Sound and Noise Attenuation with Glass

Purpose of this document.
The purpose of this document is to make the reader aware of some of the characteristics of Sound and Noise. It provides noise attenuation data glass and suggests some possible solutions for noise problems. It should not be seen as a complete treatment of the subject of sound, noise, the attenuation performance of glass or glass solutions for noise problems. This document should not be used alone to make an assessment or decision relating to any product or any potential fitness for purpose of any solution to a noise problem.

Introduction

Sound surrounds us every day of our lives and our hearing is the only sense other than our eyes which can provide information on events which occur a long distance away. Our hearing allows us not only to become aware of an event but to pinpoint its location without seeing it. Sound is present in many forms and intensities and can be pleasing or annoying, soothing or destructive. Therefore it is important that we are able to control it in order to make our lives enjoyable.

Sound

Sound is caused by the vibration of a surface being transferred to a surrounding medium such as the air. The process of transfer is by physical contact. If the vibration is imagined as an oscillation then at one extreme of the oscillation the surface is pushing on the air and at the other extreme it is moving away from the air, therefore sucking the air towards it. When the surface is pushing on the air it produces a slightly higher pressure than normal and when it is moving away it produces a slightly lower pressure than normal so the oscillation produces alternating higher and lower pressure zones. This difference in pressure causes our ear drum to vibrate and these vibrations travel through the mechanism of the ear to our brain where it is interpreted as the sensation we hear as sound. Sound can be described as a longitudinal pressure wave caused by the vibration of an object.

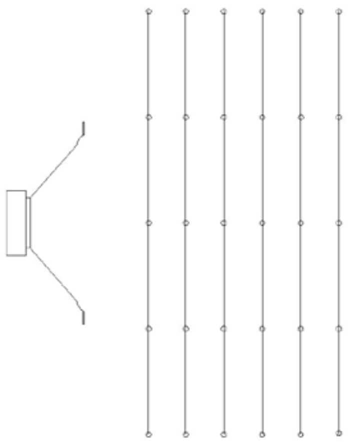

Fig 1. No Sound. And the air is undisturbed

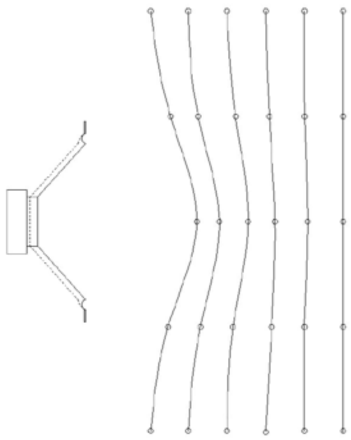

Fig 2. One vibration of the speaker and sound begins to propagate through the air

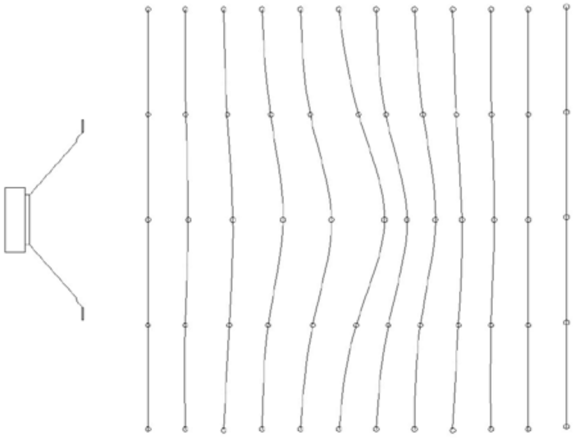

Fig 3. Speaker has stopped, the initial sound continues to propagate through the air.

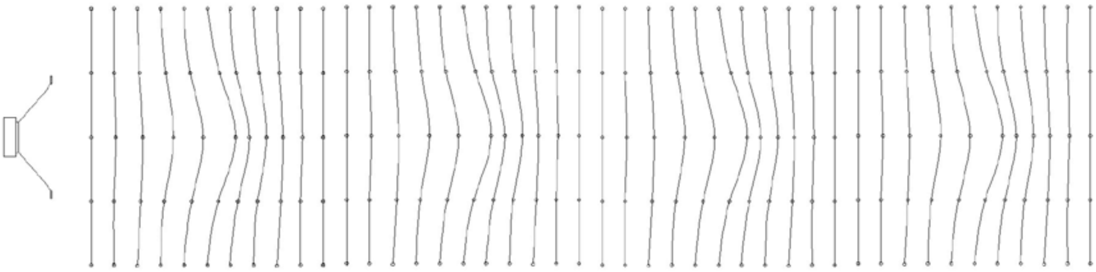

Fig 4. A series of sound waves propagating through the air.

Sound and Noise

Noise is unwanted sound. It may be unwanted for a number of reasons some of which are, it is too loud, it is inappropriate for the current activity (e.g. sleep), unpleasant (e.g. not your favoured music) and many other reasons. We do not want to be bothered by sound that we find irritating.

Characteristics of Sound

The speed of vibration can vary considerably and is called the frequency of the sound and is measured in hertz (Hz) and represents the number of vibrations per second of the object causing the sound. When we speak of high or low pitched sound we are referring to the frequency. The frequency range of human hearing ranges from 20 Hz to 20,000Hz. Sound exists outside this frequency range but we cannot hear it. The loudness of the sound is represented by the magnitude of the sound pressure. The higher the pressure the louder the sound. This pressure can be increased to a level where we feel pain and damage can be caused to the hearing mechanism of the ear. The difference between the smallest pressure our ears can sense and the point at which pain is perceived is numerically large and our ears do not sense a doubling of sound pressure as a doubling of loudness. The decibel was introduced to represent sound pressure. The sound intensity measured in Decibels (dB) is called the Sound Pressure Level and is universally used as a measurement of the Sound Intensity.

The use of the logarithmic scale does present some difficulties, simply because it is not a linear scale. A linear scale means that when the figure representing the quantity of the item being measured is doubled then there will be twice as much of the item present. Most of the quantities we encounter in our daily lives are measured in a linear fashion so if the number representing the amount of a particular item is doubled then we expect that there will be twice as much of that quantity. Encountering a scale which is not linear, such as the Decibel scale, for the first time can seem very strange. If the sound pressure level was increased by 10dB then we would feel that the sound was twice as loud so a noise increase from 60dB to 70dB would seem to have doubled. If it was reduced by 10dB then we would feel that the noise had halved so a decrease from 60 to 50dB.

dB Increase	Relative Loudness% Increase		dB Decrease	Relative Loudness% Decrease
0	0		0	0
1	7		1	7
2	15		2	13
3	23		3	19
4	32		4	24
5	41		5	29
6	52		6	34
7	63		7	38
8	74		8	43
9	86		9	46
10	100		10	50
20	400		20	75
30	800		30	88
40	1600		40	94
50	3200		50	97

Table 1. The relationship between dB and relative loudness as sensed by our ears

It should be noted that the detection of small changes in loudness is difficult. If you left a room and the sound was increased or decreased by 2dB and you later returned to the room you would not detect that the sound level had been altered. This means that you would not detect a 15% increase or a 13% decrease in loudness in this situation. If you were present in the room at the time the sound was altered you would comfortably detect the 2dB alteration.

The pressure wave method of transmission means that sound is not able to travel large distances because it has to shake all the air in between so the energy is quickly absorbed. Placing barriers in the path of sound can increase this absorption and as a consequence can reduce the distance sound is able to travel.

Human sensitivity to sound

The ear is the tool which human body uses to detect sound waves in the environment and the brain is the device which interprets the information detected by the ear. The ear does not sense all sound frequencies at equal loudness. The threshold of hearing is a measure of the quietest sounds which the ear can detect. It is interesting to note that the sound frequencies at the extreme ends of human sensitivity (20Hz and 20kHz) have to be much louder for humans to be able to hear them, than frequencies in the range human speech. This presents an issue for the analysis of sound problems. To overcome this issue sound measuring equipment has a built in filter to adjust for this variance. This filter is called an A weighting. Sound Pressure level is measured in dB and the adjusted measurement is designated as dB(A). It is used very commonly.

Sound reduction with Glass.

Measurement

The sound reduction of glass is most accurately determined by testing. The tests are undertaken at specialised acoustic laboratories. The test process measures the reduction at each third octave band frequency from 100Hz to as much as 4000Hz. The reduction at each of these octave bands is different. A typical plot is shown in the graph below.

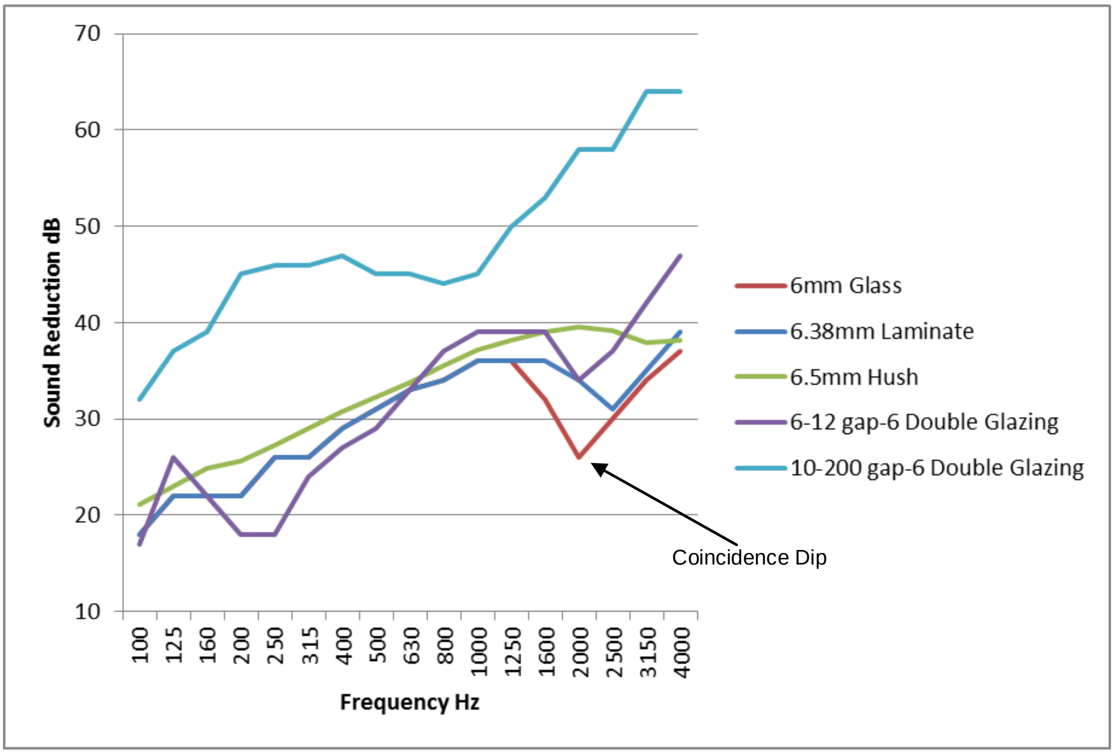

Figure 5. A typical graph of sound reduction for various glass types

This graph shows a typical sound reduction plot for several glazing types. The first thing to notice is that the graph, for all the glass types, slopes upward from left to right indicating that the sound reduction is better in the higher frequencies than the lower frequencies. There is a noticeable dip and recovery in the graph near the right hand side, this is called a coincidence dip and it can be seen in all test data for glass although the magnitude and position change with thickness and type of glass.

Dealing with sound loss levels at various frequencies can be complicated so various methods have been developed to reduce this frequency data to a single figure. STC (Sound Transmission Class) had been the most common parameter used for glass over the years and the process of determination was set out in AS 1276 but this standard has now been superseded by AS/NZS ISO 717.1:2004. This new standard determines the Weighted Sound Reduction Index R_w. The numbers which result from the two methods are often the same as can be seen in the performance tables at the end of this document. The process for the determination of STC and R_w values is very similar and often the numbers are the same or very close however there are some minor differences and they are

Feature	R_w	STC

Frequency Range	100Hz to 3.15 kHz	125Hz to 4 kHz
Quantity produced	R_w, C, C_{tr}	STC

Modification of glass performance

The plot above shows the basic behaviour of glass when subjected to sound. This can be modified by altering the glass make up. The plot above shows the behaviour of 6mm annealed glass and will also apply to 6mm toughened glass.

The plot for 6.38mm Laminated glass looks slightly different because the coincidence dip is not be as large and this is due to the lower viscosity of the interlayer used to laminate the glass together. There are now interlayers which are designed specially to reduce sound and these combine two materials in the one interlayer and these have a marked effect on the coincidence dip. This can be seen in the plot for 6.5mm Hush, The stiffness of glass is one characteristic which determines its resistance to sound penetration and this is the reason thicker glass is better than thinner glass. It is possible to combine a thicker and a thinner glass in the one laminate so the difference in thickness can be combined with the difference in viscosity of the interlayer to maximise the sound reduction effect

Air has a vastly different viscosity to glass so can be used as a sound reduction medium. This introduces the possibility to use double glazing as a sound reduction agent. Double glazing can be quite effective but the appropriate amount of air is required. Typically the double glazing used for thermal insulation provides only a modest improvement in sound reduction. However a wider air gap than is possible for hermetically sealed double glazed units is much more effective. A gap of 50mm to 200mm will provide a substantial reduction when compared to the glass alone. Typically two window frames are required to achieve this. This can be seen in Figure 5.

Solving a noise problem.

It is important to note that the following information relates to glass only.
Solving a noise problem is not as easy as it sounds. The noise level which is acceptable to one person may not be acceptable to another and it is very difficult to allow for this variation by specifying R_w parameters. A detailed solution would involve measuring the nature and intensity of the offending sound and choosing a glass product which will reduce the intensity sufficiently at all frequencies. This assessment process can also be done using single numbers. It means reducing the external noise to a single number and then subtracting the single number for the glass this will provide a single number for the noise coming through the glass. This is relatively simple but consideration must be given to the materials and structure of the building as well.

The sound reduction performance of glass is now measured in R_w and the process of determination of R_w produces two additional parameters C and C_{tr}. These adaptation terms are used to modify the R_w number to better represent the sound reduction of glass for different types of noise.

The “C” adaptation term is relevant to the following noise types
1. Living activities (talking, music, radio, TV)
2. Children playing
3. Railway traffic at medium and high speed
4. Highway traffic with speeds >80km/hr
5. Jet aircraft at short distance
6. Factories emitting mainly medium and high frequency noise

The “C_{tr}” adaptation term is relevant to the following noise types
1. Urban road traffic
2. Railway traffic at low speeds
3. Aircraft which are propeller driven
4. Jet aircraft which are a large distance away
5. Disco music

6. Factories emitting mainly low and medium frequency noise.

The tables in Appendix A of this document list the sound reduction in spectral terms and the performance in terms of R_w, C, C_{tr} and STC.

What do you need to know?
You need to be in possession of three things before a solution can be determined.
1. External noise Level
2. Desired internal noise level
3. Sound reduction data for glass

If you are in possession of this information the process is simple.
Subtract the desired internal noise level from the external noise level and you have determined the magnitude of the noise which the glass must remove.
The next step is to look through the sound reduction data for the glass which can provide this reduction. Remember to apply the appropriate adaptation term (C or C_{tr}) to the R_w value and use the resulting value for comparison.

The external noise level is often the most difficult to determine because the intensity varies with the distance from the noise source. The most accurate way for this to be determined is to have the noise measured by an Acoustic Engineer.

Conclusion
Noise is an ever present phenomenon in our environment and can be both enjoyable and annoying. Glass is an essential component in our buildings and there is no reason why an appropriate glass cannot be selected to solve a noise problem as well as satisfy all the other requirements which may be placed on it.

Appendix A

Sound Reduction Data for Glass

Frequency Hz	3mm	4mm	5mm	6mm	8mm	10mm	12mm	15mm	19mm
100	15	17	17	18	19	24	25	25	25
125	22	23	25	22	27	26	29	29	29
160	19	22	23	22	22	28	31	31	31
200	18	21	23	22	27	26	30	30	31
250	20	21	23	26	25	28	30	31	32
315	22	24	25	26	28	29	32	33	35
400	25	26	28	29	30	32	34	35	36
500	27	29	30	31	33	34	36	37	38
630	29	30	32	33	35	36	36	35	36
800	30	32	33	34	36	37	36	32	35
1000	32	34	35	36	37	36	33	33	38
1250	33	34	36	36	34	33	32	35	40
1600	34	36	36	32	30	33	36	39	44
2000	35	36	32	26	33	38	39	42	47
2500	35	31	26	30	37	41	42	45	50
3150	30	25	32	34	40	43	46	50	52
4000	26	31	35	37	41	44	47	51	55
R_w	30	31	32	32	34	36	37	37	40
C	-1	-2	-2	-2	-1	-1	-2	-1	-1
C_{tr}	-4	-3	-3	-3	-3	-3	-3	-3	-4
STC	29	29	30	30	34	36	36	37	40

Table A1. Sound Attenuation for Monolithic Glass

Frequency Hz	6.38mm	8.38mm	10.38mm	12.38mm
100	18	20	24	25
125	22	27	26	28
160	22	26	28	28
200	22	26	26	27
250	26	26	27	31
315	26	28	29	32
400	29	29	31	33
500	31	34	34	35
630	33	36	36	37
800	34	37	37	37
1000	36	35	33	36
1250	36	31	35	35
1600	36	33	34	37
2000	34	35	38	41
2500	31	39	42	44
3150	35	42	44	47
4000	39	43	46	50
R_w	33	34	36	37
C	-1	-1	-1	0
C_{tr}	-3	-3	-3	-3
STC	33	35	36	37

Table A2. Sound Attenuation for VLam Laminated Glass

Frequency Hz	6.5mm	8.5mm	10.5mm	12.5mm
100	21.1	22.3	26.3	28.9
125	23	24.1	25.7	28.9
160	24.9	28.1	28.6	29.7
200	25.6	28.3	28.4	29.6
250	27.2	30	31.5	32.3
315	29	31.3	33.5	34.4
400	30.8	33.6	34.8	35.3
500	32.3	34.2	35.2	35.9
630	33.8	35.4	37.1	37.9
800	35.5	37.3	38.7	40.1
1000	37.1	38.7	40.1	41.4
1250	38.2	39.8	40.8	41.6
1600	39.1	40.4	41	41.1
2000	39.6	40.1	39.7	41.1
2500	39.2	38.6	40	43.4
3150	37.9	39	43.7	47.6
4000	38.2	43.6	47.9	50.8
5000	42.9	48.1	51.6	54.5
R_w	36	38	39	40
C	-1	-1	-1	-1
C_{tr}	-4	-4	-3	-3
STC	36	38	39	40

Table A3. Sound Attenuation for VLam Hush

Frequency Hz	4mm 12mm Gap 4mm	6mm 12mm Gap 6mm	6mm 12mm Gap 6.38mm	10mm 12mm Gap 4mm	10mm 12mm Gap 6mm	10mm 12mm Gap 6.38mm
100	25	17	19	23	27	27
125	24	26	24	28	27	28
160	23	22	21	26	24	26
200	21	18	19	19	24	26
250	21	18	19	23	29	30
315	19	24	24	26	31	32
400	22	27	28	31	33	34
500	25	29	32	33	34	36
630	30	33	34	36	37	40
800	33	37	38	39	39	41
1000	36	39	40	41	41	42
1250	38	39	40	41	41	41
1600	40	39	39	41	39	41
2000	41	34	35	45	37	42
2500	35	37	39	45	40	44
3150	31	42	44	42	43	49
4000	40	47	49	44	47	53
R_w	31	33	34	36	38	40
C	-2	-2	-2	-2	-2	-2
C_{tr}	-4	-5	-5	-5	-4	-5
STC	31	33	34	36	38	40

Table A4. Sound Attenuation for Double Glazing

Frequency Hz	6mm 100mm Gap 4mm	6mm 150mm Gap 4mm	10mm 200mm Gap 6mm
100	25	27	32
125	27	30	37
160	27	30	39
200	33	34	45
250	33	34	46
315	37	39	46
400	41	42	47
500	46	46	45
630	50	50	45
800	54	54	44
1000	57	57	45
1250	59	58	50
1600	58	58	53
2000	52	52	58
2500	51	49	58
3150	48	47	64
4000	57	52	64
R_w	46	47	49
C	-2	-2	-1
C_{tr}	-7	-6	-4
STC	46	47	49

Table A5. Sound Attenuation for Wide Air Gap Double Glazing

Frequency Hz	8.5mm Hush 16mm Gap 12.5mm Hush	4mm VFloat 16mm Gap 8.5mm Hush	5mm VFloat 16mm Gap 8.5mm Hush	6mm VFloat 16mm Gap 8.5mm Hush	8mm VFloat 16mm Gap 8.5mm Hush	8mm VFloat 16mm Gap 10.5mm Hush	10mm VFloat 16mm Gap 10.5mm Hush	10mm VFloat 16mm Gap 12.5mm Hush
100	27.4	26.8	24.3	27.2	28.4	28.2	31.3	30.9
125	23.9	23.3	22.8	23.7	21.3	23.9	29.7	30.3
160	29.3	22.8	19.6	22.9	21.9	23.6	27.8	27.6
200	32.1	23	22.7	22.6	24.2	28	27.5	29
250	38.7	28.3	26.6	27.8	30.9	31.5	36.6	37.9
315	42.5	30.3	31.4	31.7	36.1	38.8	39.9	39.7
400	45.2	32.7	36.1	37.8	39.8	40	43.3	42.9
500	46	35.5	38	39.9	41.5	41.1	44.1	44.2
630	47.9	39.9	41.5	42.9	44.4	43.8	46.4	46.2
800	49	44.2	45	46.3	46.9	45.9	45.8	45.9
1000	49.7	47.5	47.6	48.3	48.2	47.5	44.3	44.3
1250	50.1	50.4	50.3	48.4	45.4	44.9	43.8	43.2
1600	50.5	51	49.6	48.2	45	43.9	44.2	43.3
2000	52.1	51.3	46.5	44.3	46.5	45.3	46.7	47.3
2500	55.1	50.3	44.5	45.4	48.4	49.3	51.1	52.1
3150	59.9	47.6	48.3	50.1	52.4	54.4	56.6	57.2
4000	64.7	52.8	54.9	55.8	58.1	59.4	61.9	62.5
5000	69	58.6	60.6	61	63	63.7	65.6	66.3
R_w	47	39	40	41	42	43	44	45
C	-2	-1	-3	-3	-3	-2	-1	-2
C_{tr}	-7	-5	-7	-7	-7	-6	-5	-6
STC	47	39	40	41	42	43	45	45

Table A6. Sound Attenuation for VLam Hush Double Glazing

Frequency Hz	10.76mm VLam 12mm Gap 8.5mm Hush	8.76mm VLam 12mm Gap 6.5mm Hush	6mm VFloat 12mm Gap 6.5mm Hush	4mm VFloat 12mm Gap 6.5mm Hush	8.76mm VLam 12mm Gap 8.5mm Hush	10.76mm VLam 12mm Gap 6.8mm Hush
100	24.9	26.9	25.8	24.8	26.9	29.1
125	21.9	19.6	19.5	20.6	19.1	20.7
160	22.6	21.7	21.9	21.5	21.2	23.5
200	25.3	25.1	24	21.5	24.8	26.3
250	30.8	29.2	28.3	24	27.9	30.7
315	32.3	29.3	29.4	25.8	29.5	32.1
400	36.4	33.3	32.7	30.2	33.4	36.6
500	38.8	36.5	36.2	33.2	36.5	39.3
630	40.9	39.1	39.2	36.6	38.6	41.1
800	42.2	41.5	41	39.6	41.5	41.8
1000	42.5	43.8	42.5	42.5	42.8	42.2
1250	42.6	42.4	42.7	42.8	41.5	42.5
1600	41.5	42.4	41.5	44.3	42.4	43.4
2000	42.3	44	39.8	45.1	44.9	47.2
2500	45.4	46	41.2	43.9	47.6	48.1
3150	49.6	48.8	45.5	42.3	49.5	49.8
4000	53.3	51.9	49.1	47.3	51.6	52.2
5000	56.3	54.8	52.5	51.7	54.9	55
R_w	40	39	38	36	38	40
C	-2	-2	-2	-1	-1	-1
C_{tr}	-6	-6	-5	-3	-5	-5
STC	40	39	38	37	37	40

Table A6. (cont.) Sound Attenuation for VLam Hush Double Glazing

Appendix B

Noise Reduction Solutions Using Glazing

The following tables take the recommended design sound levels within rooms from AS/NZS 2107: 2000, for various activities, and lists the glass to be used to achieve the desired sound level at the room side of the glass.

The standard makes reference to “Satisfactory” and “Maximum” levels. “Maximum” refers to the highest level of noise in the room which is believed tolerable by AS/NZS 2107: 2000 for the activity being undertaken in that room. “Satisfactory” refers to the noise level in the room which is comfortable for the activity being undertaken in the room. Therefore the “Satisfactory” solution is more desirable for the occupant than the “Maximum” solution.

In the tables “Maximum” is referred to as “Maximum suggested noise level in room” and “Recommended” is referred to as “Recommended noise level in room”.

The glass solution to achieve the “Recommended noise level in room” is found in the column “Recommended Glass”.

The glass solution to achieve the “maximum suggested noise level in room” is found in the column “Minimum Tolerable Glass”.

The tables provide the solution for both traffic and aircraft noise for the building use designations shown in AS/NZS 2107: 2000. The attenuation of traffic noise in this table is represented by R_w+C_{tr} and aircraft noise is represented by R_w+C. This table relates to the noise level at the room side of the glass not necessarily the noise level in the room because the level in the room is influenced by the roof, walls and floor not just the glass in the windows.

It should be remembered the acceptable noise levels suggested in AS2107 may not be suitable for all people. There are various methods for analysing and finding a solution to a noise problem. An acoustic consultant is an authoritative source of information and advice for analysing and developing solutions to noise problems. Consideration should be given to employing their expertise.

Type of Occupancy	External Noise Level	Traffic Noise				Aircraft Noise			
		Internal noise level (room side of glass)				Internal noise level (room side of glass)			
		Recommended Glass	dB	Minimum Tolerable Glass	dB	Recommended Glass	dB	Minimum Tolerable Glass	dB
Board Room (Recommended noise level in room = 30dB) (Maximum suggested noise level in room = 40dB)	65	10.5mm VLam Hush	29	4mm Float	37	6.5mm VLam Hush	30	4mm VFloat	36
	70	8.5mm VLam Hush + 16mm gap + 12.5mm VLam Hush	30	6.38mm VLam	40	8mm VFloat + 16mm Gap + 10.5 VLam Hush	29	6.38mm VLam	38
	75	10mm VFloat + 200mm Gap + 6mm VFloat	30	10.5mm VLam Hush	39	8.5mm VLam Hush + 16mm Gap + 12.5mm VLam Hush	30	6.5mm VLam Hush	40
	80	No listed solution	-	8.5mm VLam Hush + 16mm gap + 12.5mm VLam Hush	40	No listed solution	-	8mm VFloat + 16mm Gap + 10.5 VLam Hush	39
Cafeteria (Recommended noise level in room = 45dB) (Maximum suggested noise level in room = 50dB)	65	4mm VFloat	37	4mm VFloat	37	4mm VFloat	36	4mm VFloat	36
	70	4mm VFloat	42	4mm VFloat	42	4mm VFloat	41	4mm VFloat	41
	75	6.38mm VLam	45	4mm VFloat	47	5mm VFloat	45	4mm VFloat	46
	80	10.5mm VLam Hush	44	6.38mm VLam	50	6.5mm VLam Hush	45	6.38mm VLam	45
Call Centre (Recommended noise level in room = 40dB) (Maximum suggested noise level in room = 45dB)	65	4mm VFloat	37	4mm VFloat	37	4mm VFloat	36	4mm VFloat	36
	70	6.38mm VLam	40	4mm VFloat	42	6.38mm VLam	38	4mm VFloat	41
	75	10.5mm VLam Hush	39	6.38mm VLam	45	6.5mm VLam Hush	40	5mm VFloat	46
	80	8.5mm VLam Hush + 16mm gap + 12.5mm VLam Hush	40	10.5mm VLam Hush	44	8mm VFloat + 16mm Gap + 10.5mm VLam Hush	39	6.5mm VLam Hush	45
Computer Room (Recommended noise level in room = 45dB) (Maximum suggested noise level in room = 50dB)	65	4mm VFloat	37	4mm VFloat	37	4mm VFloat	36	4mm VFloat	36
	70	4mm VFloat	42	4mm VFloat	42	4mm VFloat	41	4mm VFloat	41
	75	6.38mm VLam	45	4mm VFloat	47	5mm VFloat	45	4mm VFloat	46
	80	10.5mm VLam Hush	44	6.38mm VLam	50	6.5mm VLam Hush	45	6.38mm VLam	45
Design Office (Recommended noise level in room = 40dB) (Maximum suggested noise level in room = 45dB)	65	4mm VFloat	37	4mm VFloat	37	4mm VFloat	36	4mm VFloat	36
	70	6.38 VLam	40	4mm VFloat	42	6.38mm VLam	38	4mm VFloat	41
	75	10.5mm VLam Hush	39	6.38mm VLam	45	6.5mm VLam Hush	40	5mm VFloat	45
	80	8.5mm VLam Hush + 16mm gap + 12.5mm VLam Hush	40	10.5mm VLam Hush	44	8mm VFloat + 16mm Gap + 10.5mm VLam Hush	39	6.5mm VLam Hush	45

Type of Occupancy	External Noise Level	Traffic Noise				Aircraft Noise			
		Internal noise level (room side of glass)				Internal noise level (room side of glass)			
		Recommended Glass	dB	Minimum Tolerable Glass	dB	Recommended Glass	dB	Minimum Tolerable Glass	dB
General Office Areas (Recommended noise level in room = 40dB) (Maximum suggested noise level in room = 45dB)	65	4mm VFloat	37	4mm VFloat	37	4mm VFloat	36	4mm VFloat	36
	70	6.38mm VLam	40	4mm VFloat	42	6.38mm VLam	38	4mm VFloat	41
	75	10.5mm VLam Hush	39	6.38mm VLam	45	6.5mm VLam Hush	40	5mm VFloat	45
	80	8.5mm VLam Hush + 16mm gap + 12.5mm VLam Hush	40	10.5mm VLam Hush	44	8mm VFloat + 16mm Gap + 10.5 VLam Hush	39	6.5mm VLam Hush	45
Private Office (Recommended noise level in room = 35dB) (Maximum suggested noise level in room = 40dB)	65	6.38mm VLam	35	4mm VFloat	37	5mm VFloat	35	4mm VFloat	36
	70	10.5mm VLam Hush	34	6.38mm VLam	40	6.5mm VLam Hush	35	6.38mm VLam	40
	75	8.5mm VLam Hush + 16mm gap + 12.5mm VLam Hush	35	10.5mm VLam Hush	39	8mm VFloat + 16mm Gap + 10.5 VLam Hush	34	6.5mm VLam Hush	40
	80	10mm VFloat + 200mm Gap + 6mm VFloat	35	8.5mm VLam Hush + 16mm gap + 12.5mm VLam Hush	40	8.5mm VLam Hush + 16mm gap + 12.5mm VLam Hush	35	8mm VFloat + 16mm Gap + 10.5 VLam Hush	39
Reception Area (Recommended noise level in room = 40dB) (Maximum suggested noise level in room = 45dB)	65	4mm VFloat	37	4mm VFloat	37	4mm VFloat	36	4mm VFloat	36
	70	6.38mm VLam	40	4mm VFloat	42	6.38mm VLam	38	4mm VFloat	41
	75	10.5mm VLam Hush	39	6.38mm VLam	45	6.5mm VLam Hush	40	5mm VFloat	45
	80	8.5mm VLam Hush + 16mm gap + 12.5mm VLam Hush	40	10.5mm VLam Hush	44	8mm VFloat + 16mm Gap + 10.5 VLam Hush	39	6.5mm VLam Hush	45
Lobby (Recommended noise level in room = 45dB) (Maximum suggested noise level in room = 50dB)	65	4mm VFloat	37	4mm VFloat	37	4mm VFloat	36	4mm VFloat	36
	70	4mm VFloat	42	4mm VFloat	42	4mm VFloat	41	4mm VFloat	41
	75	6.38mm VLam	45	4mm VFloat	47	5mm VFloat	45	4mm VFloat	46
	80	10.5mm VLam Hush	44	6.38mm VLam	50	6.5mm VLam Hush	45	6.38mm VLam	45

Type of Occupancy	External Noise Level	Traffic Noise				Aircraft Noise			
		Internal noise level (room side of glass)				Internal noise level (room side of glass)			
		Recommended Glass	dB	Minimum Tolerable Glass	dB	Recommended Glass	dB	Minimum Tolerable Glass	dB
Airport Departure Lounge	65	4mm VFloat	37	4mm VFloat	37	4mm VFloat	36	4mm VFloat	36
(Recommended noise level in room = 45dB)	70	4mm VFloat	42	4mm VFloat	42	4mm VFloat	41	4mm VFloat	41
(Maximum suggested noise level in room = 55dB)	75	6.38mm VLam	45	4mm VFloat	47	5mm VFloat	45	4mm VFloat	46
	80	10.5mm VLam Hush	44	4mm VFloat	52	6.5mm VLam Hush	45	4mm VFloat	51
Airport Passenger Check-in Area	65	4mm VFloat	37	4mm VFloat	37	4mm VFloat	36	4mm VFloat	36
(Recommended noise level in room = 45dB)	70	4mm VFloat	42	4mm VFloat	42	4mm VFloat	41	4mm VFloat	41
(Maximum suggested noise level in room = 50dB)	75	6.38mm VLam	45	4mm VFloat	47	5mm VFloat	45	4mm VFloat	46
	80	10.5mm VLam Hush	44	6.38mm VLam	50	6.5mm VLam Hush	45	6.38mm VLam	45
Art Gallery	65	4mm VFloat	37	4mm VFloat	37	4mm VFloat	36	4mm VFloat	36
(Recommended noise level in room = 40dB)	70	6.38mm VLam	40	4mm VFloat	42	6.38mm VLam	38	4mm VFloat	41
(Maximum suggested noise level in room = 45dB)	75	10.5mm VLam Hush	39	6.38mm VLam	45	6.5mm VLam Hush	40	5mm VFloat	46
	80	8.5mm VLam Hush + 16mm gap + 12.5mm VLam Hush	40	10.5mm VLam Hush	44	8mm VFloat + 16mm Gap + 10.5mm VLam Hush	39	6.5mm VLam Hush	45
Exhibition Areas	65	4mm VFloat	37	4mm VFloat	37	4mm VFloat	36	4mm VFloat	36
(Recommended noise level in room = 40dB)	70	6.38mm VLam	40	4mm VFloat	42	4mm VFloat	38	4mm VFloat	41
(Maximum suggested noise level in room = 50dB)	75	10.5mm VLam Hush	39	6.38mm VLam	47	5mm VFloat	40	4mm VFloat	46
	80	8.5mm VLam Hush + 16mm gap + 12.5mm VLam Hush	40	10.5mm VLam Hush	50	6.5mm VLam Hush	39	6.38mm VLam	45
Place of Worship	65	10.5mm VLam Hush	29	4mm Float	35	6mm VFloat	30	6mm VFloat	35
(Recommended noise level in room = 30dB)	70	8.5mm VLam Hush + 16mm gap + 12.5mm VLam Hush	30	6.38mm VLam	34	6.5mm VLam Hush	29	6.5mm VLam Hush	35
(Maximum suggested noise level in room = 35dB)	75	10mm VFloat+ 200mm Gap + 6mm VFloat	30	10.5mm VLam Hush	35	8.5mm VLam Hush + 16mm gap + 12.5mm VLam Hush	30	8mm VFloat + 16mm Gap + 10.5mm VLam Hush	34
	80	No listed solution	-	8.5mm VLam Hush + 16mm gap + 12.5mm VLam Hush	35	No listed solution	-	8.5mm VLam Hush + 16mm gap + 12.5mm VLam Hush	35
Court Room	65	8.5mm VLam Hush + 16mm gap + 12.5mm VLam Hush	25	6.38 VLam	35	8mm VFloat + 16mm Gap + 10.5mm VLam Hush	23	5mm Float	35
(Recommended noise level in room = 25dB)	70	6mm VFloat + 150mm gap + 4mm VFloat	25	10.5mm VLam Hush	34	8.5mm VLam Hush + 16mm gap + 12.5mm VLam Hush	23	6.5mm VLam Hush	35
(Maximum suggested noise level in room = 35dB)	75	No standard solution	-	8.5mm VLam Hush + 16mm gap + 12.5mm VLam Hush	35	No standard solution	-	8mm VFloat + 16mm Gap + 10.5mm VLam Hush	35
	80	No standard solution	-	6mm VFloat + 150mm gap + 4mm VFloat	35	No standard solution	-	8.5mm VLam Hush + 16mm gap + 12.5mm VLam Hush	35

Type of Occupancy	External Noise Level	Traffic Noise				Aircraft Noise			
		Internal noise level (room side of glass)				Internal noise level (room side of glass)			
		Recommended Glass	dB	Minimum Tolerable Glass	dB	Recommended Glass	dB	Minimum Tolerable Glass	dB
Library Reading Area (Recommended noise level in room = 400dB) (Maximum suggested noise level in room = 45dB)	65	4mm VFloat	37	4mm VFloat	37	4mm VFloat	36	4mm VFloat	36
	70	6.38mm VLam	40	4mm VFloat	42	4mm VFloat	38	4mm VFloat	41
	75	10.5mm VLam Hush	39	6.38mm VLam	45	5mm VFloat	40	5mm VFloat	45
	80	8.5mm VLam Hush + 16mm gap + 12.5mm VLam Hush	40	10.5mm VLam Hush	44	6.5mm VLam Hush	39	6.5mm VLam Hush	45
Museum Exhibition Area (Recommended noise level in room = 40dB) (Maximum suggested noise level in room = 45dB)	65	4mm VFloat	37	4mm VFloat	37	4mm VFloat	36	4mm VFloat	36
	70	6.38mm VLam	40	4mm VFloat	42	4mm VFloat	38	4mm VFloat	41
	75	10.5mm VLam Hush	39	6.38mm VLam	45	5mm VFloat	40	5mm VFloat	45
	80	8.5mm VLam Hush + 16mm gap + 12.5mm VLam Hush	40	10.5mm VLam Hush	44	6.5mm VLam Hush	39	6.5mm VLam Hush	45
Post Offices and General Banking Areas (Recommended noise level in room = 45dB) (Maximum suggested noise level in room = 50dB)	65	4mm VFloat	37	4mm VFloat	37	4mm VFloat	36	4mm VFloat	36
	70	6.38mm VLam	42	4mm VFloat	42	6.38mm VLam	41	4mm VFloat	41
	75	10.5mm VLam Hush	45	6.38mm VLam	47	6.5mm VLam Hush	45	5mm VFloat	46
	80	8.5mm VLam Hush + 16mm gap + 12.5mm VLam Hush	44	10.5mm VLam Hush	50	8mm VFloat + 16mm Gap + 10.5mm VLam Hush	45	6.5mm VLam Hush	48
Railway and Bus Terminal Ticket Areas (Recommended noise level in room = 45dB) (Maximum suggested noise level in room = 50dB)	65	4mm VFloat	37	4mm VFloat	37	4mm VFloat	36	4mm VFloat	36
	70	6.38mm VLam	42	4mm VFloat	42	6.38mm VLam	41	4mm VFloat	41
	75	10.5mm VLam Hush	45	6.38mm VLam	47	6.5mm VLam Hush	45	5mm VFloat	46
	80	8.5mm VLam Hush + 16mm gap + 12.5mm VLam Hush	44	10.5mm VLam Hush	50	8mm VFloat + 16mm Gap + 10.5mm VLam Hush	45	6.5mm VLam Hush	48
Restaurants (Recommended noise level in room = 45dB) (Maximum suggested noise level in room = 50dB)	65	4mm VFloat	37	4mm VFloat	37	4mm VFloat	36	4mm VFloat	36
	70	6.38mm VLam	42	4mm VFloat	42	6.38mm VLam	41	4mm VFloat	41
	75	10.5mm VLam Hush	45	6.38mm VLam	47	6.5mm VLam Hush	45	5mm VFloat	46
	80	8.5mm VLam Hush + 16mm gap + 12.5mm VLam Hush	44	10.5mm VLam Hush	50	8mm VFloat + 16mm Gap + 10.5mm VLam Hush	45	6.5mm VLam Hush	48
Coffee Bars (Recommended noise level in room = 45dB) (Maximum suggested noise level in room = 50dB)	65	4mm VFloat	37	4mm VFloat	37	4mm VFloat	36	4mm VFloat	36
	70	6.38mm VLam	42	4mm VFloat	42	6.38mm VLam	41	4mm VFloat	41
	75	10.5mm VLam Hush	45	6.38mm VLam	47	6.5mm VLam Hush	45	5mm VFloat	46
	80	8.5mm VLam Hush + 16mm gap + 12.5mm VLam Hush	44	10.5mm VLam Hush	50	8mm VFloat + 16mm Gap + 10.5mm VLam Hush	45	6.5mm VLam Hush	48

Type of Occupancy	External Noise Level	Traffic Noise				Aircraft Noise			
		Internal noise level (room side of glass)				Internal noise level (room side of glass)			
		Recommended Glass	dB	Minimum Tolerable Glass	dB	Recommended Glass	dB	Minimum Tolerable Glass	dB
Houses and Apartments near minor roads *Sleeping Areas* (Recommended noise level in room = 30dB) (Maximum suggested noise level in room = 35dB)	65	10.5mm VLam Hush	29	4mm Float	37	6mm VFloat	30	4mm VFloat	35
	70	8.5mm VLam Hush + 16mm gap + 12.5mm VLam Hush	30	6.38mm VLam	34	6.5mm VLam Hush	29	6.38mm VLam	35
	75	10mm VFloat+ 200mm Gap + 6mm VFloat	30	10.5mm VLam Hush	35	8.5mm VLam Hush + 16mm gap + 12.5mm VLam Hush	30	6.5mm VLam Hush	34
	80	No standard solution	-	8.5mm VLam Hush + 16mm gap + 12.5mm VLam Hush	35	No standard solution	-	8mm VFloat + 16mm Gap + 10.5 VLam Hush	35
Houses and Apartments near minor roads *Living Areas* (Recommended noise level in room = 30dB) (Maximum suggested noise level in room = 40dB)	65	10.5mm VLam Hush	29	4mm Float	37	6mm VFloat	30	4mm VFloat	36
	70	8.5mm VLam Hush + 16mm gap + 12.5mm VLam Hush	30	6.38mm VLam	40	6.5mm VLam Hush	29	6.38mm VLam	38
	75	10mm VFloat+ 200mm Gap + 6mm VFloat	30	10.5mm VLam Hush	39	8.5mm VLam Hush + 16mm gap + 12.5mm VLam Hush	30	6.5mm VLam Hush	40
	80	No standard solution	-	8.5mm VLam Hush + 16mm gap + 12.5mm VLam Hush	40	No standard solution	-	8mm VFloat + 16mm Gap + 10.5 VLam Hush	39
Houses and Apartments near major roads *Sleeping Areas* (Recommended noise level in room = 30dB) (Maximum suggested noise level in room = 40dB)	65	10.5mm VLam Hush	29	4mm Float	37	6mm VFloat	30	4mm VFloat	36
	70	8.5mm VLam Hush + 16mm gap + 12.5mm VLam Hush	30	6.38mm VLam	40	6.5mm VLam Hush	29	6.38mm VLam	38
	75	10mm VFloat+ 200mm Gap + 6mm VFloat	30	10.5mm VLam Hush	39	8.5mm VLam Hush + 16mm gap + 12.5mm VLam Hush	30	6.5mm VLam Hush	40
	80	No standard solution	-	8.5mm VLam Hush + 16mm gap + 12.5mm VLam Hush	40	No standard solution	-	8mm VFloat + 16mm Gap + 10.5 VLam Hush	39
Houses and Apartments near major roads *Living Areas* (Recommended noise level in room = 35dB) (Maximum suggested noise level in room = 45dB)	65	6.38mm VLam	35	4mm VFloat	37	6mm VFloat	35	4mm VFloat	36
	70	10.5mm VLam Hush	34	4mm VFloat	42	6.5mm VLam Hush	35	4mm VFloat	41
	75	8.5mm VLam Hush + 16mm gap + 12.5mm VLam Hush	35	6.38mm VLam	45	6.5mm VLam Hush	34	5mm VFloat	45
	80	10mm VFloat+ 200mm Gap + 6mm VFloat	35	10.5mm VLam Hush	44	8mm VFloat + 16mm Gap + 10.5mm VLam Hush	35	6.5mm VLam Hush	45
Hotels and Motels near minor roads *Sleeping areas* (Recommended noise level in room = 30dB) (Maximum suggested noise level in room = 35dB)	65	10.5mm VLam Hush	29	4mm Float	35	6mm VFloat	30	4mm VFloat	35
	70	8.5mm VLam Hush + 16mm gap + 12.5mm VLam Hush	30	6.38mm VLam	34	6.5mm VLam Hush	29	6.38mm VLam	35
	75	10mm VFloat+ 200mm Gap + 6mm VFloat	30	10.5mm VLam Hush	35	8.5mm VLam Hush + 16mm gap + 12.5mm VLam Hush	30	6.5mm VLam Hush	34
	80	No standard solution	-	8.5mm VLam Hush + 16mm gap + 12.5mm VLam Hush	35	No standard solution	-	8mm VFloat + 16mm Gap + 10.5 VLam Hush	35
Hotels and Motels near major roads *Sleeping Areas* (Recommended noise level in room = 35dB) (Maximum suggested noise level in room = 40dB)	65	6.38mm VLam	35	4mm Float	37	6mm VFloat	35	4mm VFloat	36
	70	10.5mm VLam Hush	34	6.38mm VLam	40	6.5mm VLam Hush	35	6.38mm VLam	40
	75	8.5mm VLam Hush + 16mm gap + 12.5mm VLam Hush	35	10.5mm VLam Hush	39	8.5mm VLam Hush + 16mm gap + 12.5mm VLam Hush	34	6.5mm VLam Hush	40
	80	10mm VFloat+ 200mm Gap + 6mm VFloat	35	8.5mm VLam Hush + 16mm gap + 12.5mm VLam Hush	40	No standard solution	35	8mm VFloat + 16mm Gap + 10.5 VLam Hush	39