SPACE SOUND LEVELS IN THE APPLICATION OF AIR TERMINALS AND AIR OUTLETS @ PROJECT MADRASETNA studios

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Section 1. Purpose

1.1 Purpose.

The purpose of this Study is to provide a consistent industry-accepted method for estimating Sound Pressure Levels in a conditioned occupied space for the application of Air Terminals and air outlets.

1.1.1 Intent.

This standard is intended for the guidance of the industry, including manufacturers, engineers, installers, contractors, and users.

1.1.2 Review and Amendment.

This standard is subject to review and amendment as technology advances.

Section 2. Scope

2.1 Scope.

This standard includes sound levels from most but not all components in the air distribution system. Air Terminals, air outlets, and the low-pressure ductwork which connects them are considered as sound sources and are the subject of this Standard.

This Standard does not make provisions to estimate space sound level contributions from the central system fan, ductwork upstream of the Air Terminal, equipment room machinery, or exterior ambient sound.

This Standard is not currently applicable for underfloor radiated or discharge sound calculations. this study does not provide for the determination of sound power in The methods described in this Standard can be used to identify acoustically critical paths in the system design. The design effects of inserting alternative components and changes in the system can be evaluated. The accuracy of evaluating the difference in sound pressure between two alternatives is greater than individual estimations.

Section 3. Definitions

All terms in this document follow the standard industry definitions in the current edition of ASHRAE Terminology of Heating, Ventilation, Air Conditioning and Refrigeration unless otherwise defined in this section.

3.1 Air Terminal (Terminal).

A device that modulates the volume of air delivered to a conditioned space in response to a given load. The various types of Air Terminals are defined as follows:

3.1.1 Bypass Terminal.

Air Terminal that diverts excess primary air to the return.

3.1.2 Integral Diffuser Terminal.

Diffuser with the features of an Air Terminal.

3.1.3 Dual Duct Terminal.

Air Terminal with two supply inlets that is used primarily for mixing cold and warm air streams at varying proportions.

3.1.4 Induction Terminal.

Air Terminal that supplies varying proportions of primary and induced air. 3.1.5 Parallel Flow Fan-Powered Terminal. Air Terminal in which primary airflow is modulated in response to the cooling demand and in which the integral fan is operated to deliver induced air.

3.1.6 Reheat Terminal.

Air Terminal that heats a single source of supply air.

3.1.7 Series Flow Fan-Powered Terminal.

Air Terminal in which the primary air flow is modulated and mixed with induced air by a continuously operated integral fan to provide a relatively constant volume discharge. 3.1.8 Single Duct Terminal. Air Terminal supplied with one source of primary air.

3.2 Ceiling/Space Effect.

Attenuation of Sound Power transmitted to an occupied space from above the ceiling as a result of the ceiling itself and the size of the space above the ceiling.

3.3 Duct Breakout.

The sound is associated with fan or airflow noise that radiates through the duct walls into the surrounding area.

3.4 Environmental Adjustment Factor.

Difference between Sound Power Levels measured using a free field calibrated reference sound source and a reverberant field calibrated reference sound source. Sound Power measured in accordance with ASHRAE Standard 130 is based upon a free field calibrated reference sound source and the Environmental Adjustment Factors are used to correct these values to those using a reverberant field calibrated reference sound source because building spaces more closely represent a reverberant sound field.

3.5 Equivalent Diameter.

Diameter of a circular equivalent of any duct for equal cross-sectional areas. 3.6 Insertion Loss. Reduction in observed Sound Pressure Level caused by installation of an Air Terminal, ductwork, or silencer.

3.7 Noise.

Any unwanted sound.

3.7.1 Background Noise.

Total noise that interferes with the measurement of the particular sound of interest which may include airborne sound, structure borne vibrations, and electrical noise in instruments.

3.8 Noise Criteria (NC).

Standard curves used to describe a spectrum of measured Sound Pressure Levels with a single number.

3.9 Octave Band.

Frequency band with an upper band limit that is twice the frequency of the lower band limit. The mid frequency (center frequency) of an octave band is the geometric mean of its upper and lower band limits. The octave band mid frequencies of interest are listed in Table 1

3.10 Published Ratings.

A statement of the assigned values of those performance characteristics, under stated rating conditions, by which a unit may be chosen to fit an application. These values apply to all units of like nominal size and type produced by the same manufacturer. As used herein, the term Published Rating includes the rating of all performance characteristics shown on the unit or published in specifications, advertising or other literature controlled by the manufacturer, at stated rating conditions.

Table 1. Octave Band Mid Frequencies

Octave Band	Mid Frequency, Hz
1	63
2	125
3	250
4	500
5	1000
6	2000
7	4000
8	8000

3.10.1 Standard Rating.

A rating based on tests performed at standard rating conditions.

3.10.2 Application Rating.

A rating based on tests performed at application rating conditions (other than standard rating conditions).

3.11 Reverberation Room.

A test room with highly reflective surfaces that is designed to create a nearly homogeneous field of sound for the measurement of Sound Power Levels of a sound source.

3.12 Room Criteria (RC).

Standard curves used to describe a well balanced spectrum of measured Sound Pressure Levels with a single number.

3.17 Sound Power Level (Lw).

In a specified frequency band, ten times the common logarithm of the ratio of the Sound Power radiated by the sound source under test to the standard reference sound power of 10-12 Watt, dB.

3.18 Sound Pressure.

In a specified frequency band, a fluctuating pressure superimposed on the static pressure by the presence of sound.

3.19 Sound Pressure Level (Lp).

In a specified frequency band, 20 times the common logarithm (base 10) of the ratio of the Sound Pressure radiated by the noise source under test to the standard reference pressure of 20 µ pascals, dB.

3.20 Source-Path-Receiver Process.

The sound estimating method used in this Standard. In this process, a given Source of sound travels over a given Path to an occupied space where a Receiver hears the sound produced by the Source as in Table 3. Air Terminals and outlets are examples of sound Sources. The sound travels over one or more Paths where attenuation takes place. A person in the occupied space hears the noise at the Receiver's location.

3.21 Space Effect.

Attenuation of Sound Power entering a space as a result of the absorption properties of the space and the distance from the sound source to the receiver

Section 5. Description of Sound Estimating Method

5.1 Introduction.
The sound estimating method used in this standard is based on a simple process called Source-Path-Receiver. A given Source of sound travels over a given Path to an occupied space where a Receiver hears the sound produced by the Source.

5.2 Outline of the Sound Pressure Estimating Procedure.
This standard estimate space Sound Pressure Levels when the acoustic performance of Air Terminals and/or outlets is known. A second use of the standard is to estimate the maximum permissible Sound Power Level from a terminal device so that a selected acoustical design criterion (NC or RC) will not be exceeded.

5.3 Four steps are required to estimate Sound Pressure Levels by Octave Band:

5.4 Obtain Air Terminal or outlet Sound Power Levels at the specific unit operating point(s).
Source: Manufacturer's Data.

5.5 Identify the sound paths to be evaluated. Source:
Acoustic Model.

5.6 Determine the attenuation path factors for each path. Source:

5.7 Logarithmically add the acoustic contribution from each sound path to determine the overall Sound Pressure Level.

5.8 Acoustical Models.
The models identify receiver sound paths and graphically illustrate the process of sound level prediction.

5.9 Upstream Sound Sources.
This standard does not take into consideration sound breaking out of the inlet ducts to Air Terminal devices as shown (by the dashed-line arrow) in the upstream duct breakout radiated path in. Sound emitted from this element can come from these sources:

1. The airborne sound from the system central fan;
2. Airborne regenerated sound from upstream takeoffs and fittings;
3. Sound traveling upstream from the terminal.

Section 6. Calculation Procedures for Estimating Sound Levels in Occupied Spaces

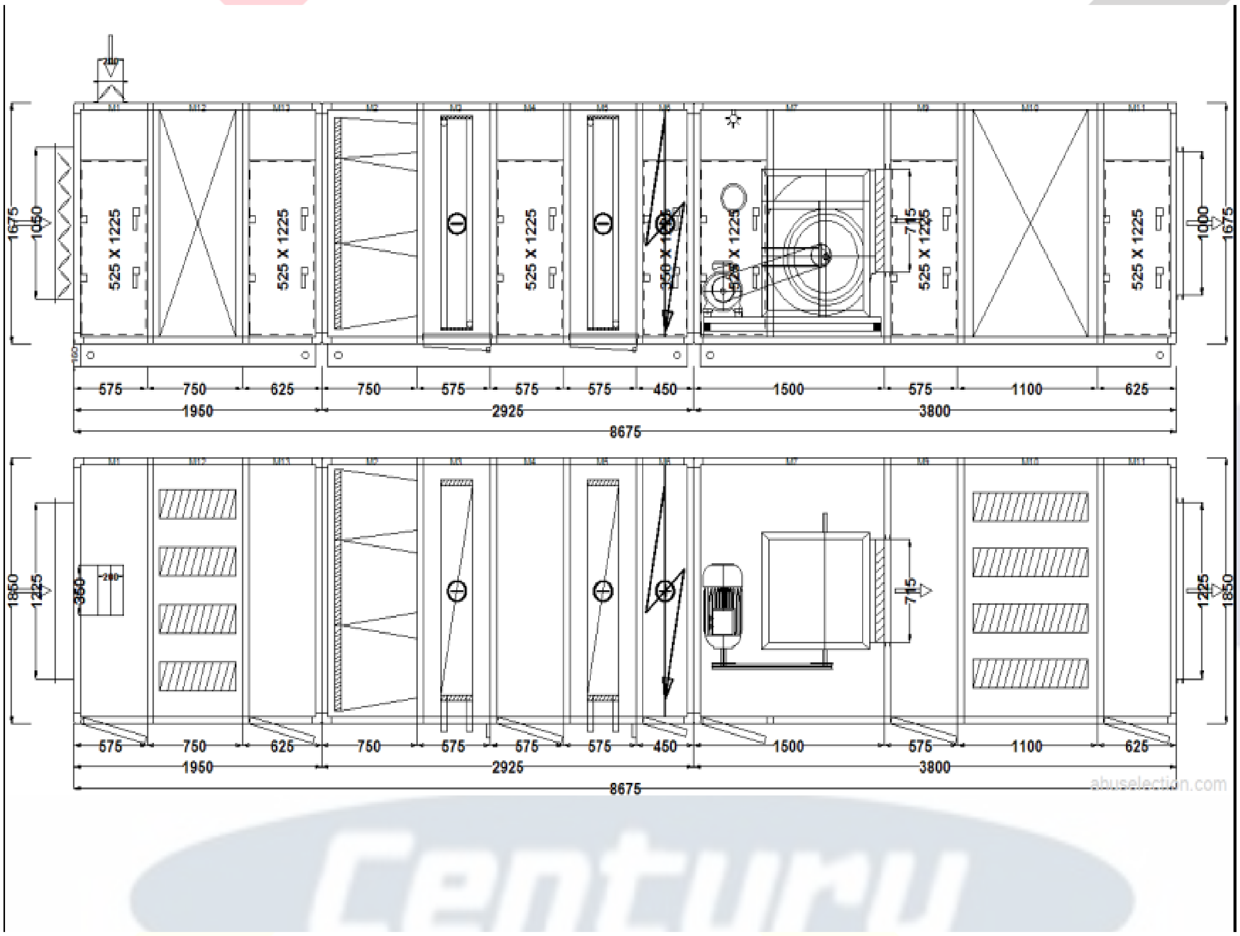
6.1 Introduction.

The source paths which must be evaluated to enable the net sound level in a conditioned space to be estimated. Each path is broken into the individual source and attenuation segments. Source sound levels are obtained from the terminal or outlet manufacturer's data and path factor attenuation is determined according to the procedures which follow.

The designer must select paths from the acoustic models which match the particular applications of the job. The Air terminal are also applied with extended discharge plenums and lateral take-offs. Each application will require a specific acoustic model.

If the designer knows which paths are most significant, the calculation procedure can be simplified. Otherwise, it is recommended that all paths of the specific acoustic model be evaluated until the designer is comfortable with a simplified model.

Typical Manufacturer's Catalog, dB



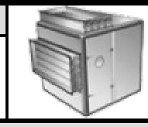
SOUND PRESSURE LEVEL (dB) [Distance = 1.5 m]										
Frequency Hz	**63**	**125**	**250**	**500**	**1000**	**2000**	**4000**	**8000**	**LwA-tot**	
Unit casting radiated and induction Inlet	**36.2**	**39.8**	**36**	**27.6**	**17.3**	**24.9**	**27.8**	**24.1**	**34.3**	**dBA**
Environmental Adjustment Factor	**-4**	**-2**	**-1**	**0**	**0**	**0**	**0**	**0**	**0**	**dBA**
Induction Inlet & Terminal Radiated Sound, Lw ©	**32.2**	**37.8**	**35**	**27.6**	**17.3**	**24.9**	**27.8**	**24.1**	**34.3**	**dBA**
Unit Discharge	**18.9**	**29.7**	**19.9**	**10**	**0**	**4.2**	**5.3**	**0**	**17.2**	**dBA**
Environmental Adjustment Factor	**-4**	**-2**	**-1**	**0**	**0**	**0**	**0**	**0**	**0**	**dBA**
Terminal Discharge Sound, Lw (D)	**14.9**	**27.7**	**18.9**	**10**	**0**	**4.2**	**5.3**	**0**	**17.2**	**dBA**
Outlet Generated	**63.9**	**64.7**	**55.9**	**44**	**33.2**	**37.2**	**41.3**	**38.8**	**52.7**	**dBA**
Environmental Adjustment Factor	**-4**	**-2**	**-1**	**0**	**0**	**0**	**0**	**0**	**0**	**dBA**
Air Inlet Induct Sound Pressure Level(o)	**59.9**	**62.7**	**54.9**	**44**	**33.2**	**37.2**	**41.3**	**38.8**	**52.7**	**dBA**

GENERAL SPECIFICATIONS				
Air Flow 7.69 m^3/s			**Frame** ANODIZED OMEGA 50	**Dimensions mm** W 2,555 x H 2,365 x L 9,725
			Insulation Material 50 mm Polyurethane Inj. 45 kg/m^3	**Total Weight** 2,950 kg
Coil Air Velocity 2.12 m/s	**Air Density** 1.2101 kg/m^3	**Mixing Ratio** % 96.50	**Outside Sheet Material** 0.8 mm Galvanized Steel Sh.M. Z	**Base Height** 160 mm
			Inside Sheet Material 0.8 mm Galvanized Steel Sh.M. Z	**Motor Power** 18.5 kW
Total Heating Capacity 9 kW	**Total Cooling Capacity** 236.8 kW		**Total Sensible Capacity** 196 kW	

SOUND PRESSURE LEVEL (dB) [Distance = 1.5 m]										
Frequency Hz	**63**	**125**	**250**	**500**	**1000**	**2000**	**4000**	**8000**	**LwA-tot**	
Airborne Sound Pressure Level	20.7	27.1	21.1	10.5	0.0	2.5	0.0	0.0	16.6	**dBA**
Air Outlet Induct Sound Pressure Level	65.7	62.1	57.1	44.5	32.7	35.5	35.3	34.0	51.6	**dBA**
Air Inlet Induct Sound Pressure Level	39.6	37.7	38.2	27.0	17.4	24.4	22.4	20.0	33.2	**dBA**

SERVICE DOORS (M1)						
ID	Type	Size	Position	Hinge Position	Alignment	Opposing Door
1	Standard (Handle + Hinge)	525 mm x 1,225 mm	Right	Left	Left	☐

ACCESSORIES (M1)



SILENCER (M12)				
Air Flow	Acoustical Insulation (250 Hz)	Pressure Drop	Silencer Thickness	Section Weight
7.69 m³/s	9 dB	1 Pa	200 mm	169.3 kg
Silencer Code			Silencer Material	Hygienic
200d 200s 5n 600L 1955H 2290A			Rockwool (70 kg/m³) 50 mm	☐

Acoustical Insulation (dB)							
63 Hz	125 Hz	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz	8000 Hz
5.0	6.0	9.0	13.0	18.0	14.0	10.0	9.0

Adjustment of Manufacturer's Data, Db

Casing Radiated and Induction Inlet Sound Power

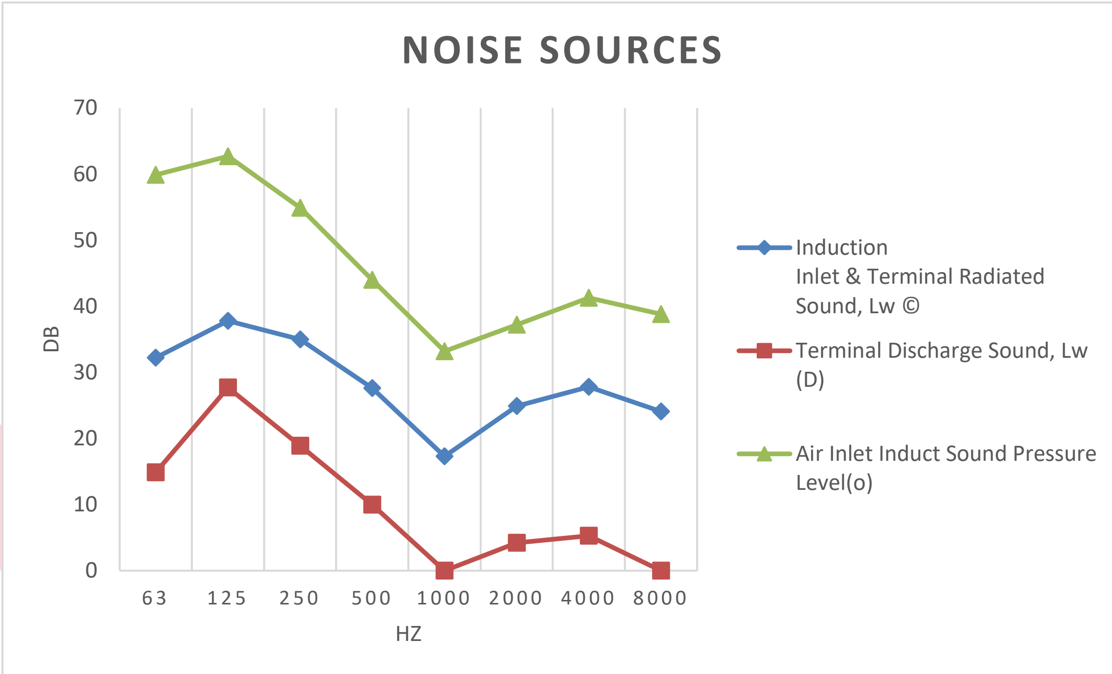
Sound Sources from Typical Manufacturer's Catalog, dB

The Environmental Adjustment Factors then subtracted from the Sound Power Level obtained with the free field calibration. Table 6 provides the calculation.

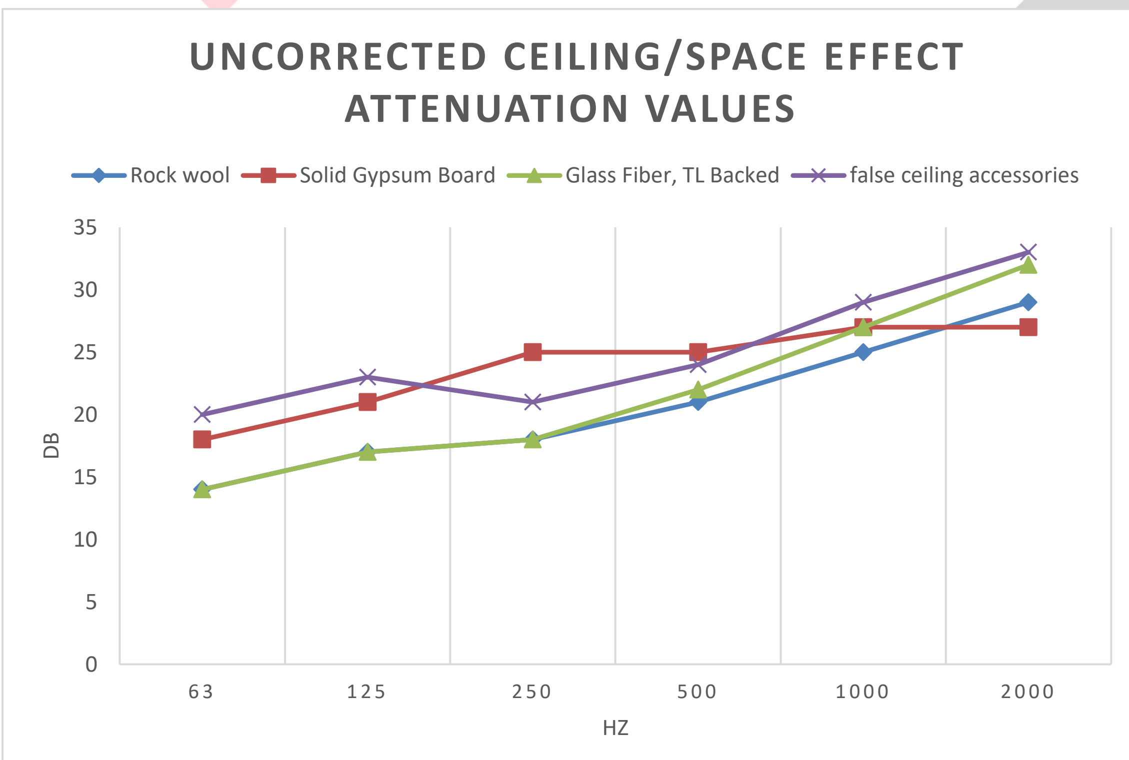
So, **Adjustment of Manufacturer's Data, dB**

Description of Sound Source	Octave Band Mid Frequency, Hz					
	125	250	500	1000	2000	4000
Induction Inlet & Terminal Radiated Sound, L_{ow}	73.4	73.8	75.9	66.8	62.1	61
Terminal Discharge Sound, L_w	54.4	54.8	48.9	35.8	28.1	27
Outlet Generated Sound, L_w	60.6	62.6	70.1	61.6	58.5	60.5

"Radiated & and Induction Inlet Path", Uncorrected Ceiling/Space Effect Attenuation Values, dB											
Type #	Tile Type	Density	Thickness	Weight	Octave Band Mid Frequency, Hz						
		[kg/m^3]	[mm]	[kg/m^2]	63	125	250	500	1000	2000	4000
1	Rock wool	[70]	[50.0]	[3.5]	14	17	18	21	25	29	35
2	Solid Gypsum Board	[690]	[12]	[9.0]	18	21	25	25	27	27	28
3	Glass Fiber, TL Backed	[60]	[50.0]	[3]	14	17	18	22	27	32	39
4	false ceiling accessories	[300]	[16]	[5]	20	23	21	24	29	33	34



NOISE SOURCES
70
60
50
40
30
20
10
0
DB
63
125
250
500
1000
2000
4000
8000
HZ
Induction
Inlet & Terminal Radiated Sound, Lw ©
Terminal Discharge Sound, Lw (D)
Air Inlet Induct Sound Pressure Level(o)



UNCORRECTED CEILING/SPACE EFFECT ATTENUATION VALUES
Rock wool
Solid Gypsum Board
Glass Fiber, TL Backed
false ceiling accessories
35
30
25
20
15
10
5
0
DB
63
125
250
500
1000
2000
HZ

Sound Insertion Loss/Attenuation in Straight Lined Sheet Metal Ducts of Rectangular Cross- Section in dB/ft												
Internal Cross-Sectional Dimensions						Octave Band Center Frequency, Hz						
L mm	W mm	L/ft	W/ft	Perimeter	area	125	250	500	1000	2000	4000	8000
1000	900	3.2808399	2.95275591	12.46719162	9.6875194	0.16376045	0.322472954	1.09964827	2.26048825	1.52558818	1.36085156	1.47294423
650	600	2.132545935	1.96850394	8.20209975	4.1979251	0.2214694	0.455276716	1.34760808	2.80044312	2.18648999	1.76957934	1.57865708
350	400	1.148293965	1.31233596	4.92125985	1.5069475	0.32107481	0.695898629	1.73064255	3.64477572	3.40446752	2.44451259	1.71917615
350	400	1.148293965	1.31233596	4.92125985	1.5069475	0.32107481	0.695898629	1.73064255	3.64477572	3.40446752	2.44451259	1.71917615
650	400	2.132545935	1.31233596	6.88976379	2.7986167	0.26174695	0.551037951	1.50814835	3.15294828	2.66849813	2.0464593	1.6403983
350	400	1.148293965	1.31233596	4.92125985	1.5069475	0.32107481	0.695898629	1.73064255	3.64477572	3.40446752	2.44451259	1.71917615
650	400	2.132545935	1.31233596	6.88976379	2.7986167	0.26174695	0.551037951	1.50814835	3.15294828	2.66849813	2.0464593	1.6403983
650	700	2.132545935	2.29658793	8.85826773	4.8975793	0.20944817	0.427154921	1.29789001	2.69171726	2.04574095	1.68571461	1.55855803
350	600	1.148293965	1.96850394	6.23359581	2.2604212	0.28413002	0.605192721	1.59385017	3.34196406	2.94275068	2.19788766	1.67159544
350	400	1.148293965	1.31233596	4.92125985	1.5069475	0.32107481	0.695898629	1.73064255	3.64477572	3.40446752	2.44451259	1.71917615
650	400	2.132545935	1.31233596	6.88976379	2.7986167	0.26174695	0.551037951	1.50814835	3.15294828	2.66849813	2.0464593	1.6403983
650	400	2.132545935	1.31233596	6.88976379	2.7986167	0.26174695	0.551037951	1.50814835	3.15294828	2.66849813	2.0464593	1.6403983
350	400	1.148293965	1.31233596	4.92125985	1.5069475	0.32107481	0.695898629	1.73064255	3.64477572	3.40446752	2.44451259	1.71917615

Insertion Loss of Unlined and lined Elbows Without Turning Vanes, dB {T}							
Octave Band Mid Frequency, Hz							
63	125	250	500	1000	2000	4000	8000
1	6	11	10	10	10	10	10

Branch Power Division (F):

Octave Band Mid Frequency, Hz							
63	125	250	500	1000	2000	4000	8000
2	2	2	2	2	2	2	2

. Space Effect, Point Source

Octave Band Mid Frequency, Hz							
63	125	250	500	1000	2000	4000	8000
-10.45207733	-11.34478572	-12.2478757	-13.1509657	-14.0540557	-14.9571457	-15.8602357	-10.45207733

End Reflection Loss/Per ASHRAE RP 1314, dB.

End Reflection Loss, dB {R}								
Duct Size		**Octave Band Mid Frequency, Hz**						
Width [in]	**Height [in]**	**63**	**125**	**250**	**500**	**1000**	**2000**	**4000**
39.3701	**35.43309**	**34.94946258**	**36.93325901**	**38.94012564**	**40.9469923**	**42.9538589**	**44.96072556**	**46.9675922**
25.590565	**23.62206**	**38.27817821**	**40.26197464**	**42.26884128**	**44.2757079**	**46.2825746**	**48.28944119**	**50.2963078**
13.779535	**15.74804**	**36.8032919**	**38.78708832**	**40.79395496**	**42.8008216**	**44.8076882**	**46.81455487**	**48.8214215**
13.779535	**15.74804**	**36.8032919**	**38.78708832**	**40.79395496**	**42.8008216**	**44.8076882**	**46.81455487**	**48.8214215**
25.590565	**15.74804**	**37.85088349**	**39.83467992**	**41.84154655**	**43.8484132**	**45.8552798**	**47.86214647**	**49.8690131**
13.779535	**15.74804**	**36.8032919**	**38.78708832**	**40.79395496**	**42.8008216**	**44.8076882**	**46.81455487**	**48.8214215**
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25.590565	**27.55907**	**38.5006733**	**40.48446973**	**42.49133636**	**44.498203**	**46.5050696**	**48.51193628**	**50.5188029**
13.779535	**23.62206**	**37.57822145**	**39.56201788**	**41.56888451**	**43.5757512**	**45.5826178**	**47.58948443**	**49.5963511**
13.779535	**15.74804**	**36.8032919**	**38.78708832**	**40.79395496**	**42.8008216**	**44.8076882**	**46.81455487**	**48.8214215**
25.590565	**15.74804**	**37.85088349**	**39.83467992**	**41.84154655**	**43.8484132**	**45.8552798**	**47.86214647**	**49.8690131**
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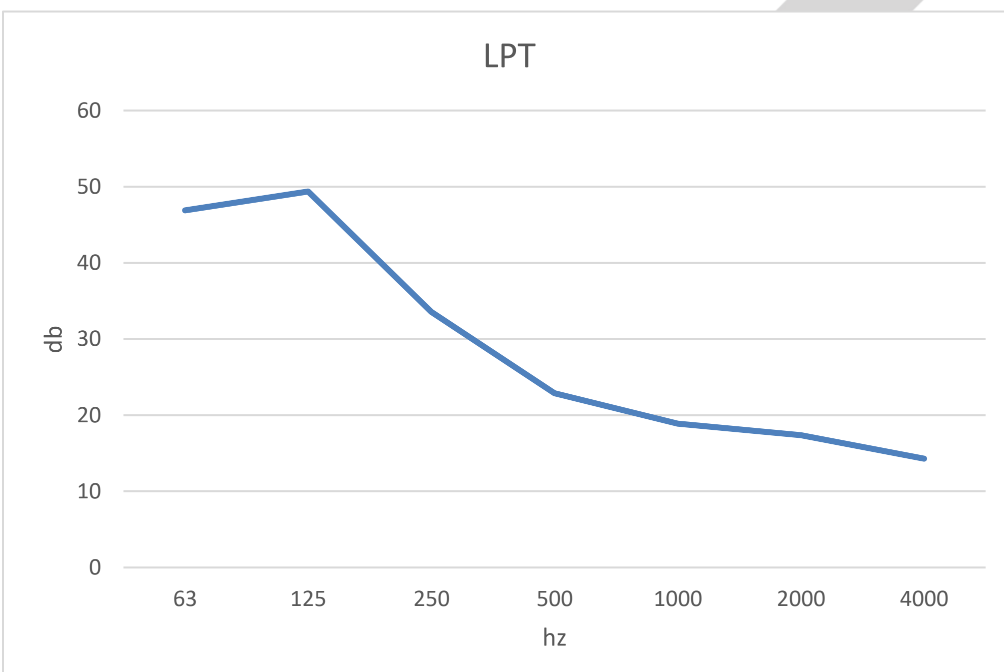
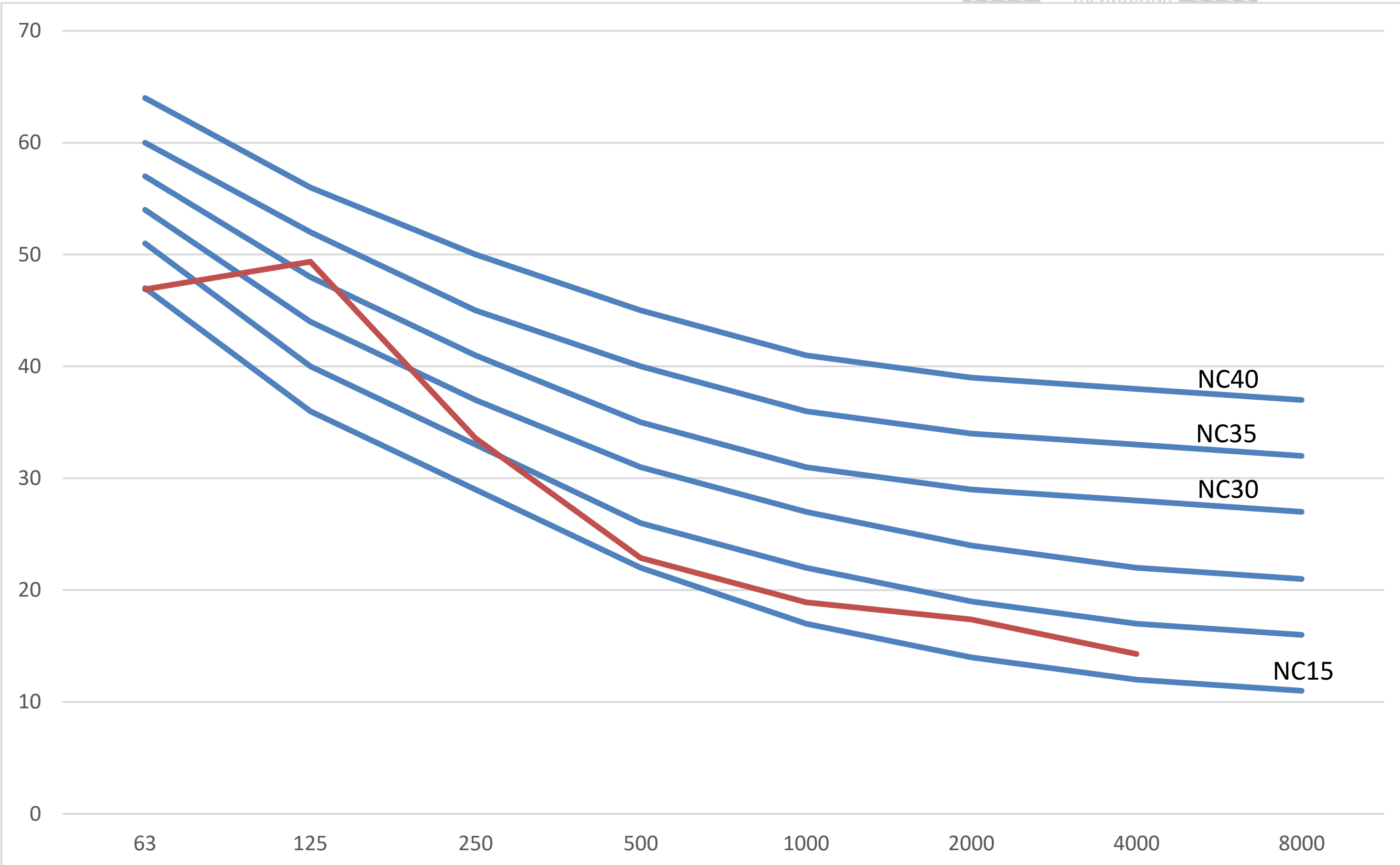
Sound Summary Calculation

Sound Path		Octave Band Mid Frequency, Hz						
Path#	Name	63	125	250	500	1000	2000	4000
1	**Radiated and Induction Inlet**	15.7	18.3	14.5	4.6	-9.7	-5.35	27.8
2	**Duct Breakout Path**	-40.65362351	-33.8536235	-46.65362351	-61.05362	-77.05362	-84.10362	-58.75362
3	**Distribution Duct Breakout**	-44.03885336	-42.6313732	-62.10087987	-78.11455	-92.7657	-99.23405	-73.80522
4	**Flexible Duct Breakout Path**	-44.35992817	-43.3272718	-63.83152241	-81.75933	-96.17017	-101.6786	-75.5244
5	**Discharge Path**	-71.23478727	-71.2932189	-92.9012462	-111.9328	-127.4474	-134.0596	-109.0092
6	**Outlet #1 Generated**	70.35207733	74.04478572	67.1478757	57.150966	47.254056	52.157146	57.160236
LPT	Sound Summary Calculation	46.9013948	49.36319819	33.57394965	22.860396	18.901626	17.385718	14.291316





70
60
50
40
30
20
10
0
63
125
250
500
1000
2000
4000
8000
NC40
NC35
NC30
NC15

Conclusion

The spectrum showing the previous graph has a rating of NC 30(R). It has a rumbly character, because the low-frequency limit curve is exceeded in the 63: 250 Hz Octave Bands.

Therefore, the design provided for sound compression relief in the Octave bands should be optimized. The most appropriate improvement is to modify the design of the muffler for more attenuation in the lower frequency ranges.

Appendix

Table 13. Tabular Representation of NC Curves, dB

NC	Octave Band							
	63	125	250	500	1000	2000	4000	8000
15	47	36	29	22	17	14	12	11
20	51	40	33	26	22	19	17	16
25	54	44	37	31	27	24	22	21
30	57	48	41	35	31	29	28	27
35	60	52	45	40	36	34	33	32
40	64	56	50	45	41	39	38	37
45	67	60	54	49	46	44	43	42
50	71	64	58	54	51	49	48	47
55	74	67	62	58	56	54	53	52
60	77	71	67	63	61	59	58	57
65	80	75	71	68	66	64	63	62

Table 13. Tabular Representation of NC Curves, dB

NC	Octave Band							
	63	125	250	500	1000	2000	4000	8000
15	47	36	29	22	17	14	12	11
20	51	40	33	26	22	19	17	16
25	54	44	37	31	27	24	22	21
30	57	48	41	35	31	29	28	27
35	60	52	45	40	36	34	33	32
40	64	56	50	45	41	39	38	37
45	67	60	54	49	46	44	43	42
50	71	64	58	54	51	49	48	47
55	74	67	62	58	56	54	53	52
60	77	71	67	63	61	59	58	57
65	80	75	71	68	66	64	63	62

Table 15. Design Guidelines for HVAC System Noise in Unoccupied Spaces	
Space	**RC (N)**
Residences, Apartments, Condominiums	25 to 35
Hotels/motels	
Individual rooms or suites	25 to 35
Meeting/banquet rooms	25 to 35
Corridors, lobbies	35 to 45
Service/support areas	35 to 45
Office Buildings	
Executive and private offices	25 to 35
Conference rooms	25 to 35
Teleconference rooms	$\leq$ 25
Open plan offices	$\leq$ 40
With sound masking	$\leq$ 35
Corridors and lobbies	40 to 45
Hospitals and clinics	
Private rooms	25 to 35
Wards	30 to 40
Operating rooms	25 to 35
Corridors and public areas	30 to 40
Performing Arts Spaces	
Drama theaters	25
Concert and recital halls	25
Music teaching studios	25
Music practice rooms	30 to 35
Laboratories (with fume hoods)	
Testing/research, minimal speech communication	45 to 55
Research, extensive telephone use, speech communication	40 to 50
Group teaching	35 to 45
Churches, mosques, synagogues	
With critical music programs	25 to 35
Schools[1]	
Classrooms	25 to 30
Large Lecture rooms	25 to 30
Without speech amplification	$\leq$ 25
Libraries	30 to 40
Courtrooms	
Unamplified speech	25 to 35
Amplified speech	30 to 40
Indoor stadiums and gymnasiums	
School and college gymnasiums and natatoriums	40 to 50
Large seating capacity spaces (with amplified speech)	45 to 55

[1] Some educators and others believe that HVAC-related sound criteria for schools, as listed in previous editions of this table,are too high and impede learning for affected groups of all ages. See ANSI Standard S12.60-2002 (Reaffirmed 2007) for classroom acoustics and a justification for lower sound criteria in schools. The HVAC component of total noise meets thebackground noise requirement of that standard if HVAC-related background sound $\leq$ RC 25(N).