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Evaluation and Demonstration
of Domestic Ventilation Systems

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Noise aspects of ventilation
systems in dwellings.

Contents

1. Introduction

Satisfaction with a ventilation system is largely determined by the percieved indoor air quality, thermal comfort (i.e. draft control) and noise aspects.
In practice, controlling noise aspects, in particular reducing noise levels, is one of the most important factors that contribute to the satisfaction with a ventilation system. Noise aspects related to ventilation systems can be divided into two main classes: direct noise and indirect noise.

Direct noise is noise generated by the system itself. The system is both the source and the means of transport for the noise.
Examples are noise generated by fans and by the mounting materials of air ducts (structure born noise), and noise generated by control valves and grilles (aerodynamic noise).

Indirect noise includes all noise of which the source is outside the system. In this case the system merely transfers noise which originates outside the system.
Examples are traffic noise, noise from industrial plants, catering establishments and aircraft (outdoor noise), and domestic noise (internal noise sources).

2. Problem identification

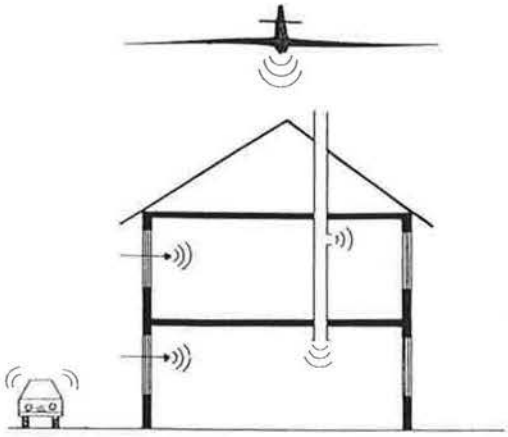
In general, the following three ventilation principles apply to dwellings:
- natural air supply and natural air exhaust;
- natural air supply and mechanical air exhaust;
- mechanical air supply and mechanical air exhaust (balanced ventilation), with or without heat recovery.

Noise related to domestic ventilation systems can be divided into three main areas:
- outdoor noise entering the dwelling through ventilation openings (cracks, grilles, and air supply- and exhaust openings);
- noise generated by the ventilation system of the rooms of the dwelling;
- sound transported within or between dwellings by the ventilation system and/or internal ventilation provisions.

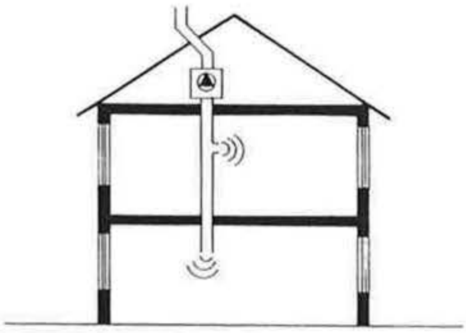
Depending on the type of ventilation system and the strategy, one or more of the three areas indicated in the diagram below are important, see also figure 1.

	Natural ventilation	Mechanical exhaust	Balanced ventilation
Outdoor noise	x	o	o
System noise	-	x	x
Sound transportation	o	o	x

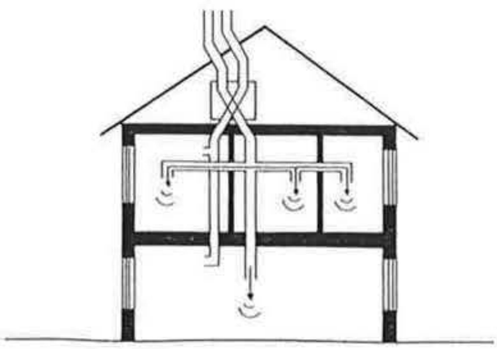
- irrelevant/not applicable
o in general of minor importance
x important



Outdoor noise by natural ventilation.



System noise by mechanical exhaust.



Soundtransportation (cross-talk) by balanced ventilation.

Figure 1: Some relations between noise aspects and ventilation systems.

3. Outdoor noise

3.1. Requirements and methods of calculation and measurement

Road traffic and other activities outside dwellings can be the cause of a noisy environment. In general, the allowable sound level in rooms is 35 dB(A) (ISO 1996).
Table 1 shows the maximum allowable sound levels in residential rooms in various countries.

Table 1: Maximum allowable sound levels generated by outdoor noise sources.

Country	Indoor noise level [dB(A)]	Note
Belgium	35	livingrooms $55 \leq L_{aeq} \leq 65$ dB(A)
	30	bedrooms $L_{aeq} \leq 65$ dB(A).
Canada	-	
Finland	30	bedrooms, livingrooms (unfurnished)
France	-	
The Netherlands	35	
Sweden	30	bedrooms, livingrooms during nighttime
United Kingdom	-	
USA	-	

The table shows that in most countries the maximum acceptable noise level generated by outdoor noise sources inside rooms is 30 to 35 dB(A). Dwellings with facades containing windows, unweatherstripped, and with regular glazing (single-sheet 4 or 6 mm or double sheet 4/6/6/ mm or 4/12/6 mm) achieve a noise reduction of approximately 20 dB(A). With the

windows in the ventilation position (ajar), a noise reduction of approximately 15 dB(A) can be achieved.
If outdoor noise levels at the facade exceed 50 to 55 dB(A), natural supply systems will require special acoustic measures, particularly with regard to the ventilation system.

The noise reduction of a facade (G_A) is the difference between the outdoor noise level (L_o) and the perceived indoor noise level (L_i):

$$G_A = L_o - L_i \qquad dB(A)$$

The resulting noise reduction is determined by the overall sound reduction index of the facade (R_A), taking account of the noise transfer through ventilation openings and joints and cracks in the construction, and the acoustic properties of the room itself (room absorption).

$$G_A = R_A + 10\log\frac{A}{S} - 3 \qquad dB(A)$$

Where:
R_A is the overall sound reduction index of the facade in dB(A)
A is the room absorption in m^2 sabine
S is the total surface area of the facade in m^2.

Ventilation through the building envelope can be achieved by:
- joints and cracks around windows and doors (uncontrolled ventilation);
- ventilation openings in the facades (grilles and windows);
- air ducts in facades and the roof, with or without grilles.

The way in which the contribution of the ventilation openings is taken into accound depends on the way in which the sound reduction of each opening is expressed. The sound reduction index of a ventilation opening may concern i.e. the flow capacity, the cross section of the ventilation surface area, the gross surface area of the ventilation grille or a standardized roomabsorption, such as 10 m^2 sabine.

3.2. Noise reduction of facades

The transfer of noise across facades takes the following paths:
- closed facade areas (brickwork, panels)
- glass
- ventilation openings
- joints and cracks

If noise reduction beyond approximately 20 dB(A) is required, any joints and cracks will have to be properly sealed. Certain noise reduction standards thus prevent the possibility of ventilation by means of infiltration of air through joints and cracks in the facade. Other ventilation provisions will then be necessary, such as special - soundproofed - supply openings. Considerations of energy conservation and comfort also render uncontrolled ventilation by means of infiltration undesirable.

Acoustic provisions taken at the ventilation openings may include:
- soundproofed ventilation openings in windows;
- soundproofed ventilation openings in facades.

Alternatively, the air supply can be effected in part through noise-free facades.

Table 2 shows the maximum noise reduction values (G_A) of properly soundinsulated facades, such as brickwork, with a ventilation opening, based on a standard room with a volume of 80 m^3 and a facade surface area of 10 m^2.

Table 2: Maximum noise reduction values (G_A) of a closed facade with ventilation openings without soundproofing.

Cross-section of the ventilation opening [cm²]	Maximum noise reduction [dB(A)]
10	40
50	34
100	31
200	28
300	26
400	25
500	24

Table 3 shows the noise reduction value of the facade as a function of the average noise reduction of a closed facade (i.e. without windows) and as a function of the size of the soundproofed ventilation opening (noise insulation of the opening is 12 dB(A), relating to the cross section of the ventilation opening).

Table 3: Maximum noise reduction values (G_A) of facades with soundproofed ventilation openings.

Noise insulation facade [dB(A)]	Cross-section of the ventilation opening (R_A = 12 dB(A)) cm²							
	0	10	50	100	200	300	400	500
20	21	21	21	21	21	21	21	21
25	26	26	26	26	26	26	26	26
30	31	31	31	31	31	30	30	30
35	36	36	36	35	35	34	34	33
40	41	41	40	39	38	37	36	35
45	45	44	43	41	39	38	37	36

Table 3 shows that a noise reduction of 35 dB(A) can be achieved using a soundproofed opening with a cross section of 200 cm^2. If the cross-section of the opening is 500 cm^2, the average noise insulation of the closed facade must be increased from 35 dB(A) to 40 dB(A).

Hence the nature of the acoustic provisions to be taken with regard to the building envelope of a dwelling or a residential building can only be determined within the wider context of the quality of the construction.

To illustrate the interdependence of the acoustic properties of the different facade elements (i.e. brickwork, glass, ventilation openings and crack sealing), a mathematical comparison has been made between the different types of facade.
The comparison is based on a room with a volume of 40 m^3. The total facade surface area is 10 m^2. The facade contains a window with a surface area of 3 m^2 and the room's reverberation time amounts to 0.5 s.
The closed facade consists of brickwork and the supply of ventilation air takes place by means of a soundproofed or non-soundproofed opening with a cross-section of 150 cm^2.
A number of glazing alternatives have been evaluated: standard double glazing (4 mm glass - 12 mm cavity - 6 mm glass), high-quality acoustic glazing (8 mm glass - 20 mm gas-filled cavity - 10 mm layered glass) and optimal soundproofing glass (42 mm layered glass).

Table 4 gives an overview of the maximum attainable noise reduction values pertaining to this type of facade.

Table 4: Maximum attainable noise reduction values (G_A) for a number of alternative facade types.

Description	Noise reduction dB(A)			
	A	B	C	D
standard glass, no weatherstripping	20.9	22.1	22.3	22.3
standard glass, minor weatherstripping	23.1	25.2	25.7	25.8
standard glass, good single	24.5	27.8	28.7	28.9
weatherstripping	26.2	32.8	36.4	37.6
HQ ac. glass, double weatherstripping	26.4	34.0	40.2	44.0
Max. ac. glass, very good				
weatherstripping				

A = ventilation opening without soundproofing
B = ventilation opening with adequate soundproofing
C = ventilation opening with excellent soundproofing
D = no ventilation opening

Noise reduction can be as much as 40 dB(A) if the ventilation openings are retained. This can only be achieved by means of proper soundproofing of the closed facade elements. In the case of a sandwich panel facade (timber thermal insulation timber), the last step towards an optimal level of provisions will not yield any improvement from C to D. Noise reduction will be restricted to approximately 32 dB(A). The reason for this is the noise contribution of the closed facade. Elaborate acoustic provisions to windows and ventilation openings can only be cost-effective if the other facade elements have good soundproofing properties.

Acoustic measures must be taken in the correct order:

- first apply adequate weatherstripping;
- then apply soundproofing to the ventilation opening;
- and finally improve the quality of the glass.

3.3. Soundproofing of air ducts

The noise reduction values of rooms with air exhaust ducts for natural ventilation (i.e. ventilation stacks or "shunt" ducts) may be influenced by noise sources at the level of the roads, i.e. aircraft and elevated roads.
If these rooms have facades without soundproofing provisions ($G_A \approx 20$ dB(A)) such air ducts will have a negligible influence on the noise reduction value (0 to 1 dB). If facades have a higher noise reduction value (i.e. 30 dB(A) to 35 dB(A)) the influence of the air duct will be noticeable. Table 5 gives an indication of the effect of an exhaust duct with a cross-section of 200 cm^2 on the noise reduction value of a room with a volume of 40 m^3.

Table 5: The effect of an exhaust duct on the noise reduction value (Δ R).

G_A	Δ R [dB(A)]
20	- 1.0
25	- 2.5
30	- 5.5
35	- 9.5

Metal air ducts of mechanical ventilation systems will have similar acoustic properties. If higher noise reduction values than the above are required, acoustic measures are necessary such as the application of silencers or soundproofed grilles.
In general, however, noise levels resulting from outdoor noise will be lower than the soundpower level L_w generated by the fan (see also chapter 4.1.).

4. Noise generated by the ventilation system

4.1. Requirements and methods of calculation and measurement

The air duct system inside dwellings is responsible for the transport of noise generated by the fan and aerodynamic noise generated by bends, control valves and grilles.

Table 6 shows the maximum indoor noise level criteria in a number of countries with respect to noise generated by the ventilation system in rooms.

Table 6: Maximum allowable indoor noise levels generated by the ventilation system.

Country	Maximum allowable noise level	Note
Belgium	--	--
Canada	NC 30	livingrooms
Finland	30 dB(A)	livingrooms, bedrooms, unfurnished
France	30 dB(A)	
The Netherlands	30 dB(A)	For noise sources from other dwellings
Sweden	30 dB(A)	night, including all installations
United Kingdom	35 dB(A)	mech.ventilation in sound insulation schemes
USA	--	--

The sound power level (L_w) at the optimal operating point of the fan can be approximated by means of the following simplified formula:

$$L_W = L_{WS} + 10 \log q_v + 20 \log \Delta p \quad \text{dB}$$

The following applies to all fan types:

$L_{WS} = 1 \pm 4$ dB

q_v is the flowcapacity in m^3/h

Δp is the total pressure difference across the fans (Pa)
In general, fans for single family dwellings have a A-weighted sound power level $L_{W(A)}$ of 60 to 65 dB(A).

For the determination of the octaveband spectrum corrections must be applied. These octaveband corrections depend on the fantype and the fanspeed. In dwellings centrifugal fans are commenly used. In table 7 an example of the corrections for this fantype is given.

Table 7: Example of octaveband corrections for a centrifugal fan.

Frequency	**(Hz)**	**63**	**125**	**250**	**500**	**1K**	**2K**	**4K**
Correction	(dB)	-9	-6	-6	-7	-12	-15	-19

4.2. Sound reducing measures inside air ducts

The noise generated by fans is propagated through the air duct system. If no special noise soundproofing measures are taken, the resulting noise levels can be considerably higher than the maximum allowable ones. Without special soundproofing measures, internal noise levels of 30 to 45 dB(A) in rooms can be expected. This requires the use of soundproofing materials inside the air duct system.

Soundproofing materials in the supply system should ideally be placed immediately after the unit, but always before the first branching of the duct. If the system is a combined ventilation/heating system, with recirculation taking place by means of a return duct, soundproofing materials should also be placed at the inlet of the fan, immediately before the heatersection.

Soundproofing provisions for domestic ventilation systems usually consist of soundproofing (flexible) tubes (silencers). Alternatively, double-walled steel ducts insulated with mineral wool and with a perforated inner duct can be used.

A silencer consist of a perforated inner duct, a casing of mineral wool and an outer duct. The ducts may be plastic or metal and are often flexible to a certain extent. If plastic ducts are being used, which are often made of reinforced foil (highly flexible tubes), the noise penetration and emissions must be observed. In the case of air heating or after-heating, the maximum allowable air temperature also requires attention.
Silencers are relatively cheap and easy to integrate in an air duct system. They demand hardly any extra space. The noise attenuation of these materials is poor at low frequencies, especially if the walls provides a certain degree of soundreduction. Silencers made of thin foil provide better soundproofing at low frequencies, as a result of the fact that low-frequency noise is emitted. This can be a problem in open setups near rooms. Another disadvantage is that the soundproofing effects decrease proportionally to the increase of the internal diameter.
These silencers are therefore suitable primarily in air duct systems with internal duct diameters not exceeding 150 mm. Silencers can still be used with duct diameters of 150 mm to 250 mm but the required silencer length increases considerably. With diameters greater than 250 mm the use of a silencer is not recommended.

Table 8 gives an indication of the required dimensions of silencers for various capacities. Silencers must not be used as bends and must be mounted tightly, just like flexible ducts.

Table 8: Indication of the required dimensions of silencers for various capacities.

	Flowcapacity q_v (m^3/h)	Diameter (mm)		Insulator length (mm)
		internal	external	
ducts directly connected to rooms	q_v < 100	100	200	1000
	100 < q_v < 250	150	250	1000
ducts directly connected to other spaces	q_v < 100	100	200	750
	100 < q_v < 250	150	250	750

Aerodynamic noise restricts the velocity of the air passing through the silencers to 4 to 5 m/s. Hence the maximum flowcapacity will be approximately 850 m^3/h of the mineral wool casing should ideally be at least 50 mm. Silencers must be carefully connected to the ducts so as to achieve an airtight connection.

Double-walled insulated ducts consist of a metal spiral seam inner and outer pipe separated by a layer of soundabsorping material with a thickness of 10 to 20 mm. Soundproofing of these ducts can be achieved by using mineral wool as an insulator and perforating the inner duct. The perforation level should be approximately 13%. This will render the ducts eminently suitable for combined thermal and soundproofing. As a result of the thinness of the casing, the noise insulating value per linear meter is relatively low, in particular at low frequencies.

The lengths to be applied must therefore be:

- at least 2.0 m for internal diameters up to 80 mm.
- at least 4.0 m for internal diameters up to 125 mm.

Double-walled insulated ducts can also be encased within concrete floors.

4.3. Acoustic properties of grilles

The A-weighted sound power level of grilles can be approximated by:

$$L_{W(A)} = -4 + 70 \log v + 30 \log \xi + 10 \log S$$

Where:

v is the air velocity across the grille in m/s

ξ is the airflow resistance factor (-).

S surface area of the grille in m^2.

Supply grilles must be selected on the basis of the nominal sound power levels to meet the required noise levels. Manufacturers have various ways of indicating the acoustic data. They usually provide a manual to help select the grilles on the basis of their acoustic properties. Sound power levels of grilles must be measured in accordance with ISO/DP5135. Instead of listing the sound power levels (L_w) generated by the grilles, some manufacturers prefer to give the sound pressure levels (L_p) in an average room.

In general the maximum allowable sound power levels (L_w) of grilles will be:

- bedrooms: approx. 35 dB(A)
- living rooms:
  - one grille : approx. 35 dB(A);
  - two grilles : approx. 32 dB(A);
  - three grilles : approx. 30 dB(A).

4.4. Aerodynamic noise inside ducts

The following points must be observed in order to prevent aerodynamic noise inside the ducts:

- The maximum allowable air velocity inside branches to the grilles is 2 m/s.
- The maximum allowable air velocity in the main ducts is 4 m/s.
- The use of round ducts is preferred.

- Sharp bends should be avoided and changes of cross-sectional areas of the ducts should be smooth.
- The system must be designed in such a way as to require the minimum number (preferably no) control valves. If the use of control valves cannot be avoided, these should be low-noise valves; perforated butterfly valves are preferred to solid butterfly valves. If possible, control valves must be positioned in front of the silencers.
- Air velocity inside the silencers must be such that the aerodynamic noise generated is 10 dB lower than the ventilation noise immediately after the silencer.

  In general, the maximum allowable air velocity inside the silencer is 4 to 5 m/s.

4.5. Fanlocation

If the vibrations generated by a fan or a fanunit are transferred directly to the construction, the maximum allowable inside room noise levels may be exceeded. Fans should be placed in a vibration-insulated position on floors with a mass of less than 200 kg/m^2 in the case of single-family dwellings and on floors with a mass of 400 kg/m^2 in the case of multi-family dwellings. Vibration insulation may be achieved by placing the four corners of the unit on rubber blocks (Shore 45), with a vulcanized plate, and provided with studs or other mounting facility. The thickness of the rubber layer must be at least 30 mm. The total surface area of the four rubber blocks must be such that the load is 4 to 5 kg/cm^2.

It is also possible to place the fan on elastic rigid mineral wool plates (compression at least 80 kg/m^2) with a thickness of at least 50 mm, if necessary on top of a pressure compensation layer.

A flexible connection piece must be used to attach the ducts to the unit. In the room in which the unit is located, metal ducts must be used with walls of at least 0.5 mm thick.

5. Sound transportation in or between dwellings

5.1. Requirements and methods of calculation and measurement

With respect to the soundrequirements between two rooms, a distinction is made between rooms within the same dwelling on the one hand and between one dwelling and another or between a room in a dwelling and a space outside it on the other hand. More stringent requirements apply to constructions which separate two adjacent dwellings. To specify the sound insulation between dwellings or between rooms it is not sufficient to use a single figure index as soundinsulation is a function of frequency. Hence it should be specified over the frequency range. It is usual to specifiy the insulation as a curve or as a figure index calculated on basis of this curve. The measured insulation of a wall or floor should not come below this curve by more than a recommended amount. Table 9 gives an overview of the current sound insulation requirements and standards in a number of countries applying to adjacent dwellings. Table 10 gives an overview of the sound insulation requirements applying to rooms within the same dwelling.

Table 9: Sound insulation requirements between dwellings.

Country	**Sound insulation between dwellings**	**Standard**	**Note**
Belgium	-->	NBN 501-400	
Canada	50 dB	NBC	(sound transm.classrating)
Finland	--		
France	--		
The Netherlands	$I_{uk} \geq$ = 0 dB	NEN 5077	
Sweden	Rw = 55 dB	SS-ISO 717/1	terraced houses,
	Rw = 52 dB	"	flats horizontal
	Rw = 53 dB	"	flats vertical
United Kingdom	--		
USA	--		

Table 10: Sound insulation requirements between rooms.

Country	**Sound insulation dB(A)**	**Standard**
Belgium	-	
Canada	-	
Finland	-	
France	-	
The Netherlands	$l_{uk} \geq$ = - 20	NEN 5077
Sweden	-	
United Kingdom	-	
USA	-	

The sound insulation characteristic of a wall is usually expressed as the sound reduction index R. The sound reduction index R between two rooms can be evaluated from:

$$R = L_{ps} - L_{pr} + 10 \log S/A \quad dB$$

where:

L_{ps} is the sound pressure in source room in dB
L_{pr} is the sound pressure in receiving room in dB
S is the surface area separating wall in m^2
A is the room absorption in m^2 sabine.

The sound reduction index R is the result of the different sound channels from the one room to the other. This composite sound reduction index R' value is determined by:

$$R' = -10 \log \sum_{j=1}^{n} \frac{S_j}{S_{tot}} 10^{-Rj/10} \qquad \text{dB}$$

One of the sound channels may be a ventilation system. This phenomenon is also called cross-talk. Cross-talk can be defined as the effect that system components have on the integrity of the sound reduction between two rooms. Cross-talk is of particular concern in balanced ventilation systems and in collective air ducts between dwellings. It can be brought about in the following ways:

- Through the air duct system:
  The sound of voices in one room, for example, is propagated through the air duct system and can be heard in other rooms, the sound apparently coming from the ventilation grille, which acts as a 'loudspeaker'. This phenomenon can take place both between rooms within the same dwelling and between rooms in two different dwellings.
- Through the overflow grilles or openings underneath doors. To facilitate the transport of air inside the dwelling, that is, from the place where air enters the rooms to the place where the air is suctioned off, overflow grilles are placed or the doors are shortened at the bottom. Cross-talk may occur in the case where two rooms have such openings near one another.
- through the duct transitions in walls or floors.

5.2. Cross-talk through the duct system between dwellings

In general the average sound reduction index R_m in the range between 125 and 2000 Hz for constructions between dwellings must be 50 to 52 dB in order to comply with the requirements in table 9.
When complying with this requirement, there must not be a decrease of the sound reduction between dwellings as a result of the transfer of noise

through shared ventilation ducts.
Both natural and collective mechanical ventilation duct systems usually require sound proofing provisions.

Such provisions may consist of:
- a silencer in front of each outlet or between outlets;
- a soundproofed grille at each outlet.

The total insertion loss must at least comply with the values given in table 11.

Table 11. Minimum insertion loss for a duct between two dwellings.

octave band medium frequency	125	250	500	1000	2000	Hz
insulation	0	5	10	15	15	dB

5.3. Cross-talk through the duct system within dwellings

In general, constructions which separate rooms must have an average sound reduction index R_m of 34 dB.
Cross-talk through a duct system can have an adverse effect here. In dwellings cross-talk occurs mainly in the supply duct of a balanced ventilation system.

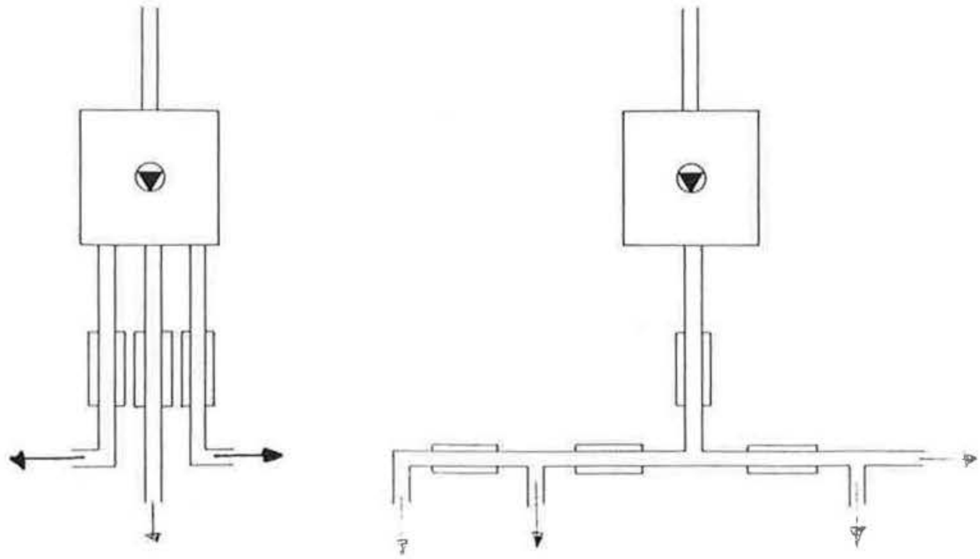


Figure 2. Two basic air supply systems

Systems with supply ducts leading from each room directly to the ventilation unit (radial system) require soundproofing (silencers or soundproofed plenum) in order to reduce the fannoise. Chapter 4.2. deals with this aspect in greater detail. Such silencers are usually placed immediately after the fan unit. The cross talk sound reduction index between two rooms complies with the above-mentioned sound insulation requirements. Additional measures are therefore not necessary.

If rooms are directly linked with one another by the supply duct system, the possibility of cross-talk exists. The effects of cross-talk in the system on the average sound reduction index is approximately 14 dB. In this case the overall sound reduction index value is 31 dB and additional measures are necessary. This can be a silencer in the duct between two rooms. This silencer must have a length of at least 0.5 m and a thickness of the absorption material of 25 mm. Alternatively, there are grilles available equipped with sound proofing material which are capable of preventing cross-talk.

5.4. Cross-talk through overflow provisions

When doors are shortened at the bottom to facilitate air transport inside a dwelling, the following factors should be taken into account:

- Doors must be shortened by 3 mm for each 10 m^3/h of air supplied to or removed from the room.
- If the doors of two adjacent rooms are directly beside one another, the sound reduction index of the separating wall must be higher than the minimum required value in order to compensate for the transfer of noise through the gap underneath the door.
  In this case, the average sound insulation index R_m of the separating wall must be 36 dB instead of 34 dB.

If return grilles are fitted in a corridor, doors must not be shortened by more than the above-mentioned 3 mm for each 10 m^3/h so as to prevent the transfer of noise.

5.5. Duct transitions

Improperly constructed duct transitions may creat acoustic leaks between the air duct and the separating wall. Soundproof connections between the duct and the separating wall are therefore recommended. These can be achieved by using a sealing glue or an airtight sealant.

Appendix 1.1.

Appendix 1.1.

Example on systems with defined sources and calculated noise levels

1. Introduction

In figure 1 an example is given of a typical dutch single family dwelling. On the ground-level there is a living room, a kitchen (as a separated room), a toilet and a hall. On the first floor there are three bedrooms and a bathroom. The attic is used as a storage place and has a location for the boiler and for a fan-unit. In table 1 some data are given are give for each room.

Table 1. Data of the example dwelling

	Area (m^2)	Volume (m^3)	Ventilation capacity * (dm^3/s)	Reverberation time (s)	Sabine absorption (m^2)
Livingroom	24,2	60,5	24,2	0,5	20,2
Kitchen	6,8	17,1	21,0	0,8	3,6
Bedroom 1	10,7	26,8	10,7	0,5	8,9
Bedroom 2	9,7	24,3	9,7	0,5	8,1
Bedroom 3	7,2	18,0	7,2	0,5	6,0
Bathroom	6,2	15,4	14,0	0,8	3,2

* According to the Dutch ventilation standards 1 dm^3/s per m^2 floor area, kitchen 21 dm^3, bathroom 14 dm^3, toilet 7 dm^2.

For this dwelling the noise aspects are considered for the following ventilation systems:

- natural ventilation by means of ventilation grilles or ventilation windows in the facade and a mechanical exhaust in kitchen, bathroom and toilet;
- mechanical supply and exhaust (balanced ventilation with heat recovery) with supply of air in the bedrooms and livingroom and exhaust in kitchen, bathroom and toilet.

Figure 1. Example single family dwelling.

2. Natural supply

In figure 2 a situation is given with a road near the dwelling.

The distance between the road and the facade is 15 m.

If there are less than 2500 vehicles /24h, with a speed of 50 km/h, the noiselevel will be $\leq$ 55 dB(A).

If the traffic intensity is about 10.000 vehicles/24h, with a speed of 50 km/h, the noiselevel will be 65 dB(A). In table 2 the A-weighted, octave-band correction for typical traffic-noise is given.

table 2. Relative traffic noise spectrum.

Frequency Hz	125	250	500	1k	2k
A-weighted correction dB	-14	-10	-5	-6	-7

The noise limit that requires acoustic measures is approximately 55 dB(A). This also appears from the calculated percieved indoor noiselevels due to traffic noise:

Asume, the facades have the following constructions:
- facade, masonry brickwork, R_a = 46 dB(A);
- windows, doubleglazing (6 mm-6mm cavity-4mm), R_a = 28 dB(A);
- simple weather stripping, R_a = 35 dB(A);
- ventilation openings, without any acoustic demping.

In the calculations, the sound reduction of these ventilation opening is related to the flowcapacity, determined by 1 Pa (this, in fact, is the air permeability coëfficiënt C in $dm^3/s\ Pa^{1/n}$ by 1 Pa). For an undamped ventilation grille the sounddreduction is -4 dB(A); for a small ventilation window the soundreduction is -5 dB(A).

N.B. A flowcapacity measured by 1 Pa means a cros-section surface area of approximately 120 cm^2/m^1.

This results in the following indoor noise levels:
livingroom : 34 dB(A)
bedroom 1 : 34 dB(A)
bedroom 3 : 35 dB(A)
bedroom 2 : 34 dB(A)
kitchen : 41 dB(A)

In the case that the noiselevel on the facade is 65 dB(A) acoustic measures are required , i.e.:
acoustic glazing 6-16-8 mm, R_a = 31 dB(A);
sound proofed ventilation grille, R_a = 9,5 dB(A) (considering the flow capacity by 1Pa);
good weather stripping, R_a = 40 dB(A).
These acoustic measures result in the following percieved indoor noiselevels:
livingroom : 34 dB(A)
bedroom 1 : 34 dB(A)
bedroom 2 : 34 dB(A)
bedroom 3 : 35 dB(A)
kitchen : 39 dB(A)

A better quality sound proofed ventilation grille (R_a = 12 dB(A)) results in approximately 1 dB lower indoor noise levels.

Calculations of the sound reduction and percieved indoor noise levels are given in appendix 1.2.

3. Balanced ventilation

In figure 3 an isometric projection is given of the airductsystem for a balanced ventilation system with heat recovery. The noiselevels are calculated for two different ventilation heatrecovery-units. These two units have the following characteristics.

Table 3. Characteristics by maximum capacity.

		Δ p (Pa)	q_v (m^3/h)	Lw(A) dB(A)
unit 1	supply	150	225	68
	exhaust	150	225	57*
unit 2	supply	140	225	67
	exhaust	160	225	43*

* Fan located behind the heat recovery block, see figure 4.

These two units have a different noise spectrum. The noise production of unit 1 has a low-frequency character. The noise spectrum of unit 2 is more high frequent. Although the A-weighted sound power levels (L_{wa}) of both units are almost the same, this difference in frequency characteristics has an important influence on the sound power levels in rooms and the required length of the silencers. While noise attenuation is rather poor at low frequences and also the natural sound damping in ducts is much more effective in high frequences, the required length of the silencers for unit 1, shall increase.

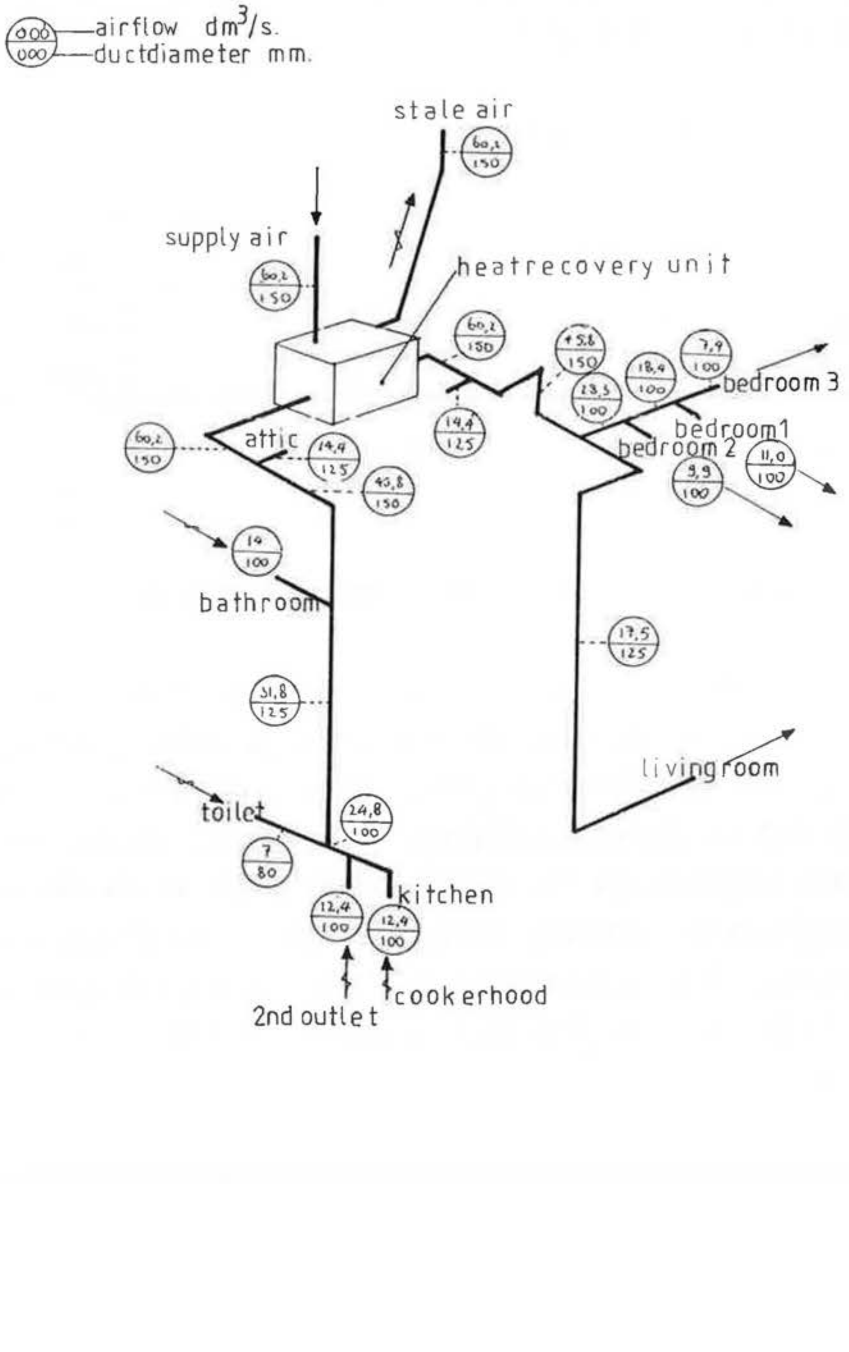


Figure 3. Isometric projection air duct system

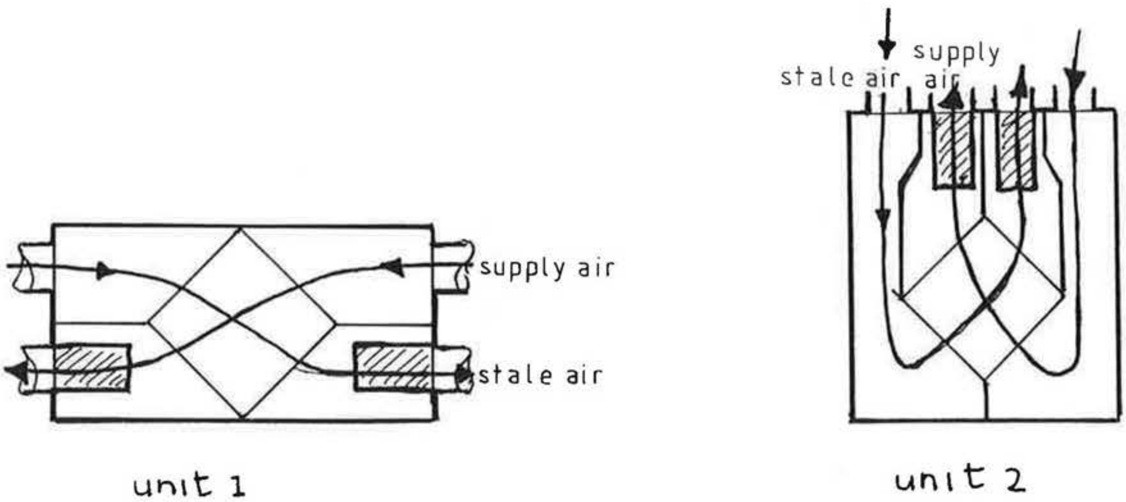


Figure 4. Two heat recovery units.

In tables 4 a scheme is given of the occuring sound pressure levels in dB(A) in the different rooms.

Table 4. Noise levels in rooms generated by heat recovery units (dB(A))

Unit 1	Without silencers	Supply silence 1m Exhaust silencer 1 m	Silencers 1 m + crosstalk silencers 0,5 m
Livingroom	48	35	30
Bedroom 1	44	31	25
bedroom 2	45	32	26
Bedroom 3	50	35	30
Kitchen	41	28	28
Bathroom	42	28	28

Unit 2	Without silencers	Supply silencer 1 m Exhaust silencer 0 m	Only crosstalk silencers 0,5 m; no other silencers
Livingroom	38	23	30
Bedroom 1	35	19	26
Bedroom 2	36	19	27
bedroom 3	42	24	32
Kitchen	26	26	26
Bathroom	27	27	27

Calculations of the noise levels generated by these heatrecovery-units are given in appendix 1.3.

4. Crosstalk

In this example the seperationwalls between the bedrooms consist of 70 mm gypsumblocks. The average sound reduction index Rm is 32 dB. Crosstalk as a result of transfer of noise through shared ducts between two bedrooms gives an adverse deviation of 2 dB through which the average sound reduction index R_m is 30 dB. By adding a silencer of 0,5 m with a thickness of 25 mm the average sound reduction index R_m of 32 dB(A) does not change. A seperationwall with a better sound insulation (for instance 100 m gypsumblocks, Rm value is 34 dB) crosstalk will decrease the Rm-value till 32 dB. In this case also, a silencer of 0,5 m is sufficient to maintain a Rm value of 34 dB.
The floor between the bedroom and the livingroom has a much higher Rm-value: Rm is 50 dB. Crosstalk through the ducts gives an adverse deviation of 9 dB. Using a silencer of 0,5 m this deviation becomes 2 dB, hence the average sound reductionindex is 48 dB. Using a silencer of 1,0 m and a thickness of 50 mm gives a Rm value of 49 dB.
Hence, if a ventilation duct is a part of the separation between two dwellings, a silencer of at least 1,0 m is required to meet the standards of the sound insulation between dwellings.

Calculations are given in appendix 1.4.

Appendix 1.2. Calculations traffic noise and percieved indoor noise level.

CAUBERG - HUYGEN   RAADGEVENDE INGENIEURS BV MAASTRICHT

ADRES :
spectrum :standard traffic noise   werk :annex 27
outdoor noise level: 55.0 dB(A)   date :10-2-94
jh

ROOM : livingroom
ventilation demand : 24.2 l/s   To : 0.5 sec.
Volume : 60.5 m3

K-factor = 35: minor weatherstripping
K-factor = 40: good single weatherstripping

FACADE 1 K-factor: 35 Cr: -3.0	S	Ra	Ra part
double glazing 4-6-6	4.5900	28.0	32.4
brickwork + therm. insulation	6.6600	46.0	48.7
ventilation opening without soundproofing	0.0242	-5.0	22.1
door 27 kg/m2	1.2300	30.0	40.1
			999.0
			999.0
Stot	12.50	Ga1	20.5

K-factor: Cr:	S	Ra	Ra part
			999.0
			999.0
			999.0
			999.0
			999.0
			999.0
Stot	0.00	Ga2	999.0

K-factor: Cr:	S	Ra	Ra part
			999.0
			999.0
			999.0
			999.0
			999.0
			999.0
Stot	0.00	Ga3	999.0

K-factor: Cr:	S	Ra	Ra part
			999.0
			999.0
			999.0
			999.0
			999.0
			999.0
Stot	0.00	Ga4	999.0

S totaa 12.5 Gatot 20.5 = noise reduction value

indoor noise level=outdoor noise level - noise reduction value 34.5 dB(A)

CAUBERG - HUYGEN   RAADGEVENDE INGENIEURS BV MAASTRICHT

ADRES :
werk :annex 27
spectrum :standard traffic noise
date :10-2-94
outdoor noise level: 65.0 dB(A)
jh

ROOM : livingroom
ventilation demand : 24.2 l/s
To : 0.5 sec.
Volume : 60.5 m3

K-factor = 35: minor weatherstripping
K-factor = 40: good single weatherstripping

FACADE 1 K-factor: 40 Cr: -3.0	S	Ra	Ra part
double glazing 6-16-8	4.5900	31.0	35.4
brickwork + therm. insulation	6.6600	46.0	48.7
soundproofed vent. opening Al Cadet st 110	0.0246	9.5	36.6
door 27 kg/m2	1.2300	30.0	40.1
			999.0
			999.0
Stot	12.50	Ga1	30.5

K-factor: Cr:	S	Ra	Ra part
			999.0
			999.0
			999.0
			999.0
			999.0
			999.0
Stot	0.00	Ga2	999.0

K-factor: Cr:	S	Ra	Ra part
			999.0
			999.0
			999.0
			999.0
			999.0
			999.0
Stot	0.00	Ga3	999.0

K-factor: Cr:	S	Ra	Ra part
			999.0
			999.0
			999.0
			999.0
			999.0
			999.0
Stot	0.00	Ga4	999.0

S totaa 12.5 Gatot 30.5 = noise reduction value

indoor noise level=outdoor noise level - noise reduction value 34.5 dB(A)

CAUBERG - HUYGEN RAADGEVENDE INGENIEURS BV MAASTRICHT

ADRES :
spectrum :standard traffic noise
outdoor noise level: 65.0 dB(A)

werk :annex 27
date :10-2-94
jh

ROOM : livingroom
ventilation demand : 24.2 l/s

To : 0.5 sec.
Volume : 60.5 m3

K-factor = 35: minor weatherstripping
K-factor = 40: good single weatherstripping

FACADE 1 K-factor: 40 Cr: -3.0	S	Ra	Ra part
double glazing 6-16-8	4.5900	31.0	35.4
brickwork + therm. insulation	6.6600	46.0	48.7
soundproofed vent. opening Al Cadet Plus 110	0.0243	12.0	39.1
door 27 kg/m2	1.2300	30.0	40.1
			999.0
			999.0
Stot	12.50	Ga1	31.1

K-factor: Cr:	S	Ra	Ra part
			999.0
			999.0
			999.0
			999.0
			999.0
			999.0
Stot	0.00	Ga2	999.0

K-factor: Cr:	S	Ra	Ra part
			999.0
			999.0
			999.0
			999.0
			999.0
			999.0
Stot	0.00	Ga3	999.0

K-factor: Cr:	S	Ra	Ra part
			999.0
			999.0
			999.0
			999.0
			999.0
			999.0
Stot	0.00	Ga4	999.0

S totaa 12.5 Gatot 31.1 = noise reduction value

indoor noise level=outdoor noise level - noise reduction value 33.9 dB(A)

CAUBERG - HUYGEN RAADGEVENDE INGENIEURS BV MAASTRICHT

ADRES : werk :annex 27
spectrum :standard traffic noise date :10-2-94
outdoor noise level: 55.0 dB(A) jh

ROOM : kitchen
ventilation demand : 21.0 l/s To : 0.8 sec.
Volume : 17.2 m3

K-factor = 35: minor weatherstripping
K-factor = 40: good single weatherstripping

FACADE 1 K-factor: 35 Cr: -3.0	S	Ra	Ra part
double glazing 4-6-6	1.3800	28.0	34.9
brickwork + therm. insulation	5.3600	46.0	47.0
ventilation opening without soundproofing	0.0210	-5.0	20.1
			999.0
			999.0
			999.0
Stot	6.76	Ga1	14.0

K-factor: Cr:	S	Ra	Ra part
			999.0
			999.0
			999.0
			999.0
			999.0
			999.0
Stot	0.00	Ga2	999.0

K-factor: Cr:	S	Ra	Ra part
			999.0
			999.0
			999.0
			999.0
			999.0
			999.0
Stot	0.00	Ga3	999.0

K-factor: Cr:	S	Ra	Ra part
			999.0
			999.0
			999.0
			999.0
			999.0
			999.0
Stot	0.00	Ga4	999.0

S totaa 6.8 Gatot 14.0 = noise reduction value

indoor noise level=outdoor noise level - noise reduction value 41.0 dB(A)

CAUBERG - HUYGEN   RAADGEVENDE INGENIEURS BV MAASTRICHT

ADRES : werk :annex 27
spectrum :standard traffic noise date :10-2-94
outdoor noise level: 65.0 dB(A) jh

ROOM : kitchen
ventilation demand : 21.0 l/s To : 0.8 sec.
Volume : 17.2 m3

K-factor = 35: minor weatherstripping
K-factor = 40: good single weatherstripping

FACADE 1 K-factor: 40 Cr: -3.0	S	Ra	Ra part
double glazing 6-16-8	1.3800	31.0	37.9
brickwork + therm. insulation	5.3600	46.0	47.0
soundproofed vent. opening Al Cadet st 110	0.0213	9.5	34.5
			999.0
			999.0
			999.0
Stot	6.76	Ga1	26.2

K-factor: Cr:	S	Ra	Ra part
			999.0
			999.0
			999.0
			999.0
			999.0
			999.0
Stot	0.00	Ga2	999.0

K-factor: Cr:	S	Ra	Ra part
			999.0
			999.0
			999.0
			999.0
			999.0
			999.0
Stot	0.00	Ga3	999.0

K-factor: Cr:	S	Ra	Ra part
			999.0
			999.0
			999.0
			999.0
			999.0
			999.0
Stot	0.00	Ga4	999.0

S totaa 6.8 Gatot 26.2 = noise reduction value

indoor noise level=outdoor noise level - noise reduction value 38.8 dB(A)

CAUBERG - HUYGEN RAADGEVENDE INGENIEURS BV MAASTRICHT

ADRES :
spectrum :standard traffic noise
outdoor noise level: 65.0 dB(A)

werk :annex 27
date :10-2-94
jh

ROOM : kitchen
ventilation demand : 21.0 l/s

To : 0.8 sec.
Volume : 17.2 m3

FACADE 1	K-factor: 40 Cr: -3.0	S	Ra	Ra part
double glazing 6-16-8		1.3800	31.0	37.9
brickwork + therm. insulation		5.3600	46.0	47.0
soundproofed vent. opening Al Cadet Plus 110		0.0211	12.0	37.1
				999.0
				999.0
				999.0
	Stot	6.76	Ga1	27.4

K-factor = 35: minor weatherstripping
K-factor = 40: good single weatherstripping

	K-factor: Cr:	S	Ra	Ra part
				999.0
				999.0
				999.0
				999.0
				999.0
				999.0
	Stot	0.00	Ga2	999.0

	K-factor: Cr:	S	Ra	Ra part
				999.0
				999.0
				999.0
				999.0
				999.0
				999.0
	Stot	0.00	Ga3	999.0

	K-factor: Cr:	S	Ra	Ra part
				999.0
				999.0
				999.0
				999.0
				999.0
				999.0
	Stot	0.00	Ga4	999.0

S totaa 6.8 Gatot 27.4 = noise reduction value

indoor noise level=outdoor noise level - noise reduction value 37.6 dB(A)

CAUBERG - HUYGEN RAADGEVENDE INGENIEURS BV MAASTRICHT

ADRES :
werk :annex 27
spectrum :standard traffic noise
date :10-2-94
outdoor noise level: 55.0 dB(A)
jh

ROOM :bedroom 1
ventilation demand : 11.0 l/s
To : 0.5 sec.
Volume : 26.7 m3

FACADE 1 K-factor: 35 Cr: -3.0	S	Ra	Ra part
double glazing 4-6-6	2.0000	28.0	33.3
brickwork + therm. insulation	4.7500	46.0	47.5
ventilation opening without soundproofing	0.0110	-5.0	22.9
			999.0
			999.0
			999.0
Stot	6.76	Ga1	20.5

K-factor = 35: minor weatherstripping
K-factor = 40: good single weatherstripping

K-factor: Cr:	S	Ra	Ra part
			999.0
			999.0
			999.0
			999.0
			999.0
			999.0
Stot	0.00	Ga2	999.0

K-factor: Cr:	S	Ra	Ra part
			999.0
			999.0
			999.0
			999.0
			999.0
			999.0
Stot	0.00	Ga3	999.0

K-factor: Cr:	S	Ra	Ra part
			999.0
			999.0
			999.0
			999.0
			999.0
			999.0
Stot	0.00	Ga4	999.0

S totaa 6.8 Gatot 20.5 = noise reduction value

indoor noise level=outdoor noise level - noise reduction value 34.5 dB(A)

CAUBERG - HUYGEN RAADGEVENDE INGENIEURS BV MAASTRICHT

ADRES : werk :annex 27
spectrum :standard traffic noise date :10-2-94
outdoor noise level: 65.0 dB(A) jh

ROOM :bedroom 1
ventilation demand : 11.0 l/s To : 0.5 sec.
Volume : 26.7 m3

FACADE 1 K-factor: 40 Cr: -3.0	S	Ra	Ra part
double glazing 6-16-8	2.0000	31.0	36.3
brickwork + therm. insulation	4.7500	46.0	47.5
soundproofed vent. opening Al Cadet st 110	0.0112	9.5	37.3
			999.0
			999.0
			999.0
Stot	6.76	Ga1	30.9

K-factor = 35: minor weatherstripping
K-factor = 40: good single weatherstripping

K-factor: Cr:	S	Ra	Ra part
			999.0
			999.0
			999.0
			999.0
			999.0
			999.0
Stot	0.00	Ga2	999.0

K-factor: Cr:	S	Ra	Ra part
			999.0
			999.0
			999.0
			999.0
			999.0
			999.0
Stot	0.00	Ga3	999.0

K-factor: Cr:	S	Ra	Ra part
			999.0
			999.0
			999.0
			999.0
			999.0
			999.0
Stot	0.00	Ga4	999.0

S totaa 6.8 Gatot 30.9 = noise reduction value

indoor noise level=outdoor noise level - noise reduction value 34.1 dB(A)

CAUBERG - HUYGEN RAADGEVENDE INGENIEURS BV MAASTRICHT

ADRES :
spectrum :standard traffic noise
outdoor noise level: 65.0 dB(A)

werk :annex 27
date :10-2-94
jh

ROOM :bedroom 1
ventilation demand : 11.0 l/s

To : 0.5 sec.
Volume : 26.7 m3

K-factor = 35: minor weatherstripping
K-factor = 40: good single weatherstripping

FACADE 1 K-factor: 40 Cr: -3.0	S	Ra	Ra part
double glazing 6-16-8	2.0000	31.0	36.3
brickwork + therm. insulation	4.7500	46.0	47.5
soundproofed vent. opening Al Cadet Plus 110	0.0111	12.0	39.8
			999.0
			999.0
			999.0
Stot	6.76	Ga1	31.6

K-factor: Cr:	S	Ra	Ra part
			999.0
			999.0
			999.0
			999.0
			999.0
			999.0
Stot	0.00	Ga2	999.0

K-factor: Cr:	S	Ra	Ra part
			999.0
			999.0
			999.0
			999.0
			999.0
			999.0
Stot	0.00	Ga3	999.0

K-factor: Cr:	S	Ra	Ra part
			999.0
			999.0
			999.0
			999.0
			999.0
			999.0
Stot	0.00	Ga4	999.0

S totaa 6.8 Gatot 31.6 = noise reduction value

indoor noise level=outdoor noise level - noise reduction value 33.4 dB(A)

CAUBERG - HUYGEN   RAADGEVENDE INGENIEURS BV   MAASTRICHT

ADRES :
werk :annex 27
spectrum :standard traffic noise
date :10-2-94
outdoor noise level: 55.0 dB(A)
jh

ROOM :bedroom 2
ventilation demand : 9.9 l/s
To : 0.5 sec.
Volume : 24.3 m3

FACADE 1	K-factor: 35	Cr: -3.0	S	Ra	Ra part
double glazing 4-6-6			1.7300	28.0	33.9
brickwork + therm. insulation			5.0200	46.0	47.3
ventilation opening without soundproofing			0.0099	-5.0	23.3
					999.0
					999.0
					999.0
		Stot	6.76	Ga1	20.5

K-factor = 35: minor weatherstripping
K-factor = 40: good single weatherstripping

	K-factor:	Cr:	S	Ra	Ra part
					999.0
					999.0
					999.0
					999.0
					999.0
					999.0
		Stot	0.00	Ga2	999.0

	K-factor:	Cr:	S	Ra	Ra part
					999.0
					999.0
					999.0
					999.0
					999.0
					999.0
		Stot	0.00	Ga3	999.0

	K-factor:	Cr:	S	Ra	Ra part
					999.0
					999.0
					999.0
					999.0
					999.0
					999.0
		Stot	0.00	Ga4	999.0

S totaa 6.8 Gatot 20.5 = noise reduction value

indoor noise level=outdoor noise level - noise reduction value 34.5 dB(A)

CAUBERG - HUYGEN   RAADGEVENDE INGENIEURS BV   MAASTRICHT

ADRES : werk :annex 27
spectrum :standard traffic noise date :10-2-94
outdoor noise level: 65.0 dB(A) jh

ROOM :bedroom 2
ventilation demand : 9.9 l/s To : 0.5 sec.
Volume : 24.3 m3

K-factor = 35: minor weatherstripping
K-factor = 40: good single weatherstripping

FACADE 1 K-factor: 40 Cr: -3.0	S	Ra	Ra part
double glazing 6-16-8	1.7300	31.0	36.9
brickwork + therm. insulation	5.0200	46.0	47.3
soundproofed vent. opening Al Cadet st 110	0.0099	9.5	37.8
			999.0
			999.0
			999.0
Stot	6.76	Ga1	30.9

K-factor: Cr:	S	Ra	Ra part
			999.0
			999.0
			999.0
			999.0
			999.0
			999.0
Stot	0.00	Ga2	999.0

K-factor: Cr:	S	Ra	Ra part
			999.0
			999.0
			999.0
			999.0
			999.0
			999.0
Stot	0.00	Ga3	999.0

K-factor: Cr:	S	Ra	Ra part
			999.0
			999.0
			999.0
			999.0
			999.0
			999.0
Stot	0.00	Ga4	999.0

S totaa 6.8 Gatot 30.9 = noise reduction value

indoor noise level=outdoor noise level - noise reduction value 34.1 dB(A)

CAUBERG - HUYGEN RAADGEVENDE INGENIEURS BV MAASTRICHT

ADRES :
spectrum :standard traffic noise
outdoor noise level: 65.0 dB(A)

werk :annex 27
date :10-2-94
jh

ROOM :bedroom 2
ventilation demand : 9.9 l/s

To : 0.5 sec.
Volume : 24.3 m3

FACADE 1 K-factor: 40 Cr: -3.0	S	Ra	Ra part
double glazing 6-16-8	1.7300	31.0	36.9
brickwork + therm. insulation	5.0200	46.0	47.3
soundproofed vent. opening Al Cadet Plus 110	0.0100	12.0	40.3
			999.0
			999.0
			999.0
Stot	6.76	Ga1	31.6

K-factor: Cr:	S	Ra	Ra part
			999.0
			999.0
			999.0
			999.0
			999.0
			999.0
Stot	0.00	Ga2	999.0

K-factor: Cr:	S	Ra	Ra part
			999.0
			999.0
			999.0
			999.0
			999.0
			999.0
Stot	0.00	Ga3	999.0

K-factor: Cr:	S	Ra	Ra part
			999.0
			999.0
			999.0
			999.0
			999.0
			999.0
Stot	0.00	Ga4	999.0

S totaa 6.8 Gatot 31.6 = noise reduction value

indoor noise level=outdoor noise level - noise reduction value 33.4 dB(A)

K-factor = 35: minor weatherstripping
K-factor = 40: good single weatherstripping

CAUBERG - HUYGEN RAADGEVENDE INGENIEURS BV MAASTRICHT

ADRES :
spectrum :standard traffic noise
outdoor noise level: 55.0 dB(A)

werk :annex 27
date :10-2-94
jh

ROOM :bedroom 3
ventilation demand : 7.4 l/s

To : 0.5 sec.
Volume : 18.0 m3

K-factor = 35: minor weatherstripping
K-factor = 40: good single weatherstripping

FACADE 1 K-factor: 35 Cr: -3.0	S	Ra	Ra part
double glazing 4-6-6	2.0000	28.0	32.8
brickwork + therm. insulation	4.0800	46.0	47.7
ventilation opening without soundproofing	0.0074	-5.0	24.2
			999.0
			999.0
			999.0
Stot	6.09	Ga1	20.2

K-factor: Cr:	S	Ra	Ra part
			999.0
			999.0
			999.0
			999.0
			999.0
			999.0
Stot	0.00	Ga2	999.0

K-factor: Cr:	S	Ra	Ra part
			999.0
			999.0
			999.0
			999.0
			999.0
			999.0
Stot	0.00	Ga3	999.0

K-factor: Cr:	S	Ra	Ra part
			999.0
			999.0
			999.0
			999.0
			999.0
			999.0
Stot	0.00	Ga4	999.0

S totaa 6.1 Gatot 20.2 = noise reduction value

indoor noise level=outdoor noise level - noise reduction value 34.8 dB(A)

CAUBERG - HUYGEN RAADGEVENDE INGENIEURS BV MAASTRICHT

ADRES : werk :annex 27
spectrum :standard traffic noise date :10-2-94
outdoor noise level: 65.0 dB(A) jh

ROOM :bedroom 3
ventilation demand : 7.4 l/s To : 0.5 sec.
Volume : 18.0 m3

K-factor = 35: minor weatherstripping
K-factor = 40: good single weatherstripping

FACADE 1	K-factor: 40 Cr: -3.0	S	Ra	Ra part
double glazing 6-16-8		2.0000	31.0	35.8
brickwork + therm. insulation		4.0800	46.0	47.7
soundproofed vent. opening Al Cadet st 110		0.0075	9.5	38.6
				999.0
				999.0
				999.0
	Stot	6.09	Ga1	29.8

	K-factor: Cr:	S	Ra	Ra part
				999.0
				999.0
				999.0
				999.0
				999.0
				999.0
	Stot	0.00	Ga2	999.0

	K-factor: Cr:	S	Ra	Ra part
				999.0
				999.0
				999.0
				999.0
				999.0
				999.0
	Stot	0.00	Ga3	999.0

	K-factor: Cr:	S	Ra	Ra part
				999.0
				799.0
				999.0
				999.0
				999.0
				999.0
	Stot	0.00	Ga4	999.0

S totaa 6.1 Gatot 29.8 = noise reduction value

indoor noise level=outdoor noise level - noise reduction value 35.2 dB(A)

CAUBERG - HUYGEN RAADGEVENDE INGENIEURS BV MAASTRICHT

ADRES :
werk :annex 27
spectrum :standard traffic noise
date :10-2-94
outdoor noise level: 65.0 dB(A)
jh

ROOM :bedroom 3
ventilation demand : 7.4 l/s
To : 0.5 sec.
Volume : 18.0 m3

K-factor = 35: minor weatherstripping
K-factor = 40: good single weatherstripping

FACADE 1 K-factor: 40 Cr: -3.0	S	Ra	Ra part
double glazing 6-16-8	2.0000	31.0	35.8
brickwork + therm. insulation	4.0800	46.0	47.7
soundproofed vent. opening Al Cadet Plus 110	0.0074	12.0	41.2
			999.0
			999.0
			999.0
Stot	6.09	Ga1	30.4

K-factor: Cr:	S	Ra	Ra part
			999.0
			999.0
			999.0
			999.0
			999.0
			999.0
Stot	0.00	Ga2	999.0

K-factor: Cr:	S	Ra	Ra part
			999.0
			999.0
			999.0
			999.0
			999.0
			999.0
Stot	0.00	Ga3	999.0

K-factor: Cr:	S	Ra	Ra part
			999.0
			999.0
			999.0
			999.0
			999.0
			999.0
Stot	0.00	Ga4	999.0

S totaa 6.1 Gatot 30.4 = noise reduction value

indoor noise level=outdoor noise level - noise reduction value 34.6 dB(A)

Appendix 1.3. Calculations noise levels generated by heat recovery units.

Balanced ventilation system with a heat recovery system type Stork Air WTW 7.

Living room		Sound level		48.1 dB(A)					
		63	125	250	500	1000	2000	4000	
Sound source:									
Stork Air, WTW 7		75	73	69	64	64	58	49	[dB]
Acoustic damping:									
naturel sound damping		0.6	0.6	0.8	7.8	15.7	22.7	22.7	[dB]
silencer, 0m		0	0	0	0	0	0	0	[dB]
grille damping		0	0	0.5	5	6	4	2	[dB]
outlet reflection damping		17	11.5	5.5	1.5	0	0	0	[dB]
room absorption		7	7	7	7	7	7	7	[dB]
Sound pressure level		50.4	53.9	55.2	42.7	35.3	24.3	17.3	[dB]
A correction	+	−26.2	−16.1	−8.6	−3.2	0	1	1.1	[dB]
A corrected sound pressure level		24.2	37.8	46.6	39.5	35.3	25.3	18.4	[dB]

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Balanced ventilation system with a heat recovery system type Stork Air WTW 7 and with extra damping.

Living room		Sound level		35.0 dB(A)					
		63	125	250	500	1000	2000	4000	
Sound source:									
Stork Air, WTW 7		75	73	69	64	64	58	49	[dB]
Acoustic damping:									
naturel sound damping		0.6	0.6	0.8	7.8	15.7	22.7	22.7	[dB]
silencer, 1m		7	9	13	25.5	38.5	40	27	[dB]
grille damping		0	0	0.5	5	6	4	2	[dB]
outlet reflection damping		17	11.5	5.5	1.5	0	0	0	[dB]
room absorption		7	7	7	7	7	7	7	[dB]
Sound pressure level		43.4	44.9	42.2	17.2	−3.2	−15.7	−9.7	[dB]
A correction	+	−26.2	−16.1	−8.6	−3.2	0	1	1.1	[dB]
A corrected sound		17.2	28.8	33.6	14	−3.2	−14.7	−8.6	[dB]

Balanced ventilation system with a heat recovery system type Stork Air WTW 7, with extra damping and with crosstalk damping between the bedrooms.

Living room Sound level 29.9 dB(A)

	63	125	250	500	1000	2000	4000	
Sound source:								
Stork Air, WTW 7	75	73	69	64	64	58	49	[dB]
Acoustic damping:								
naturel sound damping	0.6	0.6	0.8	7.8	15.7	22.7	22.7	[dB]
crosstalk absorber 0,5m	4	4	5.5	13	14	21	14	[dB]
silencer, 1m	7	9	13	25.5	38.5	40	27	[dB]
grille damping	0	0	0.5	5	6	4	2	[dB]
outlet reflection damping	17	11.5	5.5	1.5	0	0	0	[dB]
room absorption	7	7	7	7	7	7	7	[dB]
Sound pressure level	39.4	40.9	36.7	4.2	−17.2	−36.7	−23.7	[dB]
A correction	−26.2	−16.1	−8.6	−3.2	0	1	1.1	[dB]
A corrected sound	13.2	24.8	28.1	1	−17.2	−35.7	−22.6	[dB]

Balanced ventilation system with a heat recovery system type Stork Air WTW 7.

Kitchen	Sound level			41.2 dB(A)				
	63	125	250	500	1000	2000	4000	
Sound source: Stork Air, WTW 7	65	64	63	51	47	37	27	[dB]
Acoustic damping:								
naturel sound damping	3.8	3.8	4.1	8.1	13.3	17.3	17.3	[dB]
silencer, 0m	0	0	0	0	0	0	0	[dB]
grille damping	0	0	4	5	10	12	11	[dB]
outlet reflection damping	20	13.5	7	2	0.5	0	0	[dB]
room absorption	−0.5	−0.5	−0.5	−0.5	−0.5	−0.5	−0.5	[dB]
Sound pressure level	41.7	47.2	48.4	36.4	23.7	8.2	−0.8	[dB]
A correction	−26.2	−16.1	−8.6	−3.2	0	1	1.1	[dB]
A corrected sound pressure level	15.5	31.1	39.8	33.2	23.7	9.2	0.3	[dB]

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Balanced ventilation system with a heat recovery system type Stork Air WTW 7 and with extra damping.

Kitchen	Sound level			28.2 dB(A)				
	63	125	250	500	1000	2000	4000	
Sound source: Stork Air, WTW 7	65	64	63	51	47	37	27	[dB]
Acoustic damping:								
naturel sound damping	3.8	3.8	4.1	8.1	13.3	17.3	17.3	[dB]
silencer, 1m	7	9	13	25.5	38.5	40	27	[dB]
grille damping	0	0	4	5	10	12	11	[dB]
outlet reflection damping	20	13.5	7	2	0.5	0	0	[dB]
room absorption	−0.5	−0.5	−0.5	−0.5	−0.5	−0.5	−0.5	[dB]
Sound pressure level	34.7	38.2	35.4	10.9	−14.8	−31.8	−27.8	[dB]
A correction	−26.2	−16.1	−8.6	−3.2	0	1	1.1	[dB]
A corrected sound	8.5	22.1	26.8	7.7	−14.8	−30.8	−26.7	[dB]

Balanced ventilation system with a heat recovery system type Stork Air WTW 7.

Bedroom 1 Sound level 44.5 dB(A)

	63	125	250	500	1000	2000	4000	
Sound source:								
Stork Air, WTW 7	75	73	69	64	64	58	49	[dB]
Acoustic damping:								
naturel sound damping	6.5	6.5	6.7	12.7	19.4	25.4	25.9	[dB]
silencer, 0m	0	0	0	0	0	0	0	[dB]
grille damping	0	0	0.5	5	6	4	2	[dB]
outlet reflection damping	20	13.5	7.5	2	0.5	0	0	[dB]
room absorption	3.5	3.5	3.5	3.5	3.5	3.5	3.5	[dB]
Sound pressure level	45	49.5	50.8	40.8	34.6	25.1	17.6	[dB]
A correction	−26.2	−16.1	−8.6	−3.2	0	1	1.1	[dB]
A corrected sound pressure level	18.8	33.4	42.2	37.6	34.6	26.1	18.7	[dB]

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Balanced ventilation system with a heat recovery system type Stork Air WTW 7 and with extra damping.

Bedroom 1 Sound level 30.6 dB(A)

	63	125	250	500	1000	2000	4000	
Sound source:								
Stork Air, WTW 7	75	73	69	64	64	58	49	[dB]
Acoustic damping:								
naturel sound damping	6.5	6.5	6.7	12.7	19.4	25.4	25.9	[dB]
silencer, 1m	7	9	13	25.5	38.5	40	27	[dB]
grille damping	0	0	0.5	5	6	4	2	[dB]
outlet reflection damping	20	13.5	7.5	2	0.5	0	0	[dB]
room absorption	3.5	3.5	3.5	3.5	3.5	3.5	3.5	[dB]
Sound pressure level	38	40.5	37.8	15.3	−3.9	−14.9	−9.4	[dB]
A correction	−26.2	−16.1	−8.6	−3.2	0	1	1.1	[dB]
A corrected sound	11.8	24.4	29.2	12.1	−3.9	−13.9	−8.3	[dB]

Balanced ventilation system with a heat recovery system type Stork Air WTW 7, with extra damping and with crosstalk damping between the bedrooms.

Bedroom 1 Sound level 25.5 dB(A)

	63	125	250	500	1000	2000	4000	
Sound source:								
Stork Air, WTW 7	75	73	69	64	64	58	49	[dB]
Acoustic damping:								
naturel sound damping	6.5	6.5	6.7	12.7	19.4	25.4	25.9	[dB]
crosstalk absorber 0,5m	4	4	5.5	13	14	21	14	[dB]
silencer, 1m	7	9	13	25.5	38.5	40	27	[dB]
grille damping	0	0	0.5	5	6	4	2	[dB]
outlet reflection damping	20	13.5	7.5	2	0.5	0	0	[dB]
room absorption	3.5	3.5	3.5	3.5	3.5	3.5	3.5	[dB]
Sound pressure level	34	36.5	32.3	2.3	−17.9	−35.9	−23.4	[dB]
A correction	−26.2	−16.1	−8.6	−3.2	0	1	1.1	[dB]
A corrected sound	7.8	20.4	23.7	−0.9	−17.9	−34.9	−22.3	[dB]

Balanced ventilation system with a heat recovery system type Stork Air WTW 7.

Bedroom 2 Sound level 45.0 dB(A)

	63	125	250	500	1000	2000	4000	
Sound source:								
Stork Air, WTW 7	75	73	69	64	64	58	49	[dB]
Acoustic damping:								
naturel sound damping	6.4	6.4	6.6	12.6	19.2	25.2	25.2	[dB]
silencer, 0m	0	0	0	0	0	0	0	[dB]
grille damping	0	0	0.5	5	6	4	2	[dB]
outlet reflection damping	20	13.5	7.5	2	0.5	0	0	[dB]
room absorption	3.1	3.1	3.1	3.1	3.1	3.1	3.1	[dB]
Sound pressure level	45.5	50	51.3	41.3	35.2	25.7	18.7	[dB]
A correction	−26.2	−16.1	−8.6	−3.2	0	1	1.1	[dB]
A corrected sound pressure level	19.3	33.9	42.7	38.1	35.2	26.7	19.8	[dB]

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Balanced ventilation system with a heat recovery system type Stork Air WTW 7 and with extra damping.

Bedroom 2 Sound level 32.4 dB(A)

	63	125	250	500	1000	2000	4000	
Sound source:								
Stork Air, WTW 7	75	73	69	64	64	58	49	[dB]
Acoustic damping:								
naturel sound damping	6.4	6.4	6.6	12.6	19.2	25.2	25.2	[dB]
silencer, 1m	7	9	13	25.5	38.5	40	27	[dB]
grille damping	0	0	0.5	5	6	4	2	[dB]
outlet reflection damping	20	13.5	7.5	2	0.5	0	0	[dB]
room absrption	1.8	1.8	1.8	1.8	1.8	1.8	1.8	[dB]
Sound pressure level	39.8	42.3	39.6	17.1	−2	−13	−7	[dB]
A correction	−26.2	−16.1	−8.6	−3.2	0	1	1.1	[dB]
A corrected sound	13.6	26.2	31	13.9	−2	−12	−5.9	[dB]

Balanced ventilation system with a heat recovery system type Stork Air WTW 7, with extra damping and with crosstalk damping between the bedrooms.

Bedroom 2 Sound level 26.0 dB(A)

	63	125	250	500	1000	2000	4000	
Sound source:								
Stork Air, WTW 7	75	73	69	64	64	58	49	[dB]
Acoustic damping:								
naturel sound damping	6.4	6.4	6.6	12.6	19.2	25.2	25.2	[dB]
crosstalk absorber 0,5m	4	4	5.5	13	14	21	14	[dB]
silencer, 1m	7	9	13	25.5	38.5	40	27	[dB]
grille damping	0	0	0.5	5	6	4	2	[dB]
outlet reflection damping	20	13.5	7.5	2	0.5	0	0	[dB]
room absorption	3.1	3.1	3.1	3.1	3.1	3.1	3.1	[dB]
Sound pressure level	34.5	37	32.8	2.8	−17.3	−35.3	−22.3	[dB]
A correction	−26.2	−16.1	−8.6	−3.2	0	1	1.1	[dB]
A corrected sound	8.3	20.9	24.2	−0.4	−17.3	−34.3	−21.2	[dB]

Balanced ventilation system with a heat recovery system type Stork Air WTW 7.

Bedroom 3 Sound level 49.7 dB(A)

	63	125	250	500	1000	2000	4000	
Sound source:								
Stork Air, WTW 7	75	73	69	64	64	58	49	[dB]
Acoustic damping:								
naturel sound damping	3.5	3.5	3.7	8.7	14.4	19.4	19.4	[dB]
silencer, 0m	0	0	0	0	0	0	0	[dB]
grille damping	0	0	0.5	5	6	4	2	[dB]
outlet reflection damping	20	13.5	7.5	2	0.5	0	0	[dB]
room absorption	1.8	1.8	1.8	1.8	1.8	1.8	1.8	[dB]
Sound pressure level	49.7	54.2	55.5	46.5	41.3	32.8	25.8	[dB]
A correction	−26.2	−16.1	−8.6	−3.2	0	1	1.1	[dB]
A corrected sound pressure level	23.5	38.1	46.9	43.3	41.3	33.8	26.9	[dB]

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Balanced ventilation system with a heat recovery system type Stork Air WTW 7 and with extra damping.

Bedroom 3 Sound level 35.3 dB(A)

	63	125	250	500	1000	2000	4000	
Sound source:								
Stork Air, WTW 7	75	73	69	64	64	58	49	[dB]
Acoustic damping:								
naturel sound damping	3.5	3.5	3.7	8.7	14.4	19.4	19.4	[dB]
silencer, 1m	7	9	13	25.5	38.5	40	27	[dB]
grille damping	0	0	0.5	5	6	4	2	[dB]
outlet reflection damping	20	13.5	7.5	2	0.5	0	0	[dB]
room absorption	1.8	1.8	1.8	1.8	1.8	1.8	1.8	[dB]
Sound pressure level	42.7	45.2	42.5	21	2.8	−7.2	−1.2	[dB]
A correction	−26.2	−16.1	−8.6	−3.2	0	1	1.1	[dB]
A corrected sound	16.5	29.1	33.9	17.8	2.8	−6.2	−0.1	[dB]

Balanced ventilation system with a heat recovery system type Stork Air WTW 7, with extra damping and with crosstalk damping between the bedrooms.

Bedroom 3 Sound level 29.8 dB(A)

	63	125	250	500	1000	2000	4000	
Sound source:								
Stork Air, WTW 7	75	73	69	64	64	58	49	[dB]
Acoustic damping:								
naturel sound damping	3.5	3.5	3.7	8.7	14.4	19.4	19.4	[dB]
crosstalk absorber 0,5m	4	4	5.5	13	14	21	14	[dB]
silencer, 1m	7	9	13	25.5	38.5	40	27	[dB]
grille damping	0	0	0.5	5	6	4	2	[dB]
outlet reflection damping	20	13.5	7.5	2	0.5	0	0	[dB]
room absorption	2.2	2.2	2.2	2.2	2.2	2.2	2.2	[dB]
Sound pressure level	38.3	40.8	36.6	7.6	−11.6	−28.6	−15.6	[dB]
A correction	−26.2	−16.1	−8.6	−3.2	0	1	1.1	[dB]
A corrected sound	12.1	24.7	28	4.4	−11.6	−27.6	−14.5	[dB]

Balanced ventilation system with a heat recovery system type Stork Air WTW 7.

Bath room — Sound level 41.6 dB(A)

	63	125	250	500	1000	2000	4000	
Sound source:								
Stork Air, WTW 7	65	64	63	51	47	37	27	[dB]
Acoustic damping:								
naturel sound damping	3.9	3.9	4.1	7.1	10.7	13.7	13.7	[dB]
silencer, 0m	0	0	0	0	0	0	0	[dB]
grille damping	0	0	4	5	10	12	11	[dB]
outlet reflection damping	20	13.5	7.5	2	0.5	0	0	[dB]
room absorption	−1	−1	−1	−1	−1	−1	−1	[dB]
Sound pressure level	42.1	47.6	48.4	37.9	26.8	12.3	3.3	[dB]
A correction	−26.2	−16.1	−8.6	−3.2	0	1	1.1	[dB]
A corrected sound pressure level	15.9	31.5	39.8	34.7	26.8	13.3	4.4	[dB]

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Balanced ventilation system with a heat recovery system type Stork Air WTW 7 and with extra damping.

Bath room — Sound level 28.3 dB(A)

	63	125	250	500	1000	2000	4000	
Sound source:								
Stork Air, WTW 7	65	64	63	51	47	37	27	[dB]
Acoustic damping:								
naturel sound damping	3.9	3.9	4.1	7.1	10.7	13.7	13.7	[dB]
silencer, 1m	7	9	13	25.5	38.5	40	27	[dB]
grille damping	0	0	4	5	10	12	11	[dB]
outlet reflection damping	20	13.5	7.5	2	0.5	0	0	[dB]
room absorption	−1	−1	−1	−1	−1	−1	−1	[dB]
Sound pressure level	35.1	38.6	35.4	12.4	−11.7	−27.7	−23.7	[dB]
A correction	−26.2	−16.1	−8.6	−3.2	0	1	1.1	[dB]
A corrected sound	8.9	22.5	26.8	9.2	−11.7	−26.7	−22.6	[dB]

Balanced ventilation system with a heat recovery system type ITHO HRU–MU 206 L/R.

Living room Sound level 37.6 dB(A)

		63	125	250	500	1000	2000	4000	
Sound source:									
ITHO HRU–MU 206 L/R		58	63	56.5	54	58.5	53.5	58.5	[dB]
Acoustic damping:									
naturel sound damping		0.6	0.6	0.8	7.8	15.7	22.7	22.7	[dB]
silencer, 0m		0	0	0	0	0	0	0	[dB]
grille damping		0	0	0.5	5	6	4	2	[dB]
outlet reflection damping		17	11.5	5.5	1.5	0	0	0	[dB]
room absorption		7	7	7	7	7	7	7	[dB]
Sound pressure level		33.4	43.9	42.7	32.7	29.8	19.8	26.8	[dB]
A correction	+	−26.2	−16.1	−8.6	−3.2	0	1	1.1	[dB]
A corrected sound pressure level		7.2	27.8	34.1	29.5	29.8	20.8	27.9	[dB]

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Balanced ventilation system with a heat recovery system type ITHO HRU–MU 206 L/R and with extra damping.

Living room Sound level 23.2 dB(A)

		63	125	250	500	1000	2000	4000	
Sound source:									
ITHO HRU–MU 206 L/R		58	63	56.5	54	58.5	53.5	58.5	[dB]
Acoustic damping:									
naturel sound damping		0.6	0.6	0.8	7.8	15.7	22.7	22.7	[dB]
silencer, 1m		7	9	13	25.5	38.5	40	27	[dB]
grille damping		0	0	0.5	5	6	4	2	[dB]
outlet reflection damping		17	11.5	5.5	1.5	0	0	0	[dB]
room absorption		7	7	7	7	7	7	7	[dB]
Sound pressure level		26.4	34.9	29.7	7.2	−8.7	−20.2	−0.2	[dB]
A correction	+	−26.2	−16.1	−8.6	−3.2	0	1	1.1	[dB]
A corrected sound pressure level		0.2	18.8	21.1	4	−8.7	−19.2	0.9	[dB]

Balanced ventilation system with a heat recovery system type ITHO HRU−MU 206 L/R, with extra damping and with crosstalk damping between the bedrooms.

Living room Sound level 30.3 dB(A)

	63	125	250	500	1000	2000	4000	
Sound source:								
ITHO HRU−MU 206 L/R	58	63	56.5	54	58.5	53.5	58.5	[dB]
Acoustic damping:								
naturel sound damping	0.6	0.6	0.8	7.8	15.7	22.7	22.7	[dB]
crosstalk absorber 0,5m	4	4	5.5	13	14	21	14	[dB]
absorber, 0m	0	0	0	0	0	0	0	[dB]
grate damping	0	0	0.5	5	6	4	2	[dB]
outlet reflection damping	17	11.5	5.5	1.5	0	0	0	[dB]
room absorption	7	7	7	7	7	7	7	[dB]
Sound pressure level	29.4	39.9	37.2	19.7	15.8	−1.2	12.8	[dB]
A correction	−26.2	−16.1	−8.6	−3.2	0	1	1.1	[dB]
A corrected sound	3.2	23.8	28.6	16.5	15.8	−0.2	13.9	[dB]

Balanced ventilation system with a heat recovery system type ITHO HRU−MU 206 L/R.

Kitchen Sound level 25.7 dB(A)

	63	125	250	500	1000	2000	4000	
Sound source:								
ITHO HRU−MU 206 L/R	43	49	45.5	39	37	34.5	24.5	[dB]
Acoustic damping:								
naturel sound damping	3.8	3.8	4.1	8.1	13.3	17.3	17.3	[dB]
silencer, 0m	0	0	0	0	0	0	0	[dB]
grille damping	0	0	4	5	10	12	11	[dB]
outlet reflection damping	20	13.5	7	2	0.5	0	0	[dB]
room absorption	−0.5	−0.5	−0.5	−0.5	−0.5	−0.5	−0.5	[dB]
Sound pressure level	19.7	32.2	30.9	24.4	13.7	5.7	−3.3	[dB]
A correction	−26.2	−16.1	−8.6	−3.2	0	1	1.1	[dB]
A corrected sound pressure level	−6.5	16.1	22.3	21.2	13.7	6.7	−2.2	[dB]

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Balanced ventilation system with a heat recovery system type ITHO HRU–MU 206 L/R.

Bedroom 1 Sound level 35.2 dB(A)

	63	125	250	500	1000	2000	4000	
Sound source:								
ITHO HRU–MU 206 L/R	58	63	56.5	54	58.5	53.5	58.5	[dB]
Acoustic damping:								
naturel sound damping	6.5	6.5	6.7	12.7	19.4	25.4	25.9	[dB]
silencer, 0m	0	0	0	0	0	0	0	[dB]
grille damping	0	0	0.5	5	6	4	2	[dB]
outlet reflection damping	20	13.5	7.5	2	0.5	0	0	[dB]
room absorption	3.5	3.5	3.5	3.5	3.5	3.5	3.5	[dB]
Sound pressure level	28	39.5	38.3	30.8	29.1	20.6	27.1	[dB]
A correction	−26.2	−16.1	−8.6	−3.2	0	1	1.1	[dB]
A corrected sound pressure level	1.8	23.4	29.7	27.6	29.1	21.6	28.2	[dB]

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Balanced ventilation system with a heat recovery system type ITHO HRU–MU 206 L/R and with extra damping.

Bedroom 1 Sound level 18.9 dB(A)

	63	125	250	500	1000	2000	4000	
Sound source:								
ITHO HRU–MU 206 L/R	58	63	56.5	54	58.5	53.5	58.5	[dB]
Acoustic damping:								
naturel sound damping	6.5	6.5	6.7	12.7	19.4	25.4	25.9	[dB]
silencer, 1m	7	9	13	25.5	38.5	40	27	[dB]
grille damping	0	0	0.5	5	6	4	2	[dB]
outlet reflection damping	20	13.5	7.5	2	0.5	0	0	[dB]
room absorption	3.5	3.5	3.5	3.5	3.5	3.5	3.5	[dB]
Sound pressure level	21	30.5	25.3	5.3	−9.4	−19.4	0.1	[dB]
A correction	−26.2	−16.1	−8.6	−3.2	0	1	1.1	[dB]
A corrected sound pressure level	−5.2	14.4	16.7	2.1	−9.4	−18.4	1.2	[dB]

Balanced ventilation system with a heat recovery system type ITHO HRU–MU 206 L/R, with extra damping and with crosstalk damping between the bedrooms.

Bedroom 1 Sound level 26.4 dB(A)

	63	125	250	500	1000	2000	4000	
Sound source:								
ITHO HRU–MU 206 L/R	58	63	56.5	54	58.5	53.5	58.5	[dB]
Acoustic damping:								
naturel sound damping	6.5	6.5	6.7	12.7	19.4	25.4	25.9	[dB]
crosstalk absorber 0,5m	4	4	5.5	13	14	21	14	[dB]
absorber, 0m	0	0	0	0	0	0	0	[dB]
grate damping	0	0	0.5	5	6	4	2	[dB]
outlet reflection damping	20	13.5	7.5	2	0.5	0	0	[dB]
room absorption	3.5	3.5	3.5	3.5	3.5	3.5	3.5	[dB]
Sound pressure level	24	35.5	32.8	17.8	15.1	–0.4	13.1	[dB]
A correction	–26.2	–16.1	–8.6	–3.2	0	1	1.1	[dB]
A corrected sound	–2.2	19.4	24.2	14.6	15.1	0.6	14.2	[dB]

Balanced ventilation system with a heat recovery system type ITHO HRU−MU 206 L/R.

Bedroom 2 Sound level 35.9 dB(A)

	63	125	250	500	1000	2000	4000	
Sound source:								
ITHO HRU−MU 206 L/R	58	63	56.5	54	58.5	53.5	58.5	[dB]
Acoustic damping:								[dB]
naturel sound damping	6.4	6.4	6.6	12.6	19.2	25.2	25.2	[dB]
silencer, 0m	0	0	0	0	0	0	0	[dB]
grille damping	0	0	0.5	5	6	4	2	[dB]
outlet reflection damping	20	13.5	7.5	2	0.5	0	0	[dB]
room absorption	3.1	3.1	3.1	3.1	3.1	3.1	3.1	[dB]
Sound pressure level	28.5	40	38.8	31.3	29.7	21.2	28.2	[dB]
A correction	−26.2	−16.1	−8.6	−3.2	0	1	1.1	[dB]
A corrected sound pressure level	2.3	23.9	30.2	28.1	29.7	22.2	29.3	[dB]

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Balanced ventilation system with a heat recovery system type ITHO HRU−MU 206 L/R and with extra damping.

Bedroom 2 Sound level 19.4 dB(A)

	63	125	250	500	1000	2000	4000	
Sound source:								
ITHO HRU−MU 206 L/R	58	63	56.5	54	58.5	53.5	58.5	[dB]
Acoustic damping:								
naturel sound damping	6.4	6.4	6.6	12.6	19.2	25.2	25.2	[dB]
silencer, 1m	7	9	13	25.5	38.5	40	27	[dB]
grille damping	0	0	0.5	5	6	4	2	[dB]
outlet reflection damping	20	13.5	7.5	2	0.5	0	0	[dB]
room absorption	3.1	3.1	3.1	3.1	3.1	3.1	3.1	[dB]
Sound pressure level	21.5	31	25.8	5.8	−8.8	−18.8	1.2	[dB]
A correction	−26.2	−16.1	−8.6	−3.2	0	1	1.1	[dB]
A corrected sound pressure level	−4.7	14.9	17.2	2.6	−8.8	−17.8	2.3	[dB]

Balanced ventilation system with a heat recovery system type ITHO HRU–MU 206 L/R, with extra damping and with crosstalk damping between the bedrooms.

Bedroom 2 Sound level 27.0 dB(A)

	63	125	250	500	1000	2000	4000	
Sound source:								
ITHO HRU–MU 206 L/R	58	63	56.5	54	58.5	53.5	58.5	[dB]
Acoustic damping:								
naturel sound damping	6.4	6.4	6.6	12.6	19.2	25.2	25.2	[dB]
crosstalk absorber 0,5m	4	4	5.5	13	14	21	14	[dB]
absorber, 0m	0	0	0	0	0	0	0	[dB]
grate damping	0	0	0.5	5	6	4	2	[dB]
outlet reflection damping	20	13.5	7.5	2	0.5	0	0	[dB]
room absorption	3.1	3.1	3.1	3.1	3.1	3.1	3.1	[dB]
Sound pressure level	24.5	36	33.3	18.3	15.7	0.2	14.2	[dB]
A correction	−26.2	−16.1	−8.6	−3.2	0	1	1.1	[dB]
A corrected sound	−1.7	19.9	24.7	15.1	15.7	1.2	15.3	[dB]

Balanced ventilation system with a heat recovery system type ITHO HRU–MU 206 L/R.

Bedroom 3 Sound level 41.6 dB(A)

	63	125	250	500	1000	2000	4000	
Sound source:								
ITHO HRU–MU 206 L/R	58	63	56.5	54	58.5	53.5	58.5	[dB]
Acoustic damping:								
naturel sound damping	3.5	3.5	3.7	8.7	14.4	19.4	19.4	[dB]
silencer, 0m	0	0	0	0	0	0	0	[dB]
grille damping	0	0	0.5	5	6	4	2	[dB]
outlet reflection damping	20	13.5	7.5	2	0.5	0	0	[dB]
room absorption	1.8	1.8	1.8	1.8	1.8	1.8	1.8	[dB]
Sound pressure level	32.7	44.2	43	36.5	35.8	28.3	35.3	[dB]
A correction	−26.2	−16.1	−8.6	−3.2	0	1	1.1	[dB]
A corrected sound pressure level	6.5	28.1	34.4	33.3	35.8	29.3	36.4	[dB]

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Balanced ventilation system with a heat recovery system type ITHO HRU–MU 206 L/R and with extra damping.

Bedroom 3 Sound level 23.7 dB(A)

	63	125	250	500	1000	2000	4000	
Sound source:								
ITHO HRU–MU 206 L/R	58	63	56.5	54	58.5	53.5	58.5	[dB]
Acoustic damping:								
naturel sound damping	3.5	3.5	3.7	8.7	14.4	19.4	19.4	[dB]
silencer, 1m	7	9	13	25.5	38.5	40	27	[dB]
grille damping	0	0	0.5	5	6	4	2	[dB]
outlet reflection damping	20	13.5	7.5	2	0.5	0	0	[dB]
room absorption	1.8	1.8	1.8	1.8	1.8	1.8	1.8	[dB]
Sound pressure level	25.7	35.2	30	11	−2.7	−11.7	8.3	[dB]
A correction	−26.2	−16.1	−8.6	−3.2	0	1	1.1	[dB]
A corrected sound pressure level	−0.5	19.1	21.4	7.8	−2.7	−10.7	9.4	[dB]

Balanced ventilation system with a heat recovery system type ITHO HRU–MU 206 L/R, with extra damping and with crosstalk damping between the bedrooms.

Bedroom 3 Sound level 31.8 dB(A)

	63	125	250	500	1000	2000	4000	
Sound source:								
ITHO HRU–MU 206 L/R	58	63	56.5	54	58.5	53.5	58.5	[dB]
Acoustic damping:								
naturel sound damping	3.5	3.5	3.7	8.7	14.4	19.4	19.4	[dB]
crosstalk absorber 0,5m	4	4	5.5	13	14	21	13	[dB]
absorber, 0m	0	0	0	0	0	0	0	[dB]
grate damping	0	0	0.5	5	6	4	2	[dB]
outlet reflection damping	20	13.5	7.5	2	0.5	0	0	[dB]
room absorption	1.8	1.8	1.8	1.8	1.8	1.8	1.8	[dB]
Sound pressure level	28.7	40.2	37.5	23.5	21.8	7.3	22.3	[dB]
A correction	−26.2	−16.1	−8.6	−3.2	0	1	1.1	[dB]
A corrected sound	2.5	24.1	28.9	20.3	21.8	8.3	23.4	[dB]

Balanced ventilation system with a heat recovery system type ITHO HRU–MU 206 L/R.

Bath room — Sound level 26.7 dB(A)

	63	125	250	500	1000	2000	4000	
Sound source:								
ITHO HRU–MU 206 L/R	43	49	45.5	39	37	34.5	24.5	[dB]
Acoustic damping:								
naturel sound damping	3.9	3.9	4.1	7.1	10.7	13.7	13.7	[dB]
silencer, 0m	0	0	0	0	0	0	0	[dB]
grille damping	0	0	4	5	10	12	11	[dB]
outlet reflection damping	20	13.5	7.5	2	0.5	0	0	[dB]
room absorption	−1	−1	−1	−1	−1	−1	−1	[dB]
Sound pressure level	20.1	32.6	30.9	25.9	16.8	9.8	0.8	[dB]
A correction	−26.2	−16.1	−8.6	−3.2	0	1	1.1	[dB]
A corrected sound pressure level	−6.1	16.5	22.3	22.7	16.8	10.8	1.9	[dB]

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Appendix 1.4. Calculations average sound reduction index Rm and cross talk.

Crosstalk bedroom 1 to 3

	125	250	500	1000	2000	[Hz]
Source:						
soundpressurelevel transmission room	100	100	100	100	100	[dB]
Damping:						
grille transmission room	0.0	0.5	5.0	6.0	4.0	[dB]
grille damping receiving room	21.0	21.0	21.0	21.0	21.0	[dB]
system damping	3.7	3.8	4.8	6.1	7.1	[dB]
grille receiving room	0.0	0.5	5.0	6.0	4.0	[dB]
outlet reflection damping	13.5	7.5	2.0	0.5	0.0	[dB]
room absorption	1.8	1.8	1.8	1.8	1.8	[dB]
sound pressure level bedroom 3 crosstalk	60.0	64.9	60.4	58.6	62.1	[dB]

Sound transmission wall between bedroom 1 and 3

	125	250	500	1000	2000	[Hz]
Source:						
soundpressurelevel transmission room	100	100	100	100	100	[dB]
Damping:						
wall gypsum blocks 70 mm	29.0	29.0	27.0	32.0	41.0	[dB]
− 10 LOG(S/A)	−0.9	−0.9	−0.9	−0.9	−0.9	[dB]
soundpressurelevel bedroom 3 soundtransmission wall	71.9	71.9	73.9	68.9	59.9	[dB]

Rm wall = 32 dB

Resulting soundpressurelevel in bedroom 3 Lo	72.2	72.7	74.1	69.3	64.1	[dB]

+ Lt	100.0	100.0	100.0	100.0	100.0	[dB]
− Lr	−72.2	−72.7	−74.1	−69.3	−64.1	[dB]
10 LOG(S/A)	0.9	0.9	0.9	0.9	0.9	[dB]
R	28.7	28.2	26.8	31.6	36.8	[dB]

Rm,res crosstalk = 30 dB

Crosstalk bedroom 1 to 3
(EXTRA CROSSTALK DAMPING)

	125	250	500	1000	2000	[Hz]
Source:						
soundpressurelevel transmission room	100	100	100	100	100	[dB]
Damping:						
grille transmission room	0.0	0.5	5.0	6.0	4.0	[dB]
grille damping receiving room	21.0	21.0	21.0	21.0	21.0	[dB]
system damping	3.7	3.8	4.8	6.1	7.1	[dB]
silencer 0,5m	4.0	5.5	13.0	16.0	21.0	[dB]
grille receiving room	0.0	0.5	5.0	6.0	4.0	[dB]
outlet reflection damping	13.5	7.5	2.0	0.5	0.0	[dB]
room absorption	1.8	1.8	1.8	1.8	1.8	[dB]
sound pressure level bedroom 3 crosstalk	56.0	59.4	47.4	42.6	41.1	[dB]

Sound transmission wall between bedroom 1 and 3

	125	250	500	1000	2000	[Hz]
Source:						
soundpressurelevel transmission room	100	100	100	100	100	[dB]
Damping:						
wall gypsum blocks 70 mm	29.0	29.0	27.0	32.0	41.0	[dB]
− 10 LOG(S/A)	−0.9	−0.9	−0.9	−0.9	−0.9	[dB]
soundpressurelevel bedroom 3 soundtransmission wall	71.9	71.9	73.9	68.9	59.9	[dB]

Rm wall = 32 dB

Resulting soundpressurelevel in bedroom 3 Lo	72.0	72.1	73.9	68.9	60.0	[dB]

+ Lt	100.0	100.0	100.0	100.0	100.0	[dB]
− Lr	−72.0	−72.1	−73.9	−68.9	−60.0	[dB]
10 LOG(S/A)	0.9	0.9	0.9	0.9	0.9	[dB]
R	28.9	28.8	27.0	32.0	40.9	[dB]

Rm,res crosstalk = 32 dB

Crosstalk bedroom 1 to 3

	125	250	500	1000	2000	[Hz]
Source:						
soundpressurelevel transmission room	100	100	100	100	100	[dB]
Damping:						
grille transmission room	0.0	0.5	5.0	6.0	4.0	[dB]
grille damping receiving room	21.0	21.0	21.0	21.0	21.0	[dB]
system damping	3.7	3.8	4.8	6.1	7.1	[dB]
grille receiving room	0.0	0.5	5.0	6.0	4.0	[dB]
outlet reflection damping	13.5	7.5	2.0	0.5	0.0	[dB]
room absorption	1.8	1.8	1.8	1.8	1.8	[dB]
sound pressure level bedroom 3 crosstalk	60.0	64.9	60.4	58.6	62.1	[dB]

Sound transmission wall between bedroom 1 and 3

	125	250	500	1000	2000	[Hz]
Source:						
soundpressurelevel transmission room	100	100	100	100	100	[dB]
Damping:						
wall gypsum blocks 100 mm	30.0	28.0	29.0	38.0	47.0	[dB]
− 10 LOG(S/A)	−0.9	−0.9	−0.9	−0.9	−0.9	[dB]
soundpressurelevel bedroom 3 soundtransmission wall	70.9	72.9	71.9	62.9	53.9	[dB]

Rm wall = 34 dB

Resulting soundpressurelevel in bedroom 3

Lo	71.2	73.5	72.2	64.3	62.7	[dB]

+ Lt	100.0	100.0	100.0	100.0	100.0	[dB]
− Lr	−71.2	−73.5	−72.2	−64.3	−62.7	[dB]
10 LOG(S/A)	0.9	0.9	0.9	0.9	0.9	[dB]
R	29.7	27.4	28.7	36.6	38.2	[dB]

Rm,res crosstalk = 32 dB

Crosstalk bedroom 1 to 3
(EXTRA CROSSTALK DAMPING)

	125	250	500	1000	2000	[Hz]
Source:						
soundpressurelevel transmission room	100	100	100	100	100	[dB]
Damping:						
grille transmission room	0.0	0.5	5.0	6.0	4.0	[dB]
grille damping receiving room	21.0	21.0	21.0	21.0	21.0	[dB]
system damping	3.7	3.8	4.8	6.1	7.1	[dB]
silencer 0,5m	4.0	5.5	13.0	16.0	21.0	[dB]
grille receiving room	0.0	0.5	5.0	6.0	4.0	[dB]
outlet reflection damping	13.5	7.5	2.0	0.5	0.0	[dB]
room absorption	1.8	1.8	1.8	1.8	1.8	[dB]
sound pressure level bedroom 3 crosstalk	56.0	59.4	47.4	42.6	41.1	[dB]

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Sound transmission wall between bedroom 1 and 3

	125	250	500	1000	2000	[Hz]
Source:						
soundpressurelevel transmission room	100	100	100	100	100	[dB]
Damping:						
wall gypsum blocks 100 mm	30.0	28.0	29.0	38.0	47.0	[dB]
− 10 LOG(S/A)	−0.9	−0.9	−0.9	−0.9	−0.9	[dB]
soundpressurelevel bedroom 3 soundtransmission wall	70.9	72.9	71.9	62.9	53.9	[dB]

Rm wall = 34 dB

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Resulting soundpressurelevel in bedroom 3

Lo	71.0	73.1	71.9	62.9	54.1	[dB]

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+ Lt	100.0	100.0	100.0	100.0	100.0	[dB]
− Lr	−71.0	−73.1	−71.9	−62.9	−54.1	[dB]
10 LOG(S/A)	0.9	0.9	0.9	0.9	0.9	[dB]
R	29.9	27.8	29.0	38.0	46.8	[dB]

Rm,res crosstalk = 34 dB

Crosstalk livingroom to bedroom 3

	125	250	500	1000	2000	[Hz]
Source:						
soundpressurelevel transmission room	100	100	100	100	100	[dB]
Damping:						
grille transmission room	0.0	0.5	5.0	6.0	4.0	[dB]
grille damping receiving room	19.0	19.0	19.0	19.0	19.0	[dB]
system damping	4.5	4.5	8.8	13.7	16.7	[dB]
grille receiving room	0.0	0.5	5.0	6.0	4.0	[dB]
outlet reflection damping	13.5	7.5	2.0	0.5	0.0	[dB]
room absorption	1.8	1.8	1.8	1.8	1.8	[dB]
sound pressure level bedroom 3 crosstalk	61.2	66.2	58.4	53.0	54.5	[dB]

Soundtransmission floor between livingroom and bedroom 3

	125	250	500	1000	2000	[Hz]
Source:						
soundpressurelevel transmission room	100	100	100	100	100	[dB]
Damping:						
concrete floor 200 mm	43.0	45.0	48.0	54.0	58.0	[dB]
− 10 LOG(S/A)	−0.8	−0.8	−0.8	−0.8	−0.8	[dB]
sound pressure level bedroom 3 soundtransmission floor	57.8	55.8	52.8	46.8	42.8	[dB]

Rm floor = 50 dB

Resulting soundpressurelevel in bedroom 3

Lo	62.8	66.6	59.5	53.9	54.8	[dB]

+ Lt	100.0	100.0	100.0	100.0	100.0	[dB]
− Lr	−62.8	−66.6	−59.5	−53.9	−54.8	[dB]
10 LOG(S/A)	0.9	0.9	0.9	0.9	0.9	[dB]
R	38.1	34.3	41.4	47.0	46.1	[dB]

Rm,res crosstalk = 41 dB

Crosstalk livingroom to bedroom 3
(EXTRA CROSSTALK DAMPING)

	125	250	500	1000	2000	[Hz]
Source:						
soundpressurelevel transmission room	100	100	100	100	100	[dB]
Damping:						
grille transmission room	0.0	0.5	5.0	6.0	4.0	[dB]
grille damping receiving room	19.0	19.0	19.0	19.0	19.0	[dB]
system damping	4.5	4.8	8.8	13.7	16.7	[dB]
silencer 0,5m	4.0	5.5	13.0	16.0	21.0	[dB]
grille receiving room	0.0	0.5	5.0	6.0	4.0	[dB]
outlet reflection damping	13.5	7.5	2.0	0.5	0.0	[dB]
room absorption	1.8	1.8	1.8	1.8	1.8	[dB]
sound pressure level bedroom 3 crosstalk	57.2	60.4	45.4	37.0	33.5	[dB]

Soundtransmission floor between livingroom and bedroom 3

	125	250	500	1000	2000	[Hz]
Source:						
soundpressurelevel transmission room	100	100	100	100	100	[dB]
Damping:						
concrete floor 200 mm	43.0	45.0	48.0	54.0	58.0	[dB]
− 10 LOG(S/A)	−0.8	−0.8	−0.8	−0.8	−0.8	[dB]
sound pressure level bedroom 3 soundtransmission floor	57.8	55.8	52.8	46.8	42.8	[dB]

Rm floor = 50 dB

Resulting soundpressurelevel in bedroom 3

Lo	60.5	61.7	53.5	47.2	43.3	[dB]

+ Lt	100.0	100.0	100.0	100.0	100.0	[dB]
− Lr	−60.5	−61.7	−53.5	−47.2	−43.3	[dB]
10 LOG(S/A)	0.9	0.9	0.9	0.9	0.9	[dB]
R	40.4	39.2	47.4	53.7	57.6	[dB]

Rm,res crosstalk = 48 dB

Crosstalk livingroom to bedroom 3

	125	250	500	1000	2000	[Hz]
Source:						
soundpressurelevel transmission room	100	100	100	100	100	[dB]
Damping:						
grille transmission room	0.0	0.5	5.0	6.0	4.0	[dB]
grille damping receiving room	19.0	19.0	19.0	19.0	19.0	[dB]
system damping	4.5	4.5	8.8	13.7	16.7	[dB]
grille receiving room	0.0	0.5	5.0	6.0	4.0	[dB]
outlet reflection damping	13.5	7.5	2.0	0.5	0.0	[dB]
room absorption	1.8	1.8	1.8	1.8	1.8	[dB]
sound pressure level bedroom 3 crosstalk	61.2	66.2	58.4	53.0	54.5	[dB]

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Soundtransmission floor between livingroom and bedroom 3

	125	250	500	1000	2000	[Hz]
Source:						
soundpressurelevel transmission room	100	100	100	100	100	[dB]
Damping:						
concrete floor 200 mm	43.0	45.0	48.0	54.0	58.0	[dB]
− 10 LOG(S/A)	−0.8	−0.8	−0.8	−0.8	−0.8	[dB]
sound pressure level bedroom 3 soundtransmission floor	57.8	55.8	52.8	46.8	42.8	[dB]

Rm floor = 50 dB

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Resulting soundpressurelevel in bedroom 3

Lo	62.8	66.6	59.5	53.9	54.8	[dB]

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+ Lt	100.0	100.0	100.0	100.0	100.0	[dB]
− Lr	−62.8	−66.6	−59.5	−53.9	−54.8	[dB]
10 LOG(S/A)	0.9	0.9	0.9	0.9	0.9	[dB]
R	38.1	34.3	41.4	47.0	46.1	[dB]

Rm,res crosstalk = 41 dB

Crosstalk livingroom to bedroom 3
(EXTRA CROSS–TALK DAMPING)

	125	250	500	1000	2000	[Hz]
Source:						
soundpressurelevel transmission room	100	100	100	100	100	[dB]
Damping:						
grille transmission room	0.0	0.5	5.0	6.0	4.0	[dB]
grille damping receiving room	19.0	19.0	19.0	19.0	19.0	[dB]
system damping	4.5	4.8	8.8	13.7	16.7	[dB]
silencer 1m	7.0	9.0	13.0	25.5	38.5	[dB]
grille receiving room	0.0	0.5	5.0	6.0	4.0	[dB]
outlet reflection damping	13.5	7.5	2.0	0.5	0.0	[dB]
room absorption	1.8	1.8	1.8	1.8	1.8	[dB]
sound pressure level bedroom 3 crosstalk	54.2	56.9	45.4	27.5	16.0	[dB]

Soundtransmission floor between livingroom and bedroom 3

	125	250	500	1000	2000	[Hz]
Source:						
soundpressurelevel transmission room	100	100	100	100	100	[dB]
Damping:						
concrete floor 200 mm	43.0	45.0	48.0	54.0	58.0	[dB]
– 10 LOG(S/A)	–0.8	–0.8	–0.8	–0.8	–0.8	[dB]
sound pressure level bedroom 3 soundtransmission floor	57.8	55.8	52.8	46.8	42.8	[dB]

Rm floor = 50 dB

Resulting soundpressurelevel in bedroom 3 Lo	59.4	59.4	53.5	46.9	42.8	[dB]

+ Lt	100.0	100.0	100.0	100.0	100.0	[dB]
– Lr	–59.4	–59.4	–53.5	–46.9	–42.8	[dB]
10 LOG(S/A)	0.9	0.9	0.9	0.9	0.9	[dB]
R	41.5	41.5	47.4	54.0	58.1	[dB]

Rm,res crosstalk = 49 dB

15 JUIL. 1996

36