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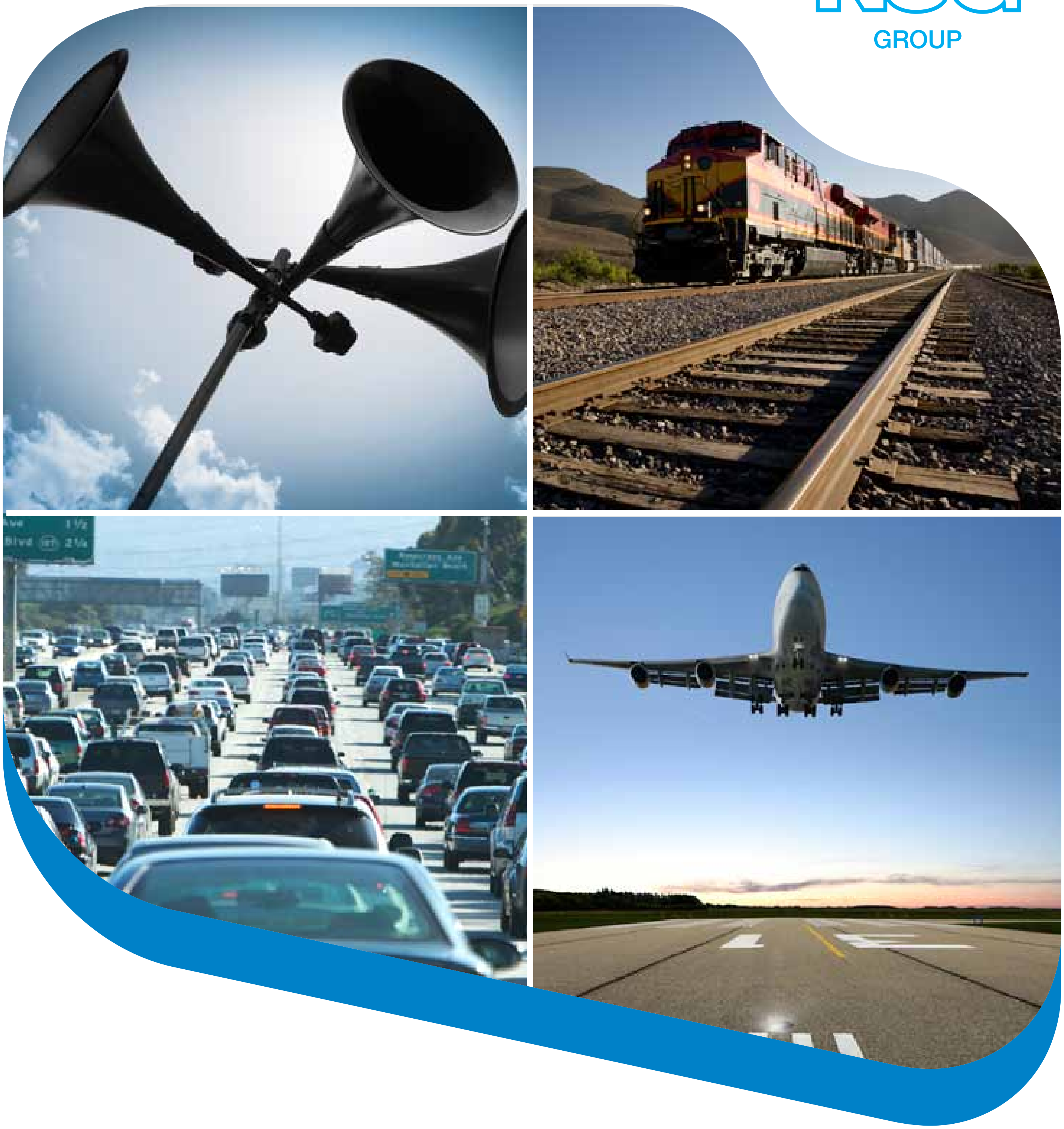


Sound Reduction:
Design Considerations for Construction Glass

About Sound

Controlling the level of sound which penetrates the occupied spaces of a building is an important design consideration in establishing a desirable acoustical environment.

In contemporary architecture, the versatility, energy efficiency, aesthetics and ease of maintenance provided by glass have made it a popular construction material. Simultaneously, the sound reducing properties of glass have become a significant factor to be taken into account in approaching its selection for a building.

Certain products manufactured by Pilkington have sound-reducing capabilities which rate them high acoustically. Pilkington prepared this manual to assist building planners in arriving at the selection of the proper glass configuration for architectural applications where the management of sound is necessary.

What is Sound?

Sound, which is defined as anything the ear can hear, originates from something making vibrations. These vibrations spread out in all directions, much like the ripples created when a stone is dropped in still water.

When a sound is generated in air it causes air pressure changes. The human ear can hear such sounds in a range from 20 to about 20,000 air pressure changes per second.

The number of these air pressure changes emanating from the source of the vibration is measured by the number of cycles per second. In the field of acoustics, the international term for cycles per second is hertz (Hz). When a sound wave is said to measure 500 Hz, it means that there are 500 "ripples" of air pressure per second from the vibration. This 500 Hz is the sound frequency.

Sound Intensity

Sound intensity is really the power of a sound and can be conveniently classified in terms of sound pressure levels, designated in decibels (dB).

The accompanying chart lists common sounds and compares their sound intensity to sound pressure levels. Because a logarithmic scale is used for decibel ratings, note that whenever the sound pressure level goes up 10 dB, the sound intensity increases 10-fold.

Because of the logarithmic basis of this chart, it cannot be used to compare the loudness of one sound against another. For example, it can't automatically be assumed that a 60 dB sound is twice as loud as one rated at 30 dB. Actually, it is 1,000 times louder.

Comparison of Sound Intensity and Sound Pressure Level

Sound Intensity	Sound Pressure Level in dB	Typical Sounds
1,000,000,000,000	120	Thunder Clap
100,000,000,000	110	Nearby Riveter
10,000,000,000	100	Boiler Factory/Subway
1,000,000,000	90	Loud Street Noise/Noisy Factory
100,000,000	80	Noisy Office
10,000,000	70	Average Street Noise
1,000,000	60	Average Radio/Average Office
100,000	50	Average Conversation
10,000	40	Quiet Radio/Private Office
1,000	30	Average Auditorium
100	20	Quiet Conversation/Whisper
10	10	Soundproof Room
1	0	Threshold of Audibility

Loudness

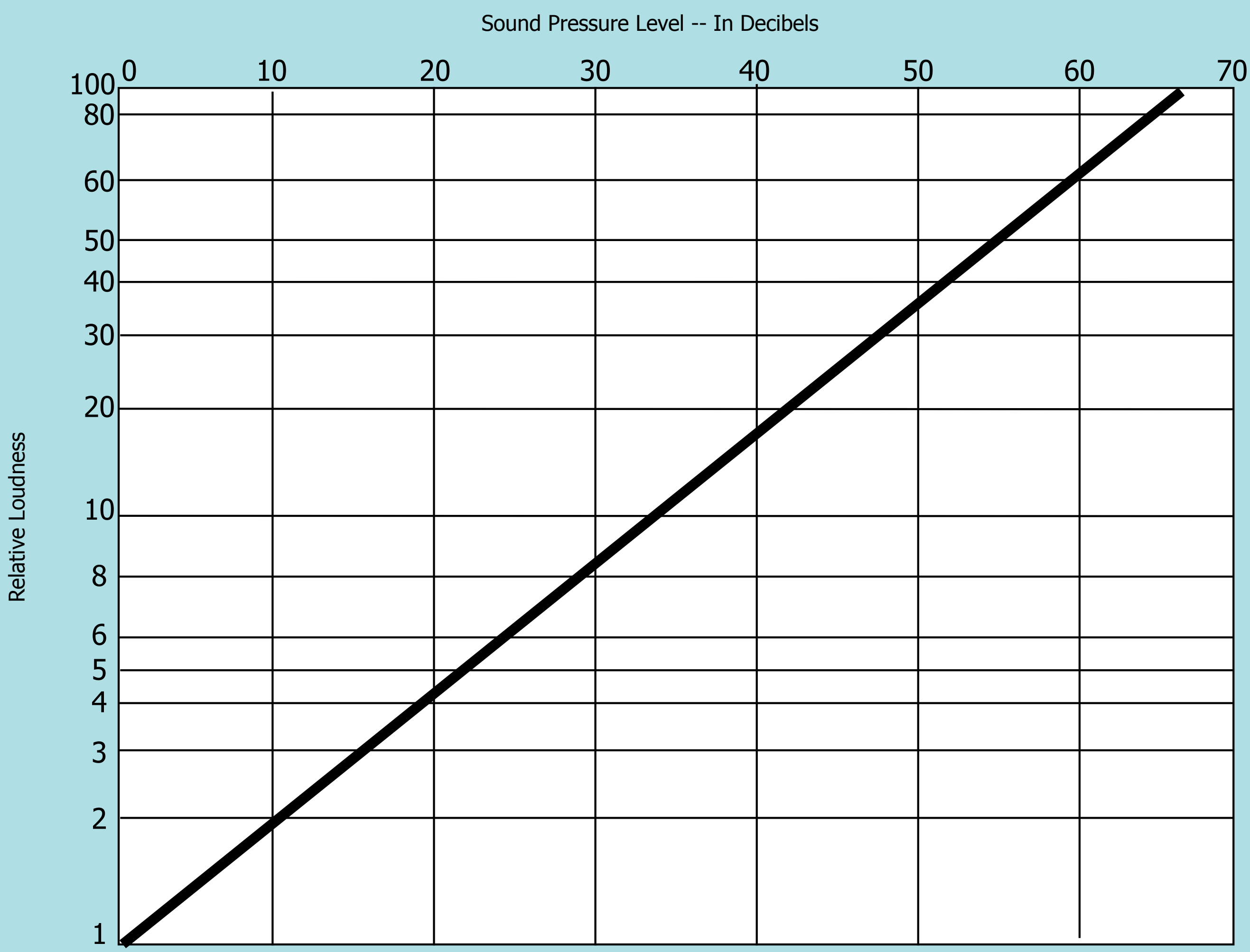
When considering the design concept of a building, it is helpful to use sound pressure level relationships to determine to what degree various building products affect loudness levels. The graph shown is designed to calculate this information and here is how it works:

Suppose a certain type of glazing is known to reduce the sound pressure level from 50 dB to 20 dB. The graph shows 50 dB to be equal to a relative loudness of 32, while for 20 dB it is 4. The decrease in loudness in this case is (32-4)/32 or about 88%.

There are several interesting points to keep in mind when evaluating changes in sound pressure levels:

- Under typical field conditions the ear cannot detect a change of 1 or 2 dB.
- The ear will not pick up a change of 3 dB if there is a time lapse between the two sounds and they are of moderate or low intensity.
- A change of 5 dB can be heard if the sounds are loud.
- A change of 7 dB always can be detected.

Relative Loudness vs. Sound Pressure Level



Sound Reduction Ratings

There are two fundamental considerations which come into play when measuring the reduction of sound through windows, walls or other building components.

First, is the rating called Sound Transmission Loss (STL) which indicates the effectiveness of a window or wall in reducing exterior sounds. In determining the ability of a window or a wall in reducing outdoor sounds such as traffic noises, engineers usually figure STL in the frequency range of 125-4,000 Hz.

Second, the reduction of sound provided by an interior wall is measured by its Sound Transmission Class (STC) rating. This rating applies only to interior partitions, walls, ceilings and floors, but not to exterior walls. In terms of glass, this means office partitions, viewing windows for radio/TV stations and similar applications.

Sound Transmission Loss Through Glass

Before exploring the sound reduction capabilities of glass it is important to establish the fact that the best sound reducing glass cannot do its job if air leaks or cracks allow sound to travel around the glass. Paths which allow sound to find its way through the glazing system, operating sash, expansion joints and partition joints should be eliminated.

Three inherent physical properties of glass have a bearing on its effectiveness in sound reduction:

1. Sound reduction will increase with increased glass thickness due to the greater mass involved.
2. Sound reduction will decrease somewhat with an increasingly larger glass area, but not enough to make much difference in the majority of architectural glass sizes.
3. Laminated glass is particularly effective for interior partitions because air pressure changes from sound bow or bend laminated glass more easily than single glass of the same thickness. This "give" in laminated glass is particularly effective in cutting down sound transmission in the frequency range of the human voice.

The charts show the sound reduction for single glass, laminated glass and glass with various air space combinations. The various thicknesses are rated for an average STL in the range of 125-4,000 Hz and their loudness reduction is compared to ¼ inch glass. The STC ratings are also included to show the effectiveness of the three types of glass in interior applications.

In each case the plastic interlayer is .045" which is best for sound reduction. (See middle chart.)

The glass labeled #1 (see bottom chart) was closest to the source of the sound during testing. However, the amount of sound reduction would not change if the lights of glass were reversed. The glass/air space combination will give better performance when sound absorbing material at least 1" thick is used as a separator around the perimeter of the air space. This can increase sound transmission loss (STL) by about 5 dB over figures in the chart which apply when no such material is used. Remember, the higher the STL number, the better the performance. The glass/air space combinations shown do well in cutting high frequency sounds. To gain better STL ratings for middle and low frequencies, like noises from cars and trucks, special perforated framing and sound absorbing material at least 4" thick are needed in the separator.

Insulating glass with a ½" air space reduces sound about as well as the single glass from which it is fabricated. If two lights of unequal thickness are used, sound reduction will be approximately the same as the thicker piece of glass.

Sound Reduction with Single Glass

Glass Thickness		Average STL 125-4000 Hertz	Loudness Reduction Compared to 1/4" Glass	STC Rating
in.	mm			
3/32	2.5	23.5 dB	-	26
1/8	3	24.1 dB	-	29
1/4	4	26.5 dB	-	29
5/16	8	28.8 dB	15%	29
3/8	10	29.7 dB	20%	30
1/2	12	31.5 dB	29%	33
5/8	15	34.5 dB	42%	30
3/4	19	34.6 dB	43%	33
7/8	22	35.4 dB	46%	32

Sound Reduction with Single Glass

Total Glass Thickness		Construction			Average STL 125-4000 Hertz	Loudness Reduction Compared to 1/4" Glass	STC Rating
in.	mm	Ply	Glass				
			in.	mm			
1/4	6	2	1/8	3	30.2 dB	23%	33
1/2	12	2	1/4	6	33.6 dB	39%	36
1/2	12	1 1	3/8 1/8	10 3	35.7 dB	47%	36
5/8	15	4	1/8	3	36.3 dB	49%	38
3/4	19	2	3/8	10	38.9 dB	58%	38
3/4	19	3	1/4	6	38.7 dB	57%	39
1	25	6	1/8	3	39.8 dB	60%	41

Sound Reduction with Single Glass

Total Glass Thickness				Air Space		Average STL 125-4000 Hertz	Loudness Reduction Compared to 1/4" Glass	STC Rating
No. 1		No. 2		in.	mm			
in.	mm	in	mm.					
1/4	6	1/4	6	1/2	12	26.5 dB	-	29
1/2	12	1/4	6	2	50	38.1 dB	55%	39
1/2	12	1/4	6	4	102	39.3 dB	59%	40
1/2	12	1/4	6	6	152	40.0 dB	61%	42
3/4	19	3/8	10	6	152	40.6 dB	62%	40
1/2	12	1/4*	6	6	152	42.6 dB	67%	44
3/15	5	5/16	8	4	102	37.4 dB	53%	39
1**	25	1/4	6	6	152	40.4 dB	62%	40

* 1/4" laminated to .045" plastic.
** 1" Thermopane.

Glass Selection

Previous charts have shown the sound reduction performance of a variety of glasses over a frequency range of 125-4,000 Hz.

However, certain design requirements may call for sound reduction to be figured over a narrow frequency span. Each type of sound has its own frequency and consequently its own STL requirements from glass. Here are some of the more common noises and their frequencies:

- **Traffic.** Usually based on the average STL over the entire 125-4,000 Hz range. Low frequencies should be emphasized since car, bus and truck noise is most intense below 1,000 Hz. Car horns are most intense in the 500-3,000 Hz range.
- **Aircraft.** For buildings in the flight path of jet planes, use the average STL over the 125-4,000 Hz range. For locations to the side of runways and not in the flight path, glass performance at 500 Hz is critical and performance above 2,000 Hz is not so important. Glass performance for propeller-driven planes is most important below 1,000 Hz. Where both propeller and jet planes operate, installations in the flight path should be figured across the 125-4,000 Hz range.
- **Trains.** Frequencies below 1,000 Hz are most significant, with the 125-700 Hz range critical in reducing whistle noise.

The following charts provide STL ratings for specific frequency levels within the 125 Hz to 4,000 Hz range for a variety of glass thicknesses in the three popular configurations – single, laminated and glass/airspace combination.

Sound Transmission Loss for Single Glass

All tests run using ASTM E90-61T
Glass size 52 3/8" x 76 3/8", except for 3/32" and 1/8" glass thickness which were 24" x 36"

Glass Thickness		Frequency -- Hertz										
in.	mm	125	175	250	350	500	700	1000	1400	2000	2800	4000
3/32	2.5	13	15	14	19	21	24	26	30	32	34	30
1/8	3	14	16	17	22	23	26	28	31	33	33	32
1/4	6	21	17	24	26	27	30	31	31	25	28	32
5/16	8	24	24	26	27	29	32	32	27	27	34	35
3/8	10	20	22	27	28	31	33	30	26	32	38	40
1/2	12	20	24	28	30	31	31	27	33	36	42	44
5/8	15	31	33	32	32	31	31	25	35	39	44	46
3/4	19	30	31	31	32	28	26	32	36	41	46	48
7/8	22	32	31	32	28	24	30	35	39	43	47	48

Sound Transmission Loss for Single Glass

All tests run using ASTM E90-61T
Glass size 52 3/8" x 76 3/8", except for 3/32" and 1/8" glass thickness which were 24" x 36"

Total Glass Thickness		Construction*			Frequency -- Hertz										
		Ply	Glass												
in.	mm		in.	mm	125	175	250	350	500	700	1000	1400	2000	2800	4000
1/4	6	2	1/8	3	22	26	25	28	29	32	32	35	33	33	37
1/2	12	2	1/4	6	23	24	30	31	33	34	32	33	38	45	47

Tests Run Using ASTM E90-66T

in.	mm	Ply	Glass in.	Glass mm	125	160	200	250	315	400	500	630	800	1000	1250	1600	2000	2500	3150	4000
1/2	12	1 1	3/8 1/8	10 3	28	30	32	30	33	33	33	34	33	32	33	38	41	44	47	50
5/8	15	4	1/8	3	28	31	31	32	33	34	34	36	37	37	37	38	38	42	45	48
3/4	19	2	3/8	10	31	34	34	33	34	34	33	33	33	36	40	45	47	49	52	54
3/4	19	3	1/4	6	30	32	34	34	35	34	35	35	35	36	39	43	46	48	50	53
1	25	6	1/8	3	32	34	35	34	36	36	37	37	38	39	40	43	44	48	50	53

*.045" plastic interlayer

Sound Transmission Loss for Two Lights and Wide Air Space
Glass Size 52 3/8" x 76 3/8"

Tests Run Using ASTM E90-66T

Glass Thickness				Air Space		Frequency -- Hertz															
No. 1		No. 2				125	160	200	250	315	400	500	630	800	1000	1250	1600	2000	2500	3150	4000
in.	mm	in.	mm	in.	mm																
1/2	12	1/4	6	2	50	29	26	35	35	34	35	38	38	38	37	38	41	38	43	48	56
1/2	12	1/4	6	4	102	32	29	39	38	36	38	39	39	39	38	39	41	38	41	48	54
1/2	12	1/4	6	6	152	33	28	34	38	38	40	41	42	42	40	41	42	38	42	47	54
3/4	19	3/8	10	6	152	32	35	42	38	36	37	37	37	39	40	37	39	43	48	53	56
1/2	12	1/4*	6	6	152	36	32	32	39	39	42	43	44	43	42	44	46	44	47	52	56
3/15	8	5/16	8	4	102	27	30	32	36	35	37	38	39	41	43	41	38	38	35	40	48

Tests Run Using ASTM E90-61T

No. 1 in.	No. 1 mm	No. 2 in.	No. 2 mm	Air Space in.	Air Space mm	125	175	250	350	500	700	1000	1400	2000	2800	4000
1**	25	1/4	6	6	152	34	29	35	37	42	45	48	48	3	41	49

* Laminated with .045" plastic interlayer

** 1" Thermopane

Opaque Wall/Glass Combinations

In buildings with walls using both glass and opaque structural material, the overall sound-reducing effectiveness of the wall must be calculated.

The accompanying graph provides a simplified means of figuring (1) the effect of glass on the sound transmission of the total wall and (2) the average STL of the wall and glass combination.

For purposes of calculation, suppose a 1,000 square foot ($93m^2$) wall contains 100 square feet ($9.3m^2$) of glass area. The wall has an STL of 50 dB and the glass an STL of 30 dB.

Based on this information, here are the steps to follow in using the graph:

1. Figure the ratio of glass area to total wall area and find that number at the top of the graph. In this instance its 100 sq. ft. ($9.3m^2$) divided by 1,000 sq. ft. ($93m^2$) or 0.10.
2. Find the difference in STL values between the glass and the total wall. In this case it's 50 dB minus 30 dB, or 20 dB. Now find that number in the "STL Wall-STL Glass" lines across the graph.
3. Find how much the wall STL is reduced because of the glass. This is the "reduction in STL of Wall" number on the left side of the graph. In this instance it is 10.4 dB.
4. Finally, to get the combined STL of the wall and the glass, subtract "reduction in STL of Wall" (10.4 dB) from the original wall STL (50 dB) and the answer is 39.6 dB.

Pilkington **Optiphon**™

Pilkington **Optiphon**™ is the ideal choice for situations where there is excess noise from road, rail or air traffic, or various other sources, for example factories or nightclubs.

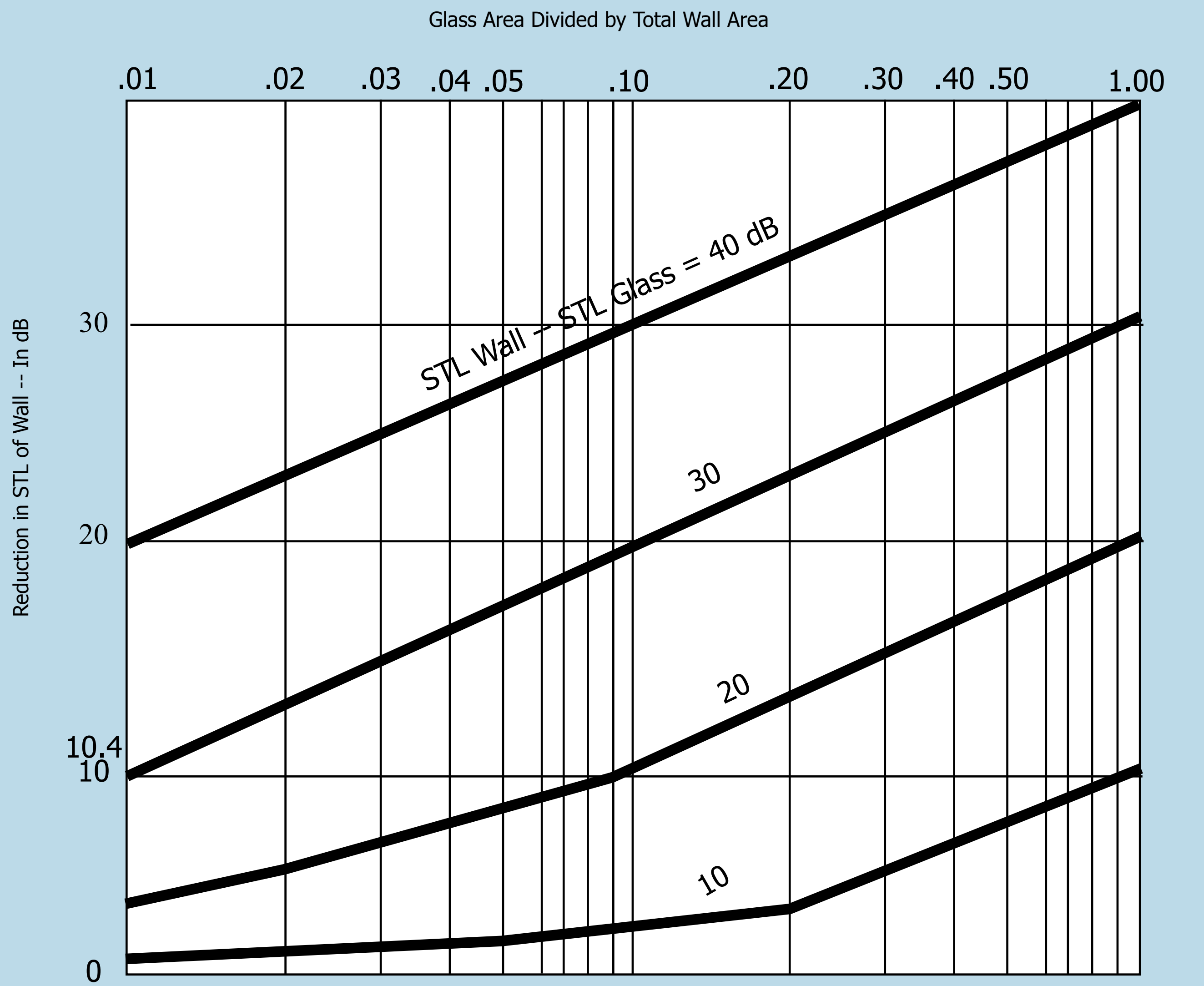
By using a special PVB (polyvinyl butyral) interlayer, Pilkington **Optiphon**™ is a high quality acoustic laminated glass that offers excellent noise reduction without compromising on light transmittance or impact performance.

The desired acoustic performance can be achieved through combining various thicknesses of glass with a PVB interlayer. Pilkington **Optiphon**™ offers the opportunity to achieve specific noise reduction requirements.

Features and Benefits

- Provides a range of noise control levels.
- A thin and lightweight solution to noise problems.
- Achieves safety class 1(B)1 (EN 12600) and is available to meet security glass classifications in accordance with EN 356.
- In case of breakage remains intact, minimizing the risk of injury.
- Easy to process, and can be incorporated into Insulating Glass Units.
- Can be single, double or triple glazed.
- Can be combined with other Pilkington products for a multifunctional noise-reduction monolithic glass or a multi-functional noise-reduction Insulating Glass Unit providing additional benefits, such as thermal insulation, solar control or self-cleaning.

STL of Wall with Glass Area

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