

# PRESSURE DROP EVALUATION OF SILENCERS

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## 1 Introduction

Porous materials are usually applied in HVAC system ducts as passive silencers. The introduction of silencer materials such as baffles in the duct stream produces pressure drop to the fan system. The standard for pressure drop testing in silencers is ASTM E-477 [1]. The pressure drop measured in pascals becomes significant in elbow silencers where 90 degree turns are the norm. The pressure drop of elbow silencer systems were evaluated using a CFD method as well as simple ASHRAE procedures. The comparison of the two methods is presented in this paper.

## 2 ASHRAE pressure drop calculation

The pressure loss in the ducts is attributed to two types of pressure losses: the pressure loss due to the duct length and local pressure loss [1, 2]. They are calculated from the following equations.

$$\Delta PL = \sum_{i=1}^n f_i \rho \frac{L_i}{D_{hi}} \frac{V_i^2}{2} \quad (1)$$

$$\Delta PC = \sum_{j=1}^m C_j \rho \frac{V_j^2}{2} \quad (2)$$

where  $\Delta PL$  and  $\Delta PC$  are pressure drop for friction and local loss respectively,  $f_i$  is the friction factor and is a function of Reynolds number and roughness of the duct,  $\rho$  is the density of air in  $\text{kg/m}^3$ ,  $L_i$  and  $D_{hi}$  are the length and hydraulic diameter of the duct in each section respectively,  $V_i$  and  $V_j$  are the flow velocity along the different sections for length pressure loss and in each section for local pressure loss, and  $C_j$  is the coefficient of dynamic loss. The friction factors, hydraulic diameters and Reynolds numbers can be evaluated from standard relationships.

## 3 Results and discussions

### 3.1 Test elbow silencers

Two elbow silencers were used to evaluate the pressure drop. The elbow silencer, schematically shown in Figure 1 has the following details.

Silencer	L1, in	L2, in	L3, in	R1, in	R2, in
Sample 1	135.4	270.8	15	3.42	20.57
Sample 2	135.4	270.8	15	8.7	15.27

Table 1: Silencer details

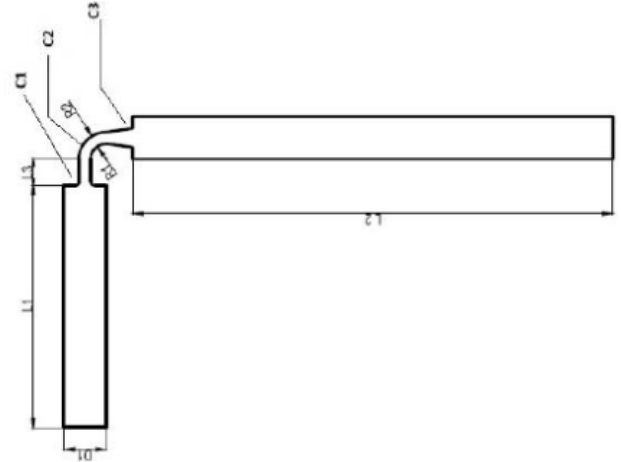


Figure 1: Details of a typical elbow silencer.

### 3.2 Pressure drop by ASHRAE

The dynamic loss coefficient can be obtained ASHRAE manuals and are shown in Table 2 for the two silencers.  $\epsilon$  is the roughness of the duct and for the current experiments is equal to  $1.5 \times 10^{-4}$  m.

Silencer	C1	C2	C3	V(fpm)
Sample 1	1.14	1.3	0.32	500
Sample 2	5.33	1.52	9.3	1500

Table 2: ASHRAE coefficients of dynamic loss of the silencers.

Calculated pressure loss based on the ASHRAE standard are presented in Table 3 below. It can be seen that the pressure losses due to the friction are very small compared to the local losses and can be neglected. Among the local pressure losses, the pressure losses in the elbows are greater than the contraction and expansion parts.

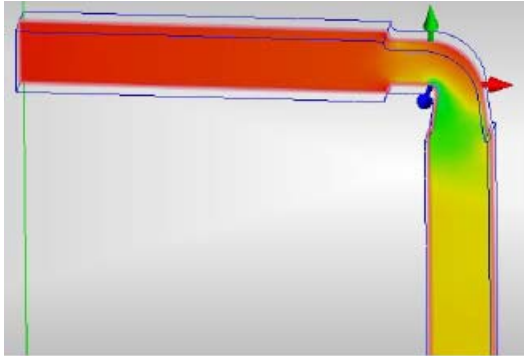
Silencer	$\Delta PC1$	$\Delta PC2$	$\Delta PC3$	$\Delta PL1$	$\Delta PL$	$\Delta PL$
Sample 1	4.4	9.9	1.24	0.18	0.36	0.02
Sample 2	186	713	325	1.4	2.8	0.15

Table 3: Pressure losses, Pa, within the two elbow silencers.

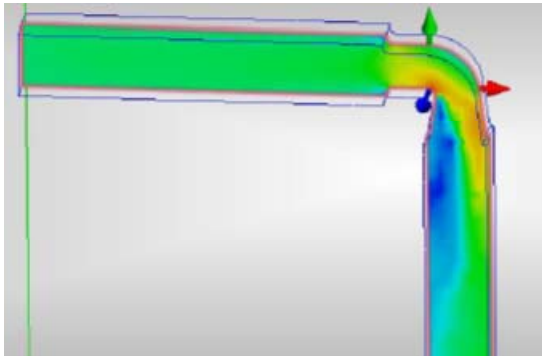
### 3.3 Pressure drop calculation by numerical methods

Conventional CFD (computational fluid dynamics) software was used to calculate the pressure distribution and velocity distribution with the elbow silencers. Based on the pressure distribution, local pressure drop values were evaluated at locations along the entire centre-line length of silencer. The

total pressure losses for sample 1 and sample 2 are 8.68 and 400 Pa respectively. By adding up the pressure losses in Table 3 it can be seen that the total pressure loss from ASHRAE standard for each case is much more than the numerical result. In order to understand this discrepancy the pressure variation along the centerline of the elbow silencer for sample 1 is depicted in Fig. 3.



a) Pressure distribution



(b) Velocity Distribution

Figure 2: Results for Sample 1

#### 4 Discussion

The results of Figure 3 show that frictional losses vary smoothly while, local losses that have sharp reduction in pressure. It can also be seen that there is a pressure recovery after the minimum pressure.

Figure 3 shows the detail of the pressure reduction. Due to the pressure recovery, the pressure losses in numerical analysis, which is the pressure difference between point A and B, are not in agreement with total pressure losses from ASHRAE, which is shown as C1, C2, and C3 in this figure.

It's worth noting that the total of local pressure losses based on ASHRAE standard is,

$$\Delta PC_{total} = \Delta PC1 + \Delta PC2 + \Delta PC3 = 4.4 + 9.9 + 1.24 = 15.54 \text{ Pa} \quad (3)$$

and the total local pressure loss based on the numerical analysis and by refer to Figure 3 is,

$$PA - PB = 10 - (-2) = 12 \text{ Pa} \quad (4)$$

which is close to the ASHRAE result.

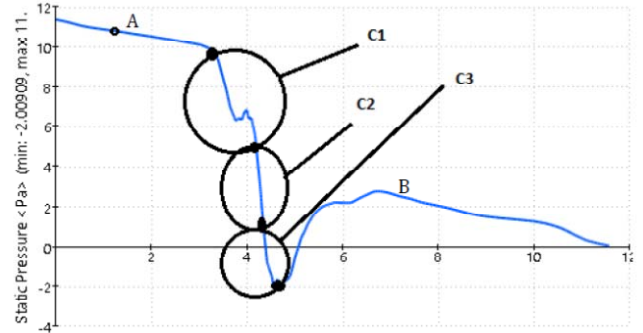


Figure 3: Pressure variation along the centre line of silencer sample 1.

#### 5 Conclusion

ASHRAE standard can be used as an accurate reference for calculating the local pressure loss in various section of the duct. By adding up the local pressure losses, the total local pressure loss can be derived. The results are in agreement with total local pressure losses based on the numerical analysis. However, since there is a pressure recovery in the real case or/and in the numerical analysis, ASHRAE standard's results for total pressure loss are not in agreement with numerical analysis and cannot be used to calculate the total pressure loss. It means that ASHRAE standard can be used for calculating the pressure loss in each component separately and this standard is not able to consider the recovery effect.

#### Acknowledgments

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#### References

- [1] ASTM E 477 – 96, Standard Test Method for Measuring Acoustical and Airflow Performance and Duct Liner Materials and Prefabricated Silencers. American Society of Testing and Materials, 1996.
- [2] F. White. Fluid Mechanics McGraw-Hill, New York, 2006.
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