ILC – A Single Number Rating System for Duct Silencers

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Single number rating systems have been used successfully to evaluate and select architectural acoustics products for many years. However, to date no such system exists for sound attenuators. The proposed Insertion Loss Class (ILC) system would provide a single number rating for comparison and selection of sound attenuators much in the same way as STC, NIC, IIC and other existing rating systems do for conventional architectural acoustics products and structures.

Single number noise reduction performance ratings such as STC, NIC, CTC, IIC, and NRC have been used successfully for architectural products for many years. Because acoustic performance varies with frequency it is difficult to evaluate and select products based on insertion loss versus frequency performance. Single number ratings help to characterize the effectiveness of various constructions and simplify comparisons when selecting products for general building design purposes.

Sound Transmission Class (STC) is a rating derived from sound transmission loss tests[1] of partitions, doors, movable walls, etc. The procedure for determining the STC value of a partition has been adopted by the American Society for Testing and Materials (ASTM)[2] and a similar procedure by the International Standards Organization (ISO).[3] Both procedures are based on the transmission loss of partitions in 1/3 octave bands. They use reference contours and produce identical results.

Noise Isolation Class (NIC)[4] is a single number rating that provides an estimate of the isolation between two enclosed spaces. The procedure used for calculating NIC is the same as that used for calculating STC except that noise reduction between the two spaces in 1/3 octave bands is used instead of transmission loss.

Ceiling Transmission Class (CTC)[5] provides a performance rating for sound transmission through the plenum space above suspended ceilings between two rooms. Impact Insulation Class (IIC)[6] is used for impact noise isolation of floor/ceiling systems. Noise Reduction Coefficient (NRC)[7] provides a rating for the effective absorption of materials.

Single number rating systems are also used in designing HVAC systems. However, they are used for defining design goals rather than for product evaluation. These include A-weighted dB(A)[8] sound pressure levels, Noise Criteria (NC)[9] curves and Room Criteria (RC)[10] curves. Of the three ratings, the A-weighted rating is the least reliable since many different spectrum shapes can result in having the same A-weighted level. NC criteria ratings consist of a family of curves that specify the maximum octave band sound pressure levels allowed in specific areas or rooms due to the noise produced by the HVAC system serving the space. RC criteria ratings are somewhat similar and are considered the preferred alternative to NC ratings because they not only take into account the spectrum shape but, unlike NC criteria, also include data in the very low 31.5 and 16 Hz octave bands.

In view of the success of single number rating systems and their simplicity for evaluating performance effectiveness as well as for comparing products, it is suggested that a similar system called Insertion Loss Class (ILC) be applied to noise reduction performance of sound attenuators used in HVAC systems.

Sound Attenuator Test Data

The acoustic performance of sound attenuators is measured by taking 1/3 octave band sound pressure level measurements in a test arrangement according to test procedures specified in ASTM E477.[11] In general, the arrangement consists of a duct system containing a sound source at one end that discharges into a qualified reverberation room at the other. With the sound source on, 1/3 octave band sound pressure level measurements are made inside the reverberation room with and without the sound attenuator placed in the duct system. The difference between the empty duct measurements and those with the sound attenuator inserted into the duct is the insertion loss (IL) of the sound attenuator. Means should also be provided to introduce airflow at various velocities into the duct system to pass through the sound attenuator while measurements are being made. Forward Flow is when air flows through the system in the same direction as the sound. Reverse Flow is when air flows in the direction opposite the sound. A complete test consists of data taken at various air flow velocities in both directions. The difference in levels, with and without the sound attenuator in place, is the Dynamic Insertion Loss (DIL) of the sound attenuator for each flow condition. Pressure Loss data across the sound attenuators and self-noise, noise generated by the sound attenuator as a result of air flowing through it, are two other measurements made during the ASTM E477 test.

It is obvious from the above that a complete ASTM E477 test produces a significant amount of data for each sound attenuator. Since these data are published in octave bands, performance comparisons between various sound attenuators can become somewhat difficult. Therefore, a single number acoustic performance classification for each sound attenuator at a specific velocity would be advantageous to simplify comparing and selecting sound attenuators for use in typical HVAC applications. It would also help in the design of new sound attenuators by providing a spectrum goal that would most benefit dynamic insertion loss in HVAC systems.

Reference ILC Contour Design

As one might expect, the most prominent noise generator in almost all HVAC systems is the fan. The noise produced by fans occurs mostly in the 63, 125, 250 and to some extent the 500 Hz octave bands. Although there are some variations, fan noise is essentially flat within ±3 or 4 dB across these octave bands. Therefore, at these low frequencies it can be assumed that noise reduction along the lines of one of the objective design curves would be appropriate. Since RC criteria are the preferred spectra with a slope of –5 dB/octave, they would seem to be a good choice and the reference ILC contour is designed with a 5 dB/octave slope across the 63, 125, 250 and 500 Hz octave bands. Although the contour requires less attenuation by the sound attenuator at low frequencies, additional attenuation is provided by typical duct system effects such as end reflection at duct openings. Above 500 Hz however, noise generated in HVAC systems is at a much lower level than the low frequency fan noise and therefore less noise reduction is required. The suggested reference contour then flattens out to 1000 Hz and then reduces by 2 dB at 2000 Hz and another 4 dB at 4000 Hz. Although many passive (absorptive) sound attenuators perform extremely well in the mid-octave bands, the requirement for such high noise reduction is usually unnecessary. This high performance is a result of the natural absorptive qualities of the materials used in sound attenuator manufacturing. Achieving adequate absorption at low frequencies is accompanied by much higher absorption in the mid frequency range. Mid and high frequency attenuation is also aided by other devices such

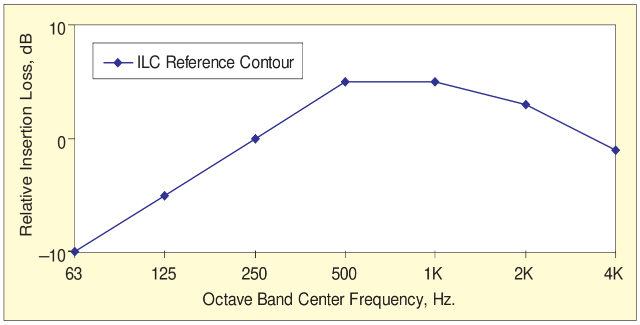

Figure 1. Reference contour for Insertion Loss Class (ILC).

as elbows, duct-linings, etc., which provide sound reduction at these higher frequencies. The resulting suggested reference ILC contour is shown in Figure 1.

Calculating ILC from Silencer Test Data

Calculating the ILC of a sound attenuator can be done either graphically or numerically. To calculate the ILC graphically, the insertion loss of the silencer is plotted on a graph with the same coordinates as the reference contour in Figure 1. A transparent overlay of the reference contour is placed over the data graph and adjusted up or down until no data point of the insertion loss curve falls below the contour. As shown in Figure 2 the ILC is the dB value at the intersection of the 250 Hz octave band with the reference contour.

Table 1 illustrates how the ILC is calculated numerically by adding 10, 5, 0, –5, –5, –3, and 1 to the insertion loss values of the sound attenuator at each octave band from 63 Hz to 4000 Hz, respectively. The lowest value at any octave band after this calculation is the ILC of the sound attenuator.

Using ILC to Select a Sound Attenuator

Chapter 47, "Sound and Vibration Control" of the 2003 *ASHRAE Applications Handbook* explains in detail the use of the preferred RC curves, including the most recent RC Mark II method. In addition, the ASHRAE chapter recommends RC design guideline values for background sound levels in various types of rooms. Simply put, by identifying the attenuation value of the duct system components and the receiver room sound absorption, the sum of those values can be compared to the sound power level of the noise source (typically the HVAC fan) to determine if additional noise control measures are required. If not, the RC design criteria will be achieved. If so, sound attenuators are frequently used to achieve the design criteria. The ILC rating method could be a useful tool to simplify this procedure. For conventional HVAC systems the RC design calculation could be made to determine the 250 Hz octave band insertion loss requirement and use this as the necessary minimum ILC sound attenuator rating. The ILC contour will provide that the attenuation in the other bands is adequate. This method would not be recommended for critical design applications such as performing arts, concert halls or unconventional applications such as laboratories where the predominant noise source could easily be a series of fume hoods in lieu of the ventilation fan.

Using the ILC rating would also allow for simplified comparisons between sound attenuators of a given manufacturer as well as comparisons between different manufacturers. It is still necessary to compare airflow and pressure loss between sound attenuators of comparable ILC rating. A seven foot long low pressure loss attenuator could easily have a comparable ILC rating as a three foot attenuator but with much higher pressure loss. Tables 2, 3 and 4 provide examples of the ILC ratings of silencers from three different manufacturers for rectangular absorptive sound attenuators. Circular, packless and lined silencers can also be similarly rated.

The numbers preceding the letters for the silencer models listed in Tables 2, 3 and 4 designate the length of the sound attenuator in feet. The letters chosen for silencer models have

Table 1. Numerical calculation of ILC.

	Octave Band Center Frequency						
	63	**125**	**250**	**500**	**1000**	**2000**	**4000**
Insertion Loss, dB	6	12	15	28	30	25	19
ILC Factors – Add	+10	+5	+0	–5	–5	–3	+1
Results	16	17	**15**	23	25	22	20
Lowest Value = 15						ILC = **15**	

Table 2. ILC ratings for manfacturer 'A' silencers at 1000 ft/min.

		Press.	Octave band center frequencies						
ILC	**Model**	**Drop**	**63**	**125**	**250**	**500**	**1000**	**2000**	**4000**
9	3-A	0.05	4	5	9	14	23	24	14
10	3-B	0.05	2	5	10	17	17	13	10
12	5-A	0.06	6	7	13	21	29	39	20
13	5-B	0.06	3	8	15	28	30	21	14
14	7-B	0.07	4	12	20	36	38	28	18
16	3-C	0.36	7	12	16	28	35	35	28
18	7-A	0.06	8	13	18	28	40	47	26
	10-B	0.09	8	18	27	42	47	40	23
	5-C	0.40	8	18	24	40	45	46	41
20	10-A	0.07	10	18	25	38	48	50	35
	7-C	0.44	10	20	35	45	50	48	45
23	10-C	0.49	13	23	42	52	55	53	51

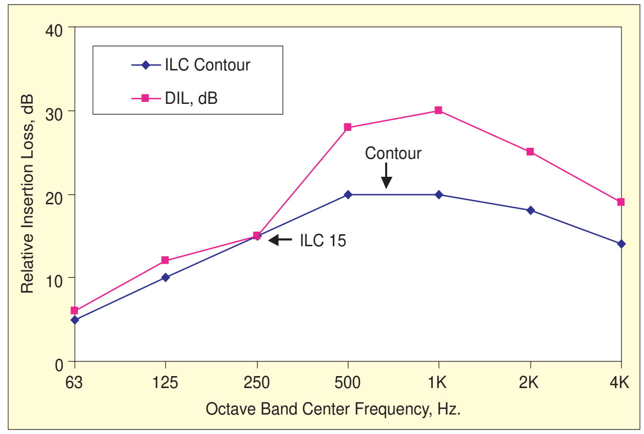

Figure 2. Example of reference ILC contour fitted to insertion loss data.

Table 3. ILC ratings for manfacturer 'B' silencers at 1000 ft/min.

		Press.	Octave band center frequencies						
ILC	**Model**	**Drop**	**63**	**125**	**250**	**500**	**1000**	**2000**	**4000**
9	3-J	0.08	0	4	10	20	29	29	16
10	3-K	0.10	1	5	12	18	26	33	23
	5-J	0.09	3	5	11	33	47	43	23
12	3-N	0.32	7	7	16	24	35	42	28
	5-K	0.12	3	7	19	32	46	52	27
	7-J	0.17	2	11	23	43	53	46	39
16	5-N	0.45	6	12	26	40	57	60	48
	7-K	0.13	6	11	26	43	58	62	39
18	7-N	0.68	8	16	36	47	59	62	55
	10-K	0.18	8	16	31	44	57	64	55
	10-J	0.14	8	14	28	42	55	62	46
20	10-N	0.32	10	26	43	58	63	63	58

Table 4. ILC ratings for manfacturer 'C' silencers at 1000 ft/min.

		Press.	Octave band center frequencies						
ILC	**Model**	**Drop**	**63**	**125**	**250**	**500**	**1000**	**2000**	**4000**
6	3-X	0.04	3	6	10	11	12	11	10
9	3-Y	0.13	4	8	12	14	17	15	13
11	5-X	0.06	4	9	16	18	18	14	12
15	7-X	0.07	5	11	22	23	25	18	16
16	5-Y	0.18	6	11	19	22	26	20	16
17	9-X	0.08	7	14	25	29	30	21	18
18	7-Y	0.22	8	14	26	30	36	25	19
20	9-Y	0.26	10	17	33	38	46	30	23

been arbitrarily selected for illustrative purposes and do not have any relationship to actual model designations.

Conclusion

Single number rating systems have been useful design and comparison tools for architectural sound control products for many years. A single number rating system could be similarly useful for HVAC sound attenuators. The ILC rating system uses principles similar to the existing STC, NIC and other accepted rating methods. The authors would be glad to receive comments and suggestions from the readers to help determine if further efforts should be made to finalize the proposed ILC rating system.

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