SOURCE-RECEPTOR PATH PRIORITIZATION CONSIDERATIONS FOR THE SPECIFICATION OF SILENCERS IN VENTILATION SYSTEMS

Brian Chapnik and Alex Lorimer
HGC Engineering, 2000 Argentia Road, Plaza One, Suite 203, Mississauga, Ontario, Canada, L5N 1P7

1. INTRODUCTION

Large commercial and institutional buildings such as airport terminals, universities, hospitals and office towers have considerable air handling equipment and ductwork so as to circulate heated or cooled air through the occupied spaces. For each large air-handling unit, the related ductwork can be geometrically quite complex, often consisting of one or more main headers and many turns and junctions in both the main ducts as well as secondary and even tertiary ducts branching off the main supply header before arriving at the individual end diffusers. This ductwork “tree” also acts as a channel for directing noise into the same spaces. Noise breakout from the duct walls can also impact spaces along the path of this "tree".

In order to keep noise to an acceptable level, silencers are typically placed near the source of the noise, and/or in each duct path that is predicted to transmit noise levels in excess of the target. The industry standard techniques for determining these noise levels, transmission and radiation effects are specified by ASHRAE [1], which has published methods for calculating the sound along a given duct path to a receiver space. However, ASHRAE does not provide direction as to which paths to consider critical in specifying optimal silencing for a system. Prioritization is important to avoid the need for calculating noise impacts at all spaces along a "tree", which can be an extremely time consuming exercise and to avoid overly conservative simplifications which can result in a more expensive (capital and operating) noise control scheme..

Several important factors are to be considered in prioritizing which source-receiver paths to analyze in specifying silencers, without analyzing all possible paths, such that noise at all locations in the "tree" will be addressed with reasonable confidence. These factors are discussed below.

2. APPLICABLE FACTORS

Some of the most important effects on noise transmitted through a duct system to a receiver room are discussed by Kingsbury [2] and by Hoover and Blazier [3]. These include:

- Attenuation of sound in unlined and lined ducts;
- Division of sound power at duct branch points;
- Attenuation of sound at elbows;
- End reflection losses;
- Break-out from duct walls;
- Radiation of sound into a receiver room (“Room Effect”).

While these effects are to some extent true for all source-receptor paths, there is little direction provided by these authors regarding how to prioritize them. Kingsbury notes that “the most critical part of the system is the room closest to the fan serving that system unless other rooms downstream require lower sound levels”. This suggests two factors that must be considered in any prioritization:

1. Proximity to the source (fan), and;
2. Noise criteria of the receiver space.

Additional factors which may be important can be derived from the above list of effects, such as:

3. The extent and size of lined versus unlined ductwork between source and receiver;
4. The number and size (area ratio) of branches between source and receiver;
5. The complexity of the path from source to receiver, i.e. elbows or other fittings;
6. The nature of the diffusers in the receiver space (grille, rectangular, or linear), which affects end losses;
7. The geometry of the ductwork (rectangular, round or oval), especially for break-out considerations, and what type of ceiling is below the ducts (exposed, T-bar, drywall).

3. IMPORTANCE OF FACTORS

Clearly, there is no straightforward way to prioritize a given factor globally – the importance of some factors depends on their predominance in a given ductwork system design. However, there are certain trends that can be gleaned from comparing the attenuation of one set of factors to another in typical cases, yielding insight into which paths should be focused on in analysis of these systems in order to specify an appropriate silencer at the fan.

3.1 Rectangular Duct Branches

Typical break-out from a main rectangular duct branch is considerably more likely to result in greater low-frequency noise impact in a receiver space than sound transmission through the supply diffusers. This is because the attenuation of additional duct lengths, branches and elbows downstream of the main rectangular branch, and the end loss at the distributed diffusers, results in small radiation of sound in comparison with that breaking out of the duct.

Consider a typical case of a 600 mm x 300 mm rectangular duct feeding smaller 300 mm x 150 mm ducts to four rooms, with one 300 mm and one 150 mm elbow in each smaller branch duct. The smaller branches are each fed to two 150 mm round drops to rectangular diffusers in the receiver rooms. Standard attenuation calculations might show the following (some minor effects neglected):

Table 1: Attenuation from Break-Out [dB] (Rect)

Frequency [Hz]	63	125	250	500
Break-out, 600x300x5m, 24ga	3	6	9	12
Ceiling/Plenum loss (T-bar)	3	6	8	10
Room effect (typical)	5	6	7	8
Total	11	18	24	30

Table 2: Attenuation to Diffusers [dB] (Rect)

Frequency [Hz]	63	125	250	500
Duct loss, 300x150x5m	5	3	2	1
Branch loss (25%)	6	6	6	6
Elbow loss (2)	0	0	1	3
End loss (150 mm w/diffuser)	9	7	4	2
Room effect (typical)	5	6	7	8
Total	25	22	20	20

It is clear that for a fan with significant low-frequency energy, which is often the case for centrifugal fans, a silencer designed to limit the break-out from the main duct will be sufficient to address noise transmission from the diffusers, without needing to explicitly consider the latter. Even if the ceiling were drywall instead of T-bar, if the fan energy in the 63 Hz band is dominant, the attenuation due to break-out mechanisms is still likely to be less than those between the main branch and the diffusers. Attenuation factors to the diffusers are lower in the higher frequency bands, but since silencers generally provide more attenuation than needed in these bands, this is usually not of significant concern unless the source itself has high-frequency energy concentration (e.g. high-speed blower or mixed-flow fan) and there is no acoustically lined ductwork in the system.

3.2 Circular Duct Branches

Circular ducts are often used to limit low-frequency break-out, in which case sound transmitted out the diffusers is much more likely to be significant in comparison with break-out, assuming some ceiling below (in the case of exposed ductwork, break-out may still be significant at higher frequencies). Consider the same example as above, but with approximately area-equivalent circular ductwork instead of rectangular.

Table 3: Attenuation from Break-Out [dB] (Circ)

Frequency [Hz]	250	500	1k	2k
Break-out, 450mmx5m, 24ga	25	17	15	13
Ceiling/Plenum loss (T-bar)	8	10	16	21
Room effect (typical)	7	8	9	10
Total	40	35	40	44

Table 4: Attenuation to Diffusers [dB] (Circ)

Frequency [Hz]	250	500	1k	2k
Duct loss, 250mmx5m	1	1	1	1
Branch loss (25%)	6	6	6	6
Elbow loss (2)	2	4	6	6
End loss (150 mm w/diffuser)	4	2	1	0
Room effect (typical)	7	8	9	10
Total	20	21	23	23

Thus, for a typical system with circular distribution ductwork and a finished ceiling, the silencer may be designed on the basis of noise transmitted through the diffusers of the nearest room, assuming this is the shortest path with similar complexity as other paths in the system. Break-out analysis need not be conducted.

4. CONCLUSIONS

It has been illustrated for two simple cases how reasonable “rules of thumb” can be developed to simplify the task of specifying a silencer for a ventilation system, without needing to consider all paths in the duct “tree”. Some additional guidelines of this nature have been developed which cannot be fully described here. Further work is needed to develop a more comprehensive set of prioritized factors which can be used by the acoustical designer of HVAC systems to reduce the time required to specify silencers for a system, while maintaining a reasonable degree of confidence in the result.

REFERENCES

[1] HVAC Systems Applications Handbook, American Society for Heating, Refrigeration and Air-Conditioning Engineers (ASHRAE), Atlanta, GA, 2007.
[2] Kingsbury, Howard (1997). Noise Sources and Propagation in Ducted Air-Distribution Systems. Chapter 85, Encyclopedia of Acoustics, John Wiley & Sons Inc., 1997.
[3] Hoover, Robert M. and Blazier, Warren E. Jr. (1994) Noise Control in Heating, Ventilating, and Air-Conditioning Systems, Chapter 7, Noise Control in Buildings (ed. Cyril M. Harris), McGraw-Hill Inc., 1994.