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Computer-Aided HVAC
Acoustical Analysis—Part 2

Acoustical Engineering Report

McGill AirSilence LLC
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Value Engineering

Introduction

Various noise control solutions can be applied to the same noise problem to achieve a quiet HVAC system. The best noise control solution is the one that provides the proper amount of attenuation and offers the lowest initial and operating costs to the customer. To choose the right solution, a designer should perform an acoustical analysis on the entire single-wall duct system.

Often when a noise problem is anticipated in a duct system, the first 40 to 50 feet or the entire system is insulated without performing an acoustical analysis. This approach seldom works. Even if it did, there is no guarantee that the solution would result in the lowest initial cost to the customer. In fact, insulating an entire system can provide too much attenuation, resulting in a hissing or rumbling noise. Worse yet, it might not provide enough noise control, causing additional cost to the owner after the system has been installed.

Duct System Analysis

The duct system shown in **Figure 1** was analyzed to determine and compare three separate noise control solutions. Each section's center-line length, duct diameter, and volume flow rate is labeled. This information is used to determine the natural attenuation and airflow-generated noise created by the single-wall system's duct and fitting components. After the initial single-wall analysis is complete, the desired outlet noise criteria (NC) levels are compared to the actual NC levels. Data used in the sample calculations are found in the references noted at the end of this report.

In any acoustical system design, it is important to incorporate actual fan manufacturer's fan sound power level data for the inlet/discharge configuration shown on the drawings. In this example, the fan has the ducted sound power level (Lw) values listed in **Figure 2**.

The amount of noise control needed is determined by the amount of fan noise and duct system airflow-generated noise that reaches the system outlets.

Table 1 summarizes each step of the single-wall duct analysis for outlet A in **Figure 1**. The section numbers are referenced (for example: 1001, 1002), and the effects of natural attenuation and airflow-generated noise are listed as they occur. The outlet Lw values are calculated and compared to the sound pressure levels (Lp) associated with the desired outlet NC. This comparison yields an attenuation requirement needed to meet the desired outlet NC level.

Notice that Lw values and NC Lp values are subtracted directly to determine the attenuation requirement. Because Lp and Lw values cannot be directly combined, Lp values must be converted to Lw values using **Equation 1**.

Equation 1:

$$Lp = Lw \underline{- 5LOG_{10}V - 3LOG_{10}Fc - 10LOG_{10}R + 25\ dB}$$

Equation 1 is ASHRAE's published room acoustics equation (Normal Rooms). Ducted noise does not involve room acoustics. The underlined portion of **Equation 1** is strictly room effect introduced by the room geometry and receiver location. When performing an in-duct acoustical analysis, room effect is not considered. Therefore, the underlined portion of **Equation 1** can be set equal to zero. The resultant equation is **Equation 2**.

Equation 2:

$$Lp = Lw$$

Figure 1 Example Duct System

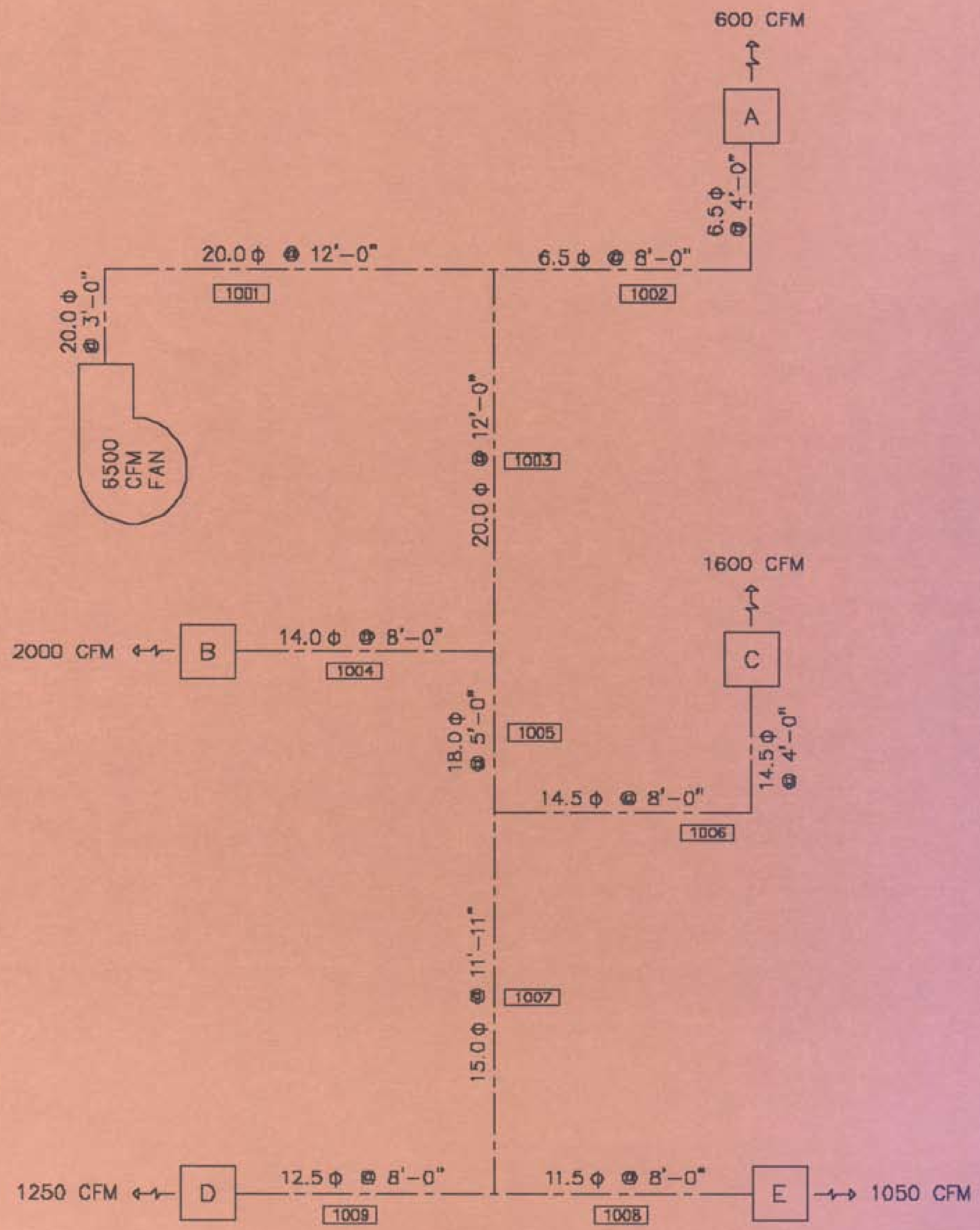


Figure 2 Fan Sound Power Levels for Example Duct System

	63	125	250	500	1,000	2,000	4,000	8,000
Fan Lw values	89	89	90	83	78	72	68	63

Table 1 Single-Wall Acoustical Analysis, Outlet A

Comment	Octave Band/Center Frequency (Hz)								
	1	2	3	4	5	6	7	8	
Outlet A	63	125	250	500	1,000	2,000	4,000	8,000	
Section 1001									
1. Fan Lw values	89	89	90	83	78	72	68	63	
<u>Natural Attenuation</u>									
2. Duct, 20" ∅	2	2	1	1	1	1	1	1	
3. Elbow, 20" ∅	0	0	0	1	2	3	3	3	
Remaining	87	87	89	81	75	68	64	59	
4. Duct GNL at 2,979 fpm	63	59	53	49	51	50	40	40	
5. Elbow GNL at 2,979 fpm	65	67	67	64	60	52	40	25	
Resultant 1	87	87	89	81	75	68	64	59	
Section 1002									
<u>Natural Attenuation</u>									
6. Power Split	10	10	10	10	10	10	10	10	
Remaining	77	77	79	71	65	58	54	49	
7. Fitting GNL	59	55	50	50	49	44	38	32	
Remaining	77	77	79	71	65	58	54	49	
<u>Natural Attenuation</u>									
8. Duct, 6.5" ∅	2	2	1	1	1	1	1	1	
9. Elbow, 6.5" ∅	0	0	0	0	1	2	3	3	
Remaining	75	75	78	70	63	55	50	45	
10. Duct GNL at 2,604 fpm	41	37	36	36	34	33	34	33	
11. Elbow GNL at 2,604 fpm	26	27	27	26	25	22	19	14	
Outlet Lw values	75	75	78	70	63	55	50	45	
Lp (NC=45) (dB)	67	60	54	49	46	44	43	42	
Attenuation Requirement (dB)	8	15	24	21	17	11	7	3	

GNL = Generated Noise Level

Table 2 Outlet Attenuation Requirements (AR)

Comment	Octave Band/Center Frequency (Hz)								
	1	2	3	4	5	6	7	8	
Outlet	63	125	250	500	1,000	2,000	4,000	8,000	
A	8	15	24	21	17	11	7	3	
B	8	15	22	20	16	11	8	4	
C	6	14	24	19	11	9	6	2	
D	6	14	24	22	18	13	9	5	
E	6	14	24	22	18	13	9	5	
Worst Attenuation Requirement	8	15	24	22	18	13	9	5	

An in-duct acoustical analysis yields the Lw values at the point of consideration, such as an outlet or variable air volume (VAV) box. After the in-duct acoustical analysis is complete, room acoustics are considered.

The attenuation requirements in **Table 2** show that a definite noise problem exists at each outlet. The next step could be to determine the amount of attenuation that is generated by downstream duct and room acoustics. However, the outlet NC levels for the system in **Figure 1** are specified at the VAV boxes at each outlet. Therefore, downstream duct and room effect attenuations are not evaluated. Downstream duct and room effect are important sources of noise attenuation but for simplification purposes are not considered in this example problem.

As stated earlier, the proper noise control treatment is that which introduces the lowest initial cost. Consider these two important points:

1. A large amount of noise control treatment may create additional system pressure losses, especially if bullet/baffle silencers are used. This increase in pressure loss will increase the operating cost of the system. If a fan has already been selected, the amount of available fan pressure must also be considered.
2. Select noise control that causes a reduction in noise at the outlets and results in a noise spectrum that matches the shape of the NC curve.

Noise Control Options

After analyzing the entire system in **Figure 1**, three noise control options were considered. **Figures 3**, **4**, and **5** show double-line drawings of the duct system with each noise control option.

1. **Option 1** incorporates a silencer (no bullet or baffle) and double-wall elbow combination in the first section. This style of noise treatment yields a large amount of low- to mid-frequency noise control without causing a large pressure drop.
2. **Option 2** incorporates only double-wall duct (ACOUSTI-k27®) with 1- and 3-inch-thick insulation. This option uses the minimum amount of double-wall duct without using a silencer.
3. **Option 3** uses double-wall duct throughout the entire system.

Figure 3 Duct System Design Option 1

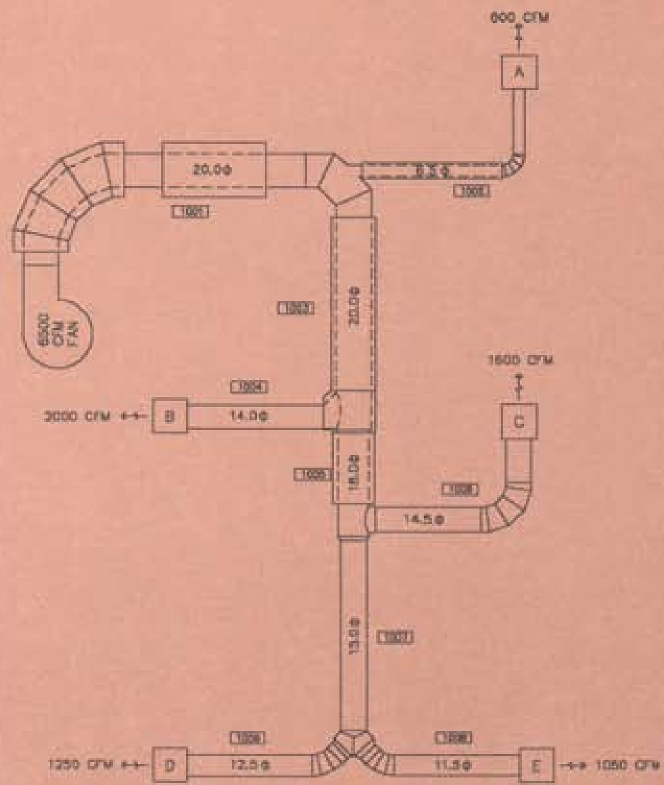


Figure 4 Duct System Design Option 2

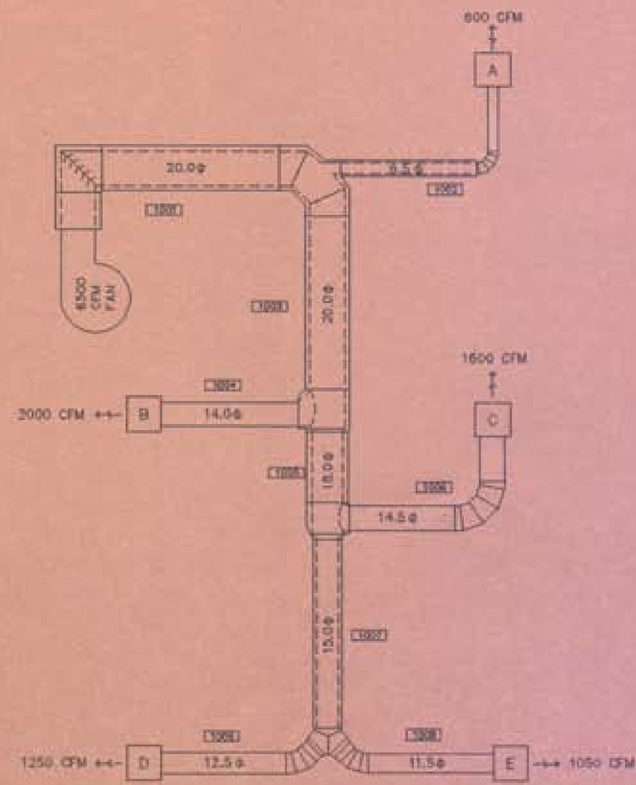
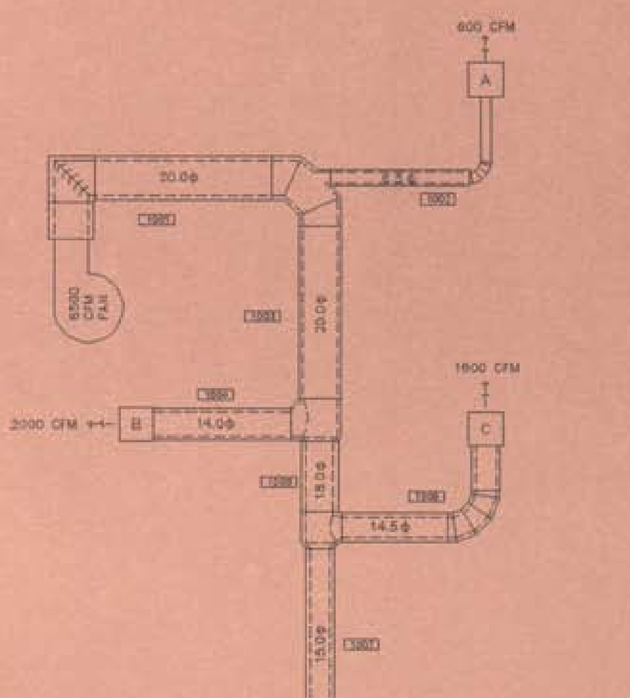


Figure 5 Duct System Design Option 3



Tables 3 and **4** show the analysis procedure for outlet A. Comparing **Tables 1**, **3**, and **4** shows that the noise levels generated by the duct and fittings had little effect in the single-wall analysis. But once noise treatment was added to the system, this generated noise became a significant part of the analysis.

These noise treatment solutions were obtained by incorporating the insertion loss data for each component [silencer (dB) or double-wall duct (dB/ft)] into the analysis of each path from fan to outlet for the entire system. Each option yields identical outlet NC levels. **Table 5** shows the type of duct (single-wall, double-wall) or silencer used for each section and the initial cost of each system.

Because **Option 2** offers the lowest initial cost, it is the best solution. Since baffle/bullet type silencers were not used, there were no significant pressure drops in the system. Therefore, no operating cost comparison was performed.

Table 3 Acoustical Analysis, Outlet A, Option 1

Comment	Octave Band/Center Frequency (Hz)								
	1	2	3	4	5	6	7	8	
Outlet A, Option 1	63	125	250	500	1,000	2,000	4,000	8,000	
Section 1001									
1. Fan Lw values	89	89	90	83	78	72	68	63	
Natural Attenuation									
2. Duct, 20" ∅	2	2	1	1	1	1	1	1	
3. Elbow, 20" ∅	0	0	0	1	2	3	3	3	
Additional Attenuation									
4. Silencer, 20" ∅	7	13	26	35	40	33	31	26	
Remaining	80	74	63	46	35	35	33	33	
5. Duct GNL at 2,979 fpm	63	59	53	49	51	50	40	40	
6. Elbow GNL at 2,979 fpm	65	67	67	64	60	52	40	25	
Resultant 1	80	75	69	64	61	54	43	41	
Section 1002									
Natural Attenuation									
7. Power Split	10	10	10	10	10	10	10	10	
Remaining	70	65	59	54	51	44	33	31	
8. Fitting GNL	59	55	50	50	49	44	38	32	
Remaining	70	65	60	56	53	47	39	35	
Natural Attenuation									
9. Duct, 6.5" ∅	2	2	1	1	1	1	1	1	
10. Elbow, 6.5" ∅	0	0	0	0	1	2	3	3	
Additional Attenuation									
11. 1" Double-Wall Duct, 6.5" ∅, L=6 ft	1	3	5	10	14	12	9	8	
Remaining	67	60	54	45	37	32	26	23	
12. Duct GNL at 2,604 fpm	41	37	36	36	34	33	34	33	
13. Elbow GNL at 2,604 fpm	26	27	27	26	25	22	19	14	
Outlet Lw values	67	60	54	46	39	36	35	33	
Lp (NC=45) (dB)	67	60	54	49	46	44	43	42	
Attenuation Requirement (dB)	0	0	0	0	0	0	0	0	

Table 4 Acoustical Analysis, Outlet A, Options 2 and 3

Comment	Octave Band/Center Frequency (Hz)							
	1	2	3	4	5	6	7	8
Outlet A, Options 2 and 3	63	125	250	500	1,000	2,000	4,000	8,000
Section 1001								
1. Fan Lw values	89	89	90	83	78	72	68	63
Natural Attenuation								
2. Duct, 20" ∅	2	2	1	1	1	1	1	1
3. Elbow, 20" ∅	0	0	0	1	2	3	3	3
Additional Attenuation								
4. 3" Double-Wall Duct, 20" ∅, L=15 ft	6	10	19	31	21	17	15	15
5. 3" Double-Wall Elbow, 20" ∅	0	5	11	21	19	15	17	20
Remaining	81	72	59	29	35	36	32	24
6. Duct GNL at 2,979 fpm	63	59	53	49	51	50	40	40
7. Elbow GNL at 2,979 fpm	65	67	67	64	60	52	40	25
Resultant 1	81	73	68	64	61	54	43	40
Section 1002								
Natural Attenuation								
8.Power Split	10	10	10	10	10	10	10	10
Remaining	71	63	58	54	51	44	33	30
9. Fitting GNL	59	55	50	50	49	44	38	32
Remaining	71	64	59	56	53	47	39	34
Natural Attenuation								
10. Duct, 6.5" ∅	2	2	1	1	1	1	1	1
11. Elbow, 6.5" ∅	0	0	0	0	1	2	3	3
Additional Attenuation								
12. 1" Double-Wall Duct, 6.5" ∅, L=6 ft	1	3	5	10	14	12	9	8
Remaining	68	59	53	45	37	32	26	22
13. Duct GNL at 2,604 fpm	41	37	36	36	32	31	34	33
14. Elbow GNL at 2,604 fpm	26	27	27	26	25	22	19	14
Outlet Lw values	68	59	53	46	39	35	35	33
Lp (NC=45) (dB)	67	60	54	49	46	44	43	42
Attenuation Requirement (dB)	1	0	0	0	0	0	0	0

Table 5 Comparison of Noise Control Options			
Section	Option 1	Option 2	Option 3
1001	Silencer[1]	3-inch DW	3-inch DW
1002	1-inch DW	1-inch DW	1-inch DW
1003	3-inch DW	3-inch DW	2-inch DW
1004	SW	SW	2-inch DW
1005	3-inch DW	3-inch DW	2-inch DW
1006	SW	SW	1-inch DW
1007	SW	1-inch DW	1-inch DW
1008	SW	SW	1-inch DW
1009	SW	SW	1-inch DW
Initial Cost	$2,975	$2,430	$3,010

SW = Single-wall
DW = Double-wall, ACOUSTI-k27®, United McGill Corporation
[1] = Model DKE, SOUNPAK® round duct silencer, United McGill Corporation

Conclusion

An acoustical analysis is necessary in the design of a successful HVAC system. Knowledge of basic HVAC acoustics will help you design quiet systems at the lowest cost to the customer. It is always easier to solve a noise problem before a system is installed. Considering the effects of each system component will help you confidently predict the system's acoustical performance.

Performing a single-wall acoustical analysis will help you select the minimum noise control required for the system. Sometimes the proper amount of noise control can be determined easily. Other times, when the HVAC system is large and noise problems exist at outlets throughout, calculations become time consuming. An acoustical analysis is simplified by using a microcomputer program like United McGill's UNI-DUCT® computer-aided duct system design program. This program designs both supply and exhaust duct systems and performs a complete acoustical analysis. With the UNI-DUCT® program, a multitude of designs and initial costs can be analyzed and estimated within minutes.

References:

1. Acoustical Engineering Report Number 7, *Computer-Aided HVAC Acoustical Analysis—Part 1*, United McGill Corporation, 1993.
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3. Engineering Report Number 136, *Generated Self Noise of Lined Duct*, United McGill Corporation, 1979.
4. *Algorithms for HVAC Acoustics*, ASHRAE, 1991.
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6. *Noise Control for Buildings and Manufacturing Plants*, Bolt, Beranek, and Newman, Inc., 1989.

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