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ATTENUATION OF CYLINDRICAL SILENCERS IN HVAC SYSTEMS

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CETIAT-BP 2042 - 69603 Villeurbanne Cedex -FRANCE

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in HVAC systems

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Synopsis

In this study, we have tested more than 80 silencers of different sizes (from ∅ 250 to 1250), length, insulating thickness and with or without central pod.

The attenuation, measured at several velocities between 0 - 8 m/s, was compared to some literature estimations (Sabine, ASHRAE, ...) and has shown strong differences. They induce that literature estimations should be used only in the same conditions they were made and, not too widely, as it is currently done because real knowledge of the influence of parameters is lacking.

The influence of construction parameters such as insulation material, thickness and density, has been shown and correlations between attenuation and free area were found on the full range of silencers.

List of symbols

ΔL	global attenuation (dB)	
$\Delta Llin$	global attenuation per meter (dB/m) equal to $\Delta L/$	
P	perimeter of the cylindrical silencer (m)	
A	cross area of the cylindrical silencer (m^2)	
Anom	free cross area of the silencer with central pod (m^2)	
L	length of silencer (m)	
Φ	diameter (mm)	
F	pod diameter (mm)	
c	sound velocity (m/s)	in air $c = 20\sqrt{T} = 342$ m/s (T = 293 K)
λ	wave length (m)	$\lambda = c / f$
fc	cut off frequency (Hz)	
α	Sabine absorption coefficient	

1. INTRODUCTION

In this study we have tested more than 80 silencers of different sizes :

- 42 silencers without pod (Ø 250 up to 1250 mm)
- 39 silencers with pod (Ø 315 up to 1250 mm)

according to EN ISO 7235 "Acoustics Measurement procedures for ducted silencers".

The lining was of different thickness (70 to 100 mm) depending of the silencer diameter.
The length of each silencer varied from one to twice the diameter.
The attenuation was tested for three air velocities in the silencer (0, 4 m/s, 8 m/s) but no real regenerated noise has been observed.

2. BIBLIOGRAPHIC STUDY

We did not find a lot of information about cylindrical silencers except the following ones :

2.1 Sabine formula

This formula is widely used for circular ducts :

$$\Delta L = 1{,}05 \,.\, \alpha^{1{,}4} \,.\, P / S \,.\, L = 4{,}2 \,.\, \alpha^{1{,}4} \,.\, L / \Phi$$

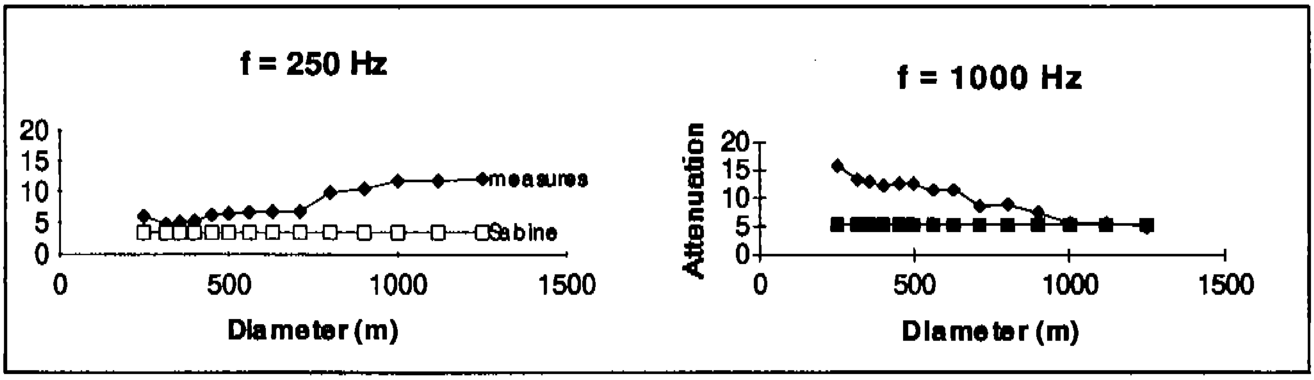


Figure 1

Figure 1 shows the comparison between measurements and Sabine estimation for 2 frequencies (250 and 1000 Hz).
In fact, some authors like Harris [1] restrict the application of Sabine formula for rectangular ducts to :

1- width of duct between one and twice the height
2- $0.2 < \alpha < 0.4$
3- $250 < f < 2000$ Hz

The absorption coefficient α of the lining of the tested silencers was over 0.65 for all frequencies from 250 Hz up to 4000 Hz. Therefore, our lining was not compatible to these limits.

2.2 ASHRAE formula

In ASHRAE ([2] and [3]), we can find a polynomial formula :

$$\Delta L = (A + B.e + C.e^2 + D.\Phi + E.\Phi^2 + F.\Phi^3). L$$

The formula was established for diameter of duct between ∅ 150 mm and ∅ 1500 mm, in fiberglass lining of density 12 kg/m^3 and thickness 25 to 75 mm.

Figure 2 shows that a strong difference can be observed mainly due to our lining density.

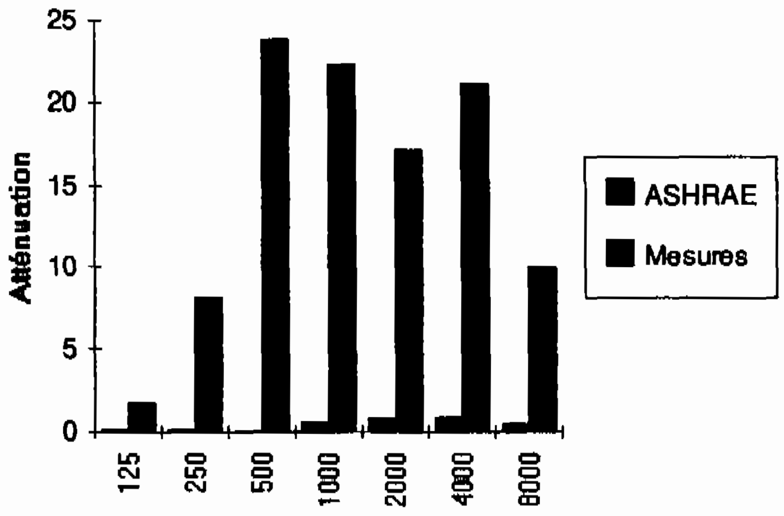


Figure 2: comparison between measurements and ASHRAE formula (D=500mm)

Actually, coefficients B and C of ASHRAE formula are equal to zero for frequencies over 1000 Hz. Therefore, the attenuation does not depend on the lining thickness for high frequencies (f ≥ 1000 Hz). This has been verified in our tests.

2.3 Silencers with pods

Hischorm [4] indicates that the maximum of attenuation may vary of 2 octave-bands between ∅ 305 and ∅ 1524 mm.

Figures 3 and 4 show the comparison of his values with our measurements.

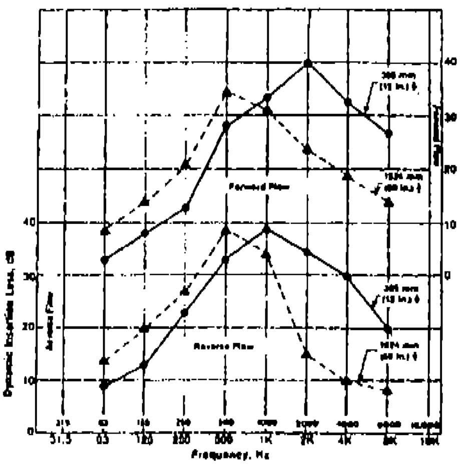


Figure 3: difference of insertion loss between
∅ 305 and ∅ 1524 mm (front velocity : 30 m/s) [4]

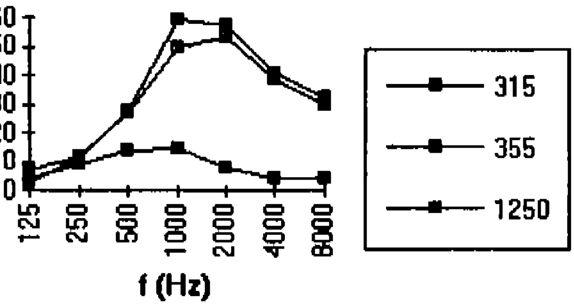


Figure 4: difference of insertion loss between
∅315, 355 and ∅ 1250 mm. Measurements CETIAT

For the measurements performed in CETIAT, this change of one octave band was only noticed between ∅ 315 and ∅ 355 mm. Then, the maximum stayed in the same octave band for all diameters.

3. TEST RESULTS

3.1 General comments

Attenuation appears mostly to be linear, except for smallest diameters (∅ 250 and ∅ 315 mm) which have stabilised around 25 dB. Therefore, in the following, we will consider :

$$\Delta Llin = \Delta L/L$$

when the lining thickness changes, we note discontinuities for low frequencies up to 500 Hz. From 1000 Hz and up, our tests confirm that the attenuation does not depend on the lining thickness.

The measurements did not show any change for frequencies over the cut-off frequency.

3.2 Regression

For each frequency, we have noted a regression :

$$\mathbf{Log\ (\Delta Llin) = k_1 - k_2\ Log\ (Anom)}$$

This regression is mainly valid in high frequencies but can be applied to the full range of frequency with a maximum error of 3 dB for silencer without pod and 5 dB with pod.

Coefficients k_1 and k_2 depend on :
- silencer geometry,
- lining thickness,
- frequency.

For silencers with pod, these coefficients change for 2 ranges of diameters :
- ∅ 355 - ∅ 900 mm
- ∅ 1000 - ∅ 1250 mm.

We couldn't explain the origin of this change since geometry and construction of these silencers did not appear to change between ∅ 900 mm and ∅ 1000 mm. This fact and the change of octave band, in which the maximum attenuation is measured, show that this regression must be used with caution for silencers with pod.

3.3 Influence of lining thickness and density

As the range of silencers we studied only contain 3 different lining thickness with 2 different density, we cannot make any regression.
Nevertheless, it appears that the attenuation is more sensible to density than to lining thickness.

4. CONCLUSION

We note that estimations of attenuation, given by the literature, currently used without any limit of application, should be taken with care and restricted to the exact conditions they were established for.
The attenuation of a cylindrical silencer is linked to the free cross-area, the density and thickness of its lining and its geometry.
The density appears to be much more sensible on attenuation than the thickness of lining. For silencers without pod, the attenuation does not depend on this thickness for high frequencies ($f \geq 1000$ Hz).

BIBLIOGRAPHY

[1] Handbook of Noise Control - Cyril M. Harris PhD
MacGraw Hill, 1957, Chap. 27.

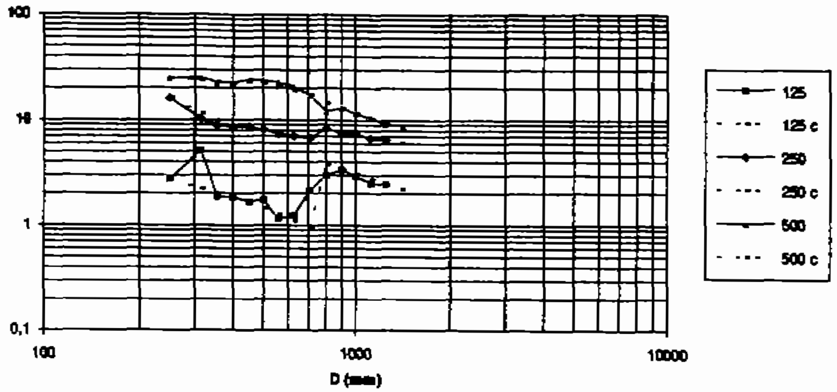
[2] HVAC Applications - 1991 ASHRAE Handbook - ch. 42, pp 42.12-14,
ASHRAE, Atlanta, 1991.

[3] Algorithms for HVAC Acoustics, Douglas D. REYNOLDS,
Jeffrey M. Bledsoe, ASHRAE, 1991.

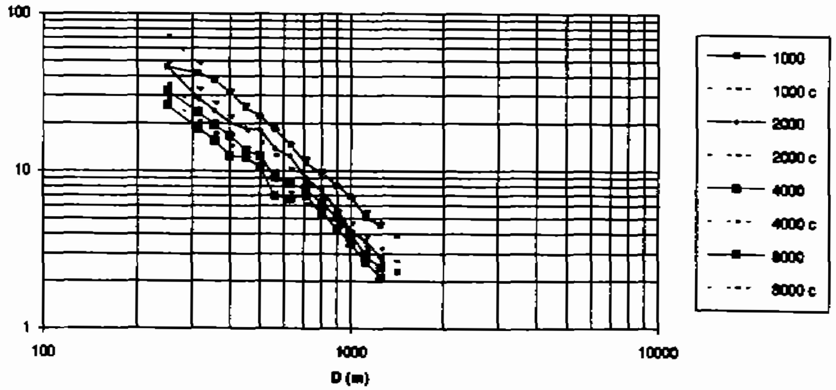
[4] Martin Hirschorn
Acoustic and aerodynamic characteristics of duct silencers for air-handling systems.
Acoustic index 87-88 (b1 - ref. 147) - 1981, pp 625-646.

APPENDIX 1: Comparison regressions-measurements for silencers without pod

(125 - 500 Hz)



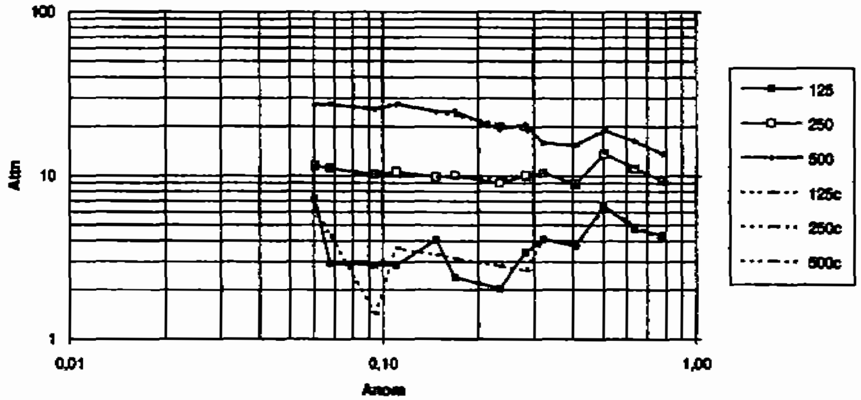
(1000 - 8000 Hz)



(*) c = calculated with regression

APPENDIX 2: comparison regressions-measurements for silencers with pod

(125 Hz - 500 Hz)



(1 000 Hz - 8 000 Hz)