Investigation of Airflow and Sound Transmission through Vented-Acoustical Panels for Natural Ventilation

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1 Introduction

Commonly, airflow pathways through partitions are simple holes partially blocked by a louver or grille. However, by diverting airflow through a partition, there is an opportunity to silence noise transmission. This work studies airflow and sound transmission through vented thin panel partitions. The focus application was ventilation openings for naturally ventilated buildings. As such, low pressure and low velocity airflow were investigated in detail.

The research was conducted in labs built for directly testing acoustical transmission loss and airflow on the same specimen installation, in full-size. First, four simple partition channel shapes were tested and evaluated; they were named 'L', 'U', 'straight', and 'Z' and their cross sections are shown in Figure 1. These tests provided justification for continuing detailed research into the Z shape. By varying the dimensions of the Z channel and the arrangement of sound absorbing materials, many permutations were tested. The performance data was then organized into a test inventory spreadsheet, which can be used to design a vented partition for size, sound transmission, and ventilation requirements.

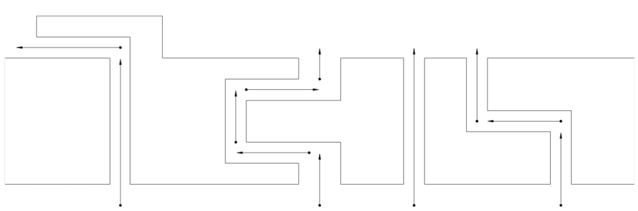

Figure 1: Section view of channel shapes L, U, Straight, and Z.

The wings of the Center for Interactive Research on Sustainability (CIRS) building are naturally and mechanically ventilated, and therefore very low pressures drive airflow. In the original design, large open areas were left above the movable wall partitions for airflow, but these openings transmit sound which causes a distracting work environment. To increase the transmission loss of the partitions while allowing for adequate ventilation, the operating conditions of these wings were studied, and six finish-quality vented partitions were designed and installed in the openings of four meeting rooms. Finally, in situ measurements were taken to find the installed performance of the vented partitions and the new operating conditions of the meeting rooms.

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2 Lab Experiments and Characterizations

The first part of this work was centered on the laboratory testing of channel configurations for sound transmission loss and airflow performance. The laboratories used have two active test rooms and a test partition between them, in which the sample is mounted. Both ventilation and acoustic test procedures were adapted from ASTM standards (ASTM E779-10 'Standard Test Method for Determining Air Leakage Rate by Fan Pressurization' [1] and ASTM E336-11 'Standard Test Method for Measurement of Airborne Sound Attenuation between Rooms in Buildings' [2]).

2.1 Ventilation Experiments

Using a calibrated measurement blower fan and differential pressure gauges, one room is pressurized. The pressure across the test partition and the flow through the fan were read from the gauges. Measurements of steady-state flow were taken at a number of fan speeds for pressures from 0.2 to 50 Pa. The leakage for each lab's pressurized source room was also measured across this range, and the leakage flow is subtracted from the flow through the fan to get the flow through the test sample.

The flow is characterized by its equivalent open area for flow, EOA_f. This compares the flow through a ventilator to the flow through a hole in flat plate. For each measurement point, this is done by comparing the sample's discharge coefficient to the discharge coefficient of an opening in a flat plate of 0.61:

$$EOA_f = \frac{Q}{0.61}\sqrt{\frac{\rho}{2\Delta P}}$$

2.2 Acoustical Experiments

To measure the acoustical transmission loss (TL), white noise was sounded in the source room and the noise reduction across the partition, as well as receiver room reverberation time, were measured in third octave bands at multiple points in the rooms. Frequency dependant transmission loss is calculated using averages as:

$$TL = Leq_s - Leq_r + 10\log\left(\frac{A_v T_{60}}{0.161 V_r}\right)$$

where Leq_s is the sound level in the source room, Leq_r is the sound level in the receiver room, A_v is the area of the sample, T_{60} is the reverberation time, and V_r is the volume of the receiver room.

Sound Transmission Class (STC) was used as a single number characterization for the TL curve, and is computed as in ASTM E 413-10, Classification for Rating Sound Insulation [3].

The equivalent open area characterization can also be adopted for speech sound transmission. The difference of a normalized speech spectrum and the TL spectrum is summed logarithmically from 100 to 10,000 Hz, then multiplied by the area of the sample to get:

$$EOA_{s\_speech} = A_v \sum_{f=100}^{10,000} 10^{(L_{speech}-TL)/10}$$

3 Evaluation of Simple Channel Shapes

Four channel shapes were evaluated, ‘L’, ‘U’, ‘straight’, and ‘Z’. The dimensions of each channel were chosen to provide the best performance comparison and to fit applicable architectural size constraints. For each configuration, the channel depth was 4” and, except for the Straight channel, all spanned 20” of the partitions width. There were no acoustical linings applied to the channels.

Table 1 gives single number ratings for the airflow and acoustical performance. For both airflow and acoustical transmission loss, the L, U, and Z shapes are in the same range of performance. The Straight channel has a much higher airflow capacity but much lower transmission loss.

Table 1: Single number performance ratings for 4 channel shapes.

Channel Shape	EOAf	STC
L	210	7.4
U	238	9.1
Z	207	8.6
Straight	415	-1.7

Due to the geometry of a flat partition, the Z shape was chosen as the primary channel to study. For the same partition thickness, the U shape must have half the channel width of the Z and L shape. So, by applying a partition thickness constraint, the airflow capacity of the U shape would be reduced to possibly half of the tested value above.

4 Iterative Testing of Z-Channels

Many permutations of the Z-channel were systematically tested in the laboratory, varying channel dimensions and the placement and material of acoustical linings, so results could be used to design and predict the performance of vented panels for the acoustical, ventilation, and architectural requirements of any application, including CIRS.

Each Z-channel configuration was described by seven parameters, and the tested values are listed for each paramter are listed in Table 2. Figure 2 shows a section view of the Z-channel and labels the parametric dimensions and absorption placement; dimension H extends into/out of the page.

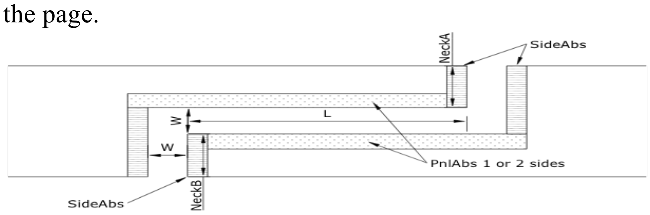

Figure 2: Parametric dimensions and absorption for the Z-channel, H extends into/out of the page.

Table 2: Lists of values tested for dimensions and absorption.

W [in]	**H [in]**	**L [in]**	**NeckA [in]**	**NeckB [in]**	**Fibreglass Absorption** *Panel*	*Sides*
1.5	22	6	0.75	0.75	None	None
2	44	11.75	1.25	1.25	Only 1 panel	1” thickness
2.5	72	18	1.75	1.75	Both panels	
3		28.75	2.25	2.25	1/2” thickness	
4			4.25	4.25	1” thickness	
6			5.25	5.25		

In total, 45 channel configurations were tested. The single number characterization results (STC, EOA_{S_Speech}, and EOA_f) from these tests were compiled into a test inventory spreadsheet that lets the user easily compare the performance of channel configurations. Some general findings were:

- long necks produce good sound absorption and airflow
- bends after a short length cause poor pressure relief and have high flow resistance
- airflow scales linearly with H but not with others
- transmission loss is independent of H
- cotton lined fiberglass (Knauff Plenum Board) outperforms high density acoustical foam

5 Ventilator Panel Design for CIRS

The final phase of this work was to design, build, install, and test vented panel partitions at CIRS. By investigating the building’s operating conditions and using this study’s laboratory results, six panels for four meeting rooms were designed to improve sound isolation and provide adequate ventilation. CIRS operates by a hybrid of mechanical displacement and natural cross-ventilation strategies, both at very low pressures. Using pressures estimated from tracer gas experiments and minimum ventilation rates dictated by ASHRAE, a requirement was set for EOA_f. Given the area of the openings at CIRS, the channel dimensions were chosen to meet this requirement, and provide STC ratings similar to the rest of the existing partition.

6 Conclusion

Through iterative lab testing, performance ranges were determined for innovative panels that provide silenced airflow. When designing a Z channel vented-acoustical panel, the test inventory spreadsheet is a useful reference tool for performance data and ranking dimensional choices.

References

[1] Standard test method for determining air leakage rate by fan pressurization, ASTM Standard E779-10, 2010.

[2] Standard test method for laboratory measurement of airborne sound transmission loss of building partitions and elements, ASTM E90-11, 2011.

[3] Classification for Rating Sound Insulation, ASTM E413-10, 2010.