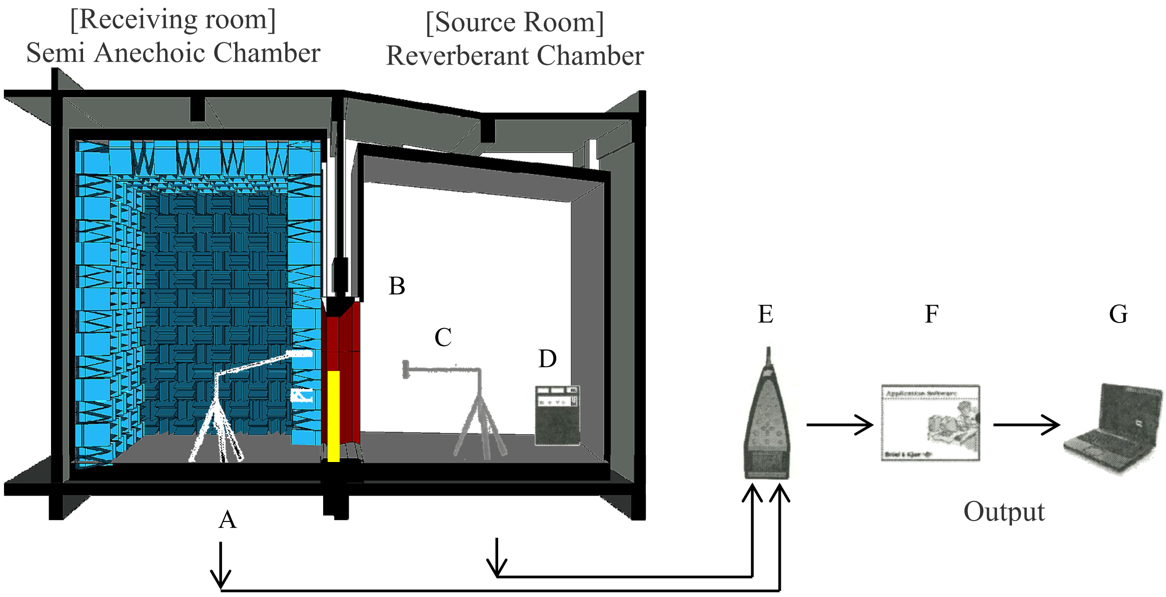
where $(L_P)_{\mathrm{avg}\,i}$ is the space-averaged sound pressure level in the reverberation room, measured with a microphone on a rotating boom, and $(L_I)_{\mathrm{avg}\,t}$ is the sound intensity level normal to and averaged over the measuring surface in the receiving room, measured by a sound intensity probe with two microphones.

The insertion loss was determined by:

$$IL = Lwi - Lwt \tag{3}$$

where ($Lwi$) is the space-averaged sound pressure level in the reverberation room, measured with a microphone on a rotating boom, and ($Lwt$) is the space-averaged sound pressure level in the receiving room.

by means of Bruel & Kjaer 2260 Sound Level Meters analyzer equipped with software for $R_w$ calculation. The sound source employed to excite the emitting room is a twelve loudspeakers omni-directional source ; source supply signal is white noise. The opening in which the test sample is installed shall be located at a sufficient distance from the edges of the frame. Furthermore, the frame shall not be located close to the edges of the wall (see Figure 3) so that the edges and the others walls do not influence to the sound field. The test sample shall be tightly installed in the frame in Fig. 4.




A: microphone pair intensity probes- (B&K 2683)
B: test opening
C: Microphone -1/2-inch Free-field Microphone-(B&K 4189)
D: source-(B&K 4224)
E: Sound Level Meters-(B&K 2260)
F: Sound Level Meters and Analyzers-(B&K 7815)
G: Notebook

***Fig. 3*** *Plan of the test rooms showing the experiment set-up*

***Fig. 4*** *Positioning of the test sample and the frame*

This study measures those specimens sound insulation and noise reduction performance of variable-volume resonant silencers. At study discusses all factors affecting the sound insulation characteristics of variable-volume resonant silencers, including noise of fans and different of variable-volume, structures and forms of arrangement. The first experimental campaign was performed on 8 different samples of variable-volume resonant silencers system, whose characteristics are reported in Table 2.

***Tab. 2*** *Characteristics of the samples*

| Sample No. | variable-volume resonant | 3D model |
|---|---|---|
| 1. sound insulation performance<br>2. noise reduction performance | | |
| 1 | Without variable-volume resonant |  |
| 2 | Install TYPE.A.B.C.D.E.F.G |  |
| 3 | Install TYPE.A.B |  |
| 4 | Install TYPE.G |  |

# 4 Results

## 4.1 Sound insulation measurements on variable-volume resonant silencers

Maintained 3 m/s by means of airflow at the duct, single number sound reduction index $R_w$ and fan measurements results are reported in Table 3. Sound reduction R measurements were performed according to ISO 140-3 and ISO 15186-1 procedures and single number sound reduction index *R*w was calculated, all the samples have Rw values bigger or equal to 25 dB, the results are reported in Figure 3, sound insulation performance of sample with all frequency of variable-volume resonant silencers have *R*w values bigger or equal to 28 dB.

***Tab. 3*** *Single number sound reduction index Rw of the samples with variable-volume resonant silencers*

| Sample No. | Variable-volume resonant | $R_w$ (dB) ISO 140-3 method |
|---|---|---|
| 1 | Install TYPE.A.B.C.D.E.F.G (all frequency) | 25 |
| 2 | Install TYPE. A.B (low frequency) | 28 |
| 3 | Install TYPE.G (high frequency) | 26 |
| 4 | Install TYPE.A.B.C.D.E.F.G (all frequency) | 25 |

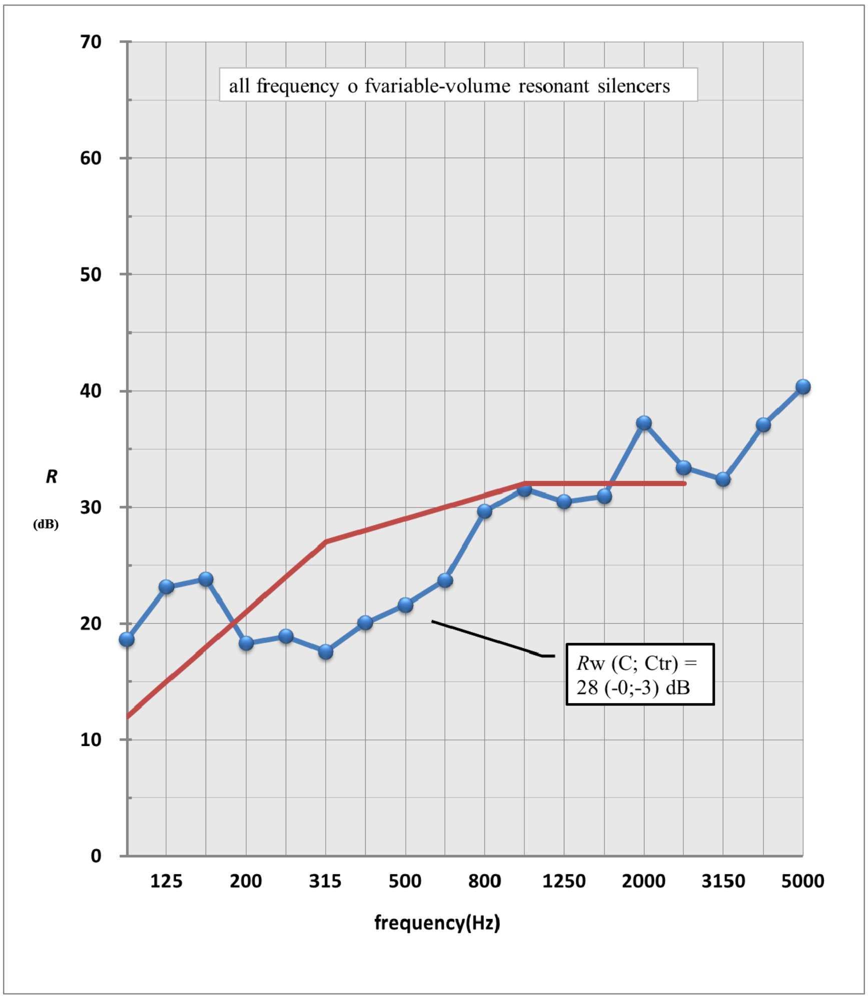



***Fig. 5*** *ISO 140-3 and 717-1 sound insulation index R vs. frequency of the Sample No.1 Install TYPE.A.B.C.D.E.F.G (all frequency)*

## 4.2 noise reduction measurements on variable-volume resonant silencers

Table 4. and Figure 6 shows the impact of using 7 sheets of variable-volume resonant, creating 17 resonant systems one with the external sheet of back air space and one with the internal in a narrow open. Due to the relatively small air space, the resonance occurs at high frequencies. In terms of the extra IL attenuation caused by variable-volume resonant, acoustic performance considerably at individual frequencies and there are peaks at certain frequencies due to the effects of resonance much greater impact is evident between 630–5k Hz. Is more obvious when the wind effect of the silencer which is retrofitted with the baffle, the difference between the baffle is put on or not when the blower is set at the middle and strong speed, the mean difference increased at least 0.13 m/s. It shows that putting on the baffle obviously improve the flow of the air and the wind velocity inside.

Under experimentation, different resonant volumes will change the resonance frequency. The bigger the volume, the lower the frequency, and on the contrary, the smaller the volume, the higher the frequency, when the lengths of the resonant volume are 195cm$^3$, 97.55cm$^3$, 143cm$^3$, 91m$^3$, 58.5cm$^3$, 32.5cm$^3$ and 19.5cm$^3$, the resonance frequency are 232.9 Hz, 329.4 Hz, 399.8 Hz, 501.2 Hz, 630.2 Hz, 807 Hz and 1082.8 Hz. According to this concept, a muffler can be designed to confine a wanted low frequency noise without largely changing the original exhaust ventilation system.

***Tab. 4*** *Noise reduction (IL) of the samples with variable-volume resonant silencers*

| Sample No. | Variable-volume resonant | Average of noise reduction |
|---|---|---|
| 1 | Without variable-volume resonant | 4.8 |
| 2 | Install TYPE.A.B.C.D.E.F.G (all frequency) | 15.4 |
| 3 | Install TYPE. A.B (low frequency) | 11.5 |
| 4 | Install TYPE.G (high frequency) | 5.8 |

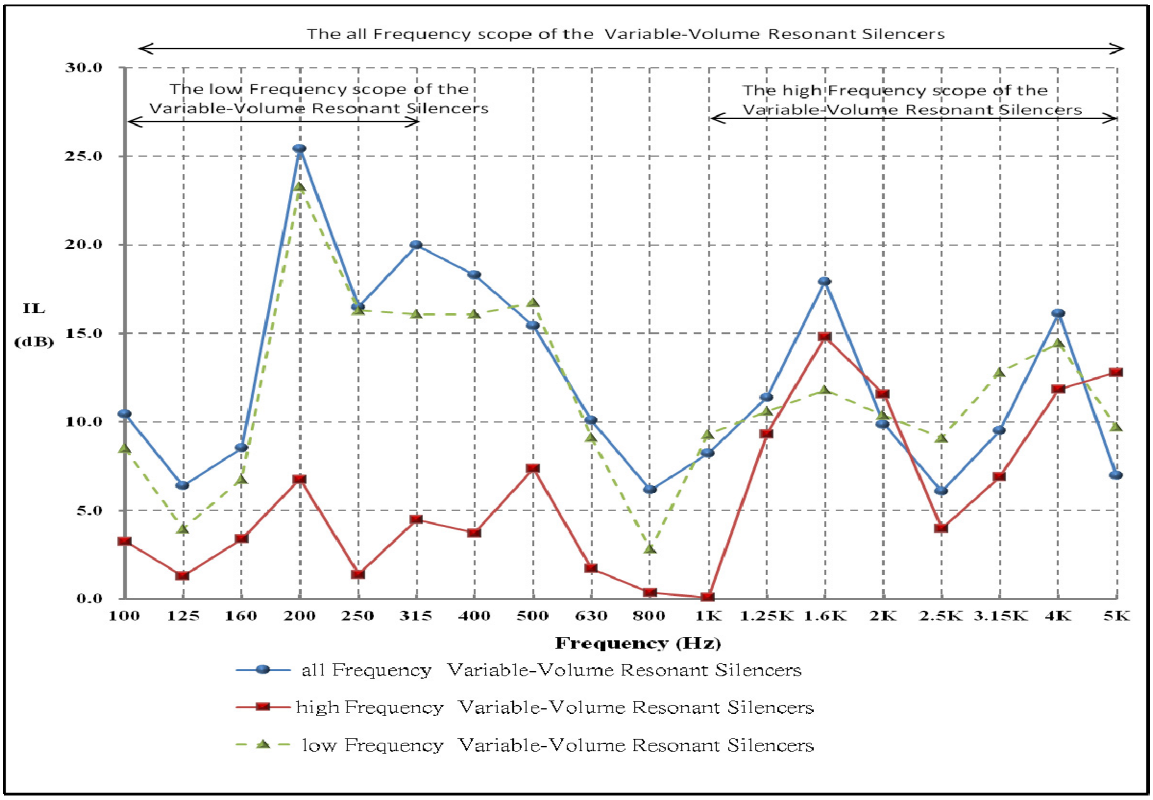



***Fig. 6*** *Insertion loss with measurement configuration different of variable-volume silencers*

# 5 Conclusions

The purpose of this study is to solve reduce noise transmission whilst allowing Airflow into the indoor. By changing the length of the resonant volume, in order to control the maximum noise reduction frequency at the end of the pipe, a variable volume resonant muffler was designed.

The results presented illustrate that it is feasible to use variable-volume resonant in silencers systems to reduce noise while still allowing for significantly more ventilation than most current systems, changing conditions of variable-volume resonant silencers with all frequency of variable-volume resonant have the values over 15 dB by Noise Reduction.

Based on a series of experimental studies, it has been shown that considerable reduction in noise, Whilst such a silencers system can perform better than closed single glazed windows, further improvements are possible by using different variable-volume resonant configurations since and passive method in the silencers system, and the integration of silencers system and window system.

## Acknowledgement

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