NBS TECHNICAL NOTE 710-8

U.S. DEPARTMENT OF COMMERCE / National Bureau of Standards

BUILDING RESEARCH TRANSLATION

French Acoustical Comfort Standards

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French Acoustical Comfort Standards

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Preface

The United States and Frances' Cooperative Program on Building Technology involves an exchange of personnel and information between the Center for Building Technology of the National Bureau of Standards and the Centre Scientifique et Technique du Batiment (CSTB). Information contained in this report was selected for translation and reproduction for sale to the building community by the Government Printing Office. The CSTB papers made public through this Technical Note do not necessarily represent the views of the National Bureau of Standards on either policy or technical levels. Building researchers at the National Bureau of Standards consider it a public service to share with the U. S. building community these insights into some of the research activities of CSTB.

Center for Building Technology
Institute for Applied Technology
National Bureau of Standards

Cahiers du Centre Scientifique et Technique du Batiment, No. 168
April 1976 (Cahier 1373)

EXAMPLES OF SOLUTIONS IN COMPLIANCE WITH BUILDING CODE AND/OR "ACOUSTICAL COMFORT" STANDARDS

III. ACOUSTICS

Recent increases in our knowledge of acoustics as applied to construction has made it necessary to update our Cahier 1090 so as to provide current examples of solutions which meet building code requirements, as well as of solutions qualifying for the "Acoustical Comfort Label."

This updating was performed by a working group which included representatives of the following bodies or agencies:

- Ministry of Social Affairs
- Ministry of Equipment and Housing
- Ministry for the Quality of Life
- French Association of Acoustical Engineers
- Paris Steam Equipment Association
- Bureau of Technical Studies for City Planning and Equipment
- Veritas Bureau
- Construction and Public Works Experimental Study and Research Center
- National Center for Housing Study and Initiative
- National Center for Telecommunications Studies

Building Industry Scientific and Technical Center

Association of Air Conditioning Engineering Contractors

Scientific and Technical Committee of the Heating Industries

Heat Production and Distribution Corporation

Tunzini Enterprises (represented by Mr Georges-Meller)

French-Speaking Acousticians' Group

National Consumers' Institute

Associated Consulting Engineers' Acoustics Laboratory

Mechanics and Acoustics Laboratory

National Testing Laboratory

Heating Industry Association

The French Radio and Television Office (ORTF)

The Order of Architects

Postal and Telecommunications Ministry

Auxiliary Real Estate Management Society

Society for Technical Supervision and Expertise in Construction

National Railroads Corporation (SNCF)

National Association of Heating Operators and Thermal Fluids Distributors

National Union of Middle-Income Housing (HLM) Agencies

Interprofessional Technical Union

The City of Paris

M. A. Bareau, Consulting Engineer.

The fruits of their deliberations are embodied in this publication.

Building Science and Technology Center
4 Avenue du Recteur-Poincare, Paris 16°
524-43-02 and 288-81-80

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* "bis" (French for "alternate version") in this paper refers to the additional, or more stringent "Acoustical Comfort Label" standards

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FOREWORD

The purpose of the following is, among other things, to point out some ways of providing levels of residential acoustical comfort which will meet the specifications contained in the decree and order of 14 June 1969, and also to indicate some ideas that may make it easier to meet the tougher requirements of the "Acoustical Comfort Label." It goes without saying, of course, that there may be sound solutions other than those set forth here: and also that the hope of seeing these solutions produce the desired results will depend on their design as well as on the quality of workmanship, although for that matter one can never be absolutely sure about the effect of unforeseen or imponderable factors.

As a general rule, good design will make the result more reliable, and do it with less work all around, than will mediocre or slipshod acoustical design, such as cutting down noise levels in apartment buildings by juxtaposing rooms of different kinds, alternating noisy rooms with quiet ones, etc.

Furthermore, the solutions suggested here are worthless unless they last. For some installations (floors and floor coverings, notably), this may require regular inspection for wear, maintenance, and, if necessary, replacement with materials of at least equivalent acoustical quality.

We distinguish two types of solutions: first of all, those which can meet the building code regulations; and then those hereinafter numbered "bis" that can bring dwelling units up to the Acoustical Comfort Standard.

CHAPTER 1

PROTECTION AGAINST AIRBORNE NOISE

1.1. Review of Code Requirements

The orders of 14 June 1969 and 22 December 1975 spelled out the requirements for protection against airborne noise. Sound insulation between units in a multiple occupancy building calls for 51 db(A) for an emitted noise whose spectrum is the one indicated for noise at the source in Article I of the order of 14 June 1969 (generally referred to as "pink noise").

That level drops, however, to 48 db(A) between kitchens, as well as between service rooms belonging to separate units.

The required sound insulation for a unit in a building against noise from building circulation systems (plumbing, heating, air) is 41 db(A) for a given emitted noise.

The sound insulation required for dwelling as opposed to commercial, shop, or industrial premises is 56 db(A) for a given noise emission.

1.1 bis Definitions of the Acoustical Comfort Standard

These are to be found in the order of 10 February 1972, which deals with the acoustical comfort standard.

1.2. General Remarks on Code Compliance Techniques

a. Always allow for any natural features likely to interfere with sound-conditioning

The object here is to select party walls which will produce the required isolation, allowing for lateral sound transmission (sometimes referred to as "side transmission") due to the walls and partitions which may surround or overlie the party wall, for the surface, S, of the party wall, and for the volume, V, of the space receiving the sound.

Hence, in the specific common case in which the various walls of a structure, including the party walls, are more or less of the same mass, taking all these various factors into consideration leads to selection of a party wall those acoustical impedance index, R, as a function of the desired insulation between units, D, is the one shown on the table below.

FINDING THE ACOUSTICAL IMPEDANCE INDEX FOR A PARTY WALL AS A FUNCTION OF THE DESIRED LEVEL OF SOUND ATTENUATION, D.

Surface of party wall	Volume of Receiving Chamber, V (m^3)								
S (m^2)	100	80	63	50	40	32	25	20	16
25	D+4	D+5	D+6	D+7	D+8	D+9			
20	D+3	D+4	D+5	D+6	D+7	D+8	D+9		
16	D+2	D+3	D+4	D+5	D+6	D+7	D+8	D+9	
12	D+1	D+2	D+3	D+4	D+5	D+6	D+7	D+8	D+9
10	D	D+1	D+2	D+3	D+4	D+5	D+6	D+7	D+8
8		D	D+1	D+2	D+3	D+4	D+5	D+6	D+7
6			D	D+1	D+2	D+3	D+4	D+5	D+6
5				D	D+1	D+2	D+3	D+4	D+5

This table is valid given the assumption that all surfaces (floors, cross-walls, partitions, etc.) are simple, and of approximately the same mass, and it allows for the inevitable differential of around 5 db between R and D arising from side transmissions encountered under this hypothesis.

For example, the impedance index, R, of a party wall between two units is around 5 db higher than that of the isolation between these two units, in case the various walls in the building have the same mass and in case the surface and volume of the party wall are in the usual range (10 m^2 and 32 m^3, approx.).

R and D can be expressed directly in db(A), provided the spectrum of the noise emission is given (in this case, the pink spectrum). We can compare R and D expressed in db(A) with R and D expressed as an arithmetical mean in the mean frequencies, in the case of a party wall offering an increased impedance factor of 6 db per octave.

In the specific case of insulation between the common interior circulation systems within a building and each housing unit therein, the possible variety of arrangements hardly allows of a general rule for the separation index to be used. This index must be worked out in each case as a function of the volumes and surfaces involved. We have done this, using three typical cases, in paragraph 1.4.

b. Always take advantage of any natural features likely to facilitate sound-conditioning.

Generally speaking, heavy bearing walls can be judiciously used to insure proper isolation between the several parts of a given dwelling unit (bedrooms thus separated from service rooms), as can expansion joints which, when properly fitted, provide quite satisfactory acoustical insulation between contiguous units.

1.2 bis. General Technical Conditions for Meeting the Acoustical Comfort Standard

The foregoing considerations are the more valid in that the requirements for the right to display the Acoustical Comfort Label are more stringent than those for compliance with the 14 June 1969 order. You need better sound attenuating partitions than are required for simple compliance with the order, even on the (optimistic) assumption that the units are separated by rooms of the same kind: bedroom backed to bedroom, living-room backed to living-room, service room backed to service room.

1.3. Acceptable Party Walls Between Contiguous Units

a. Simple Walls

By a simple wall we mean a wall whose components are rigidly attached to one another.

Sound attenuation between contiguous units can be satisfactory if the acoustical attenuation index expressed in db(A) for an emitted pink noise is 56 db(A), and the rooms are of normal size as shown in the table under paragraph 1.2.

Sound conditioning between contiguous units can be satisfactory if the party wall is a simple wall which is air-tight, has a mass in excess of 350 kg/m^2, and has no holes or openings.(1)*

Examples:

-- Formed concrete wall 14 cm thick, plus a 1-cm coat of plaster on each face;

-- Formed concrete wall 16 cm thick;

-- Full parpen walls of 18-cm poured concrete, plastered on both faces, provided the whole assembly is completely pointed;

-- Full brick wall 22 cm thick with plaster on both faces, provided the wall is fully pointed.

---

*See p. 55 et seq for notes.

b. Compound walls consisting of two independent partitions

To achieve the required level of acoustical insulation, you can use:

1. A party wall consisting of two walls, each of them plastered on one face, and having a mass of at least 200 kg per m^2 (see paragraph I.5.: Static Transmission, 2d indent, for the reasons for that mass figure), the space between the walls being at least 1 cm at all points and each of the walls being plastered on at least one face;

2. A medium-weight wall backed with an airtight flexible (2) wall, under the following conditions:

-- that the heavy part be full, and at least 10 cm thick, with a mass of at least 150 kg/m^2; it shall include plaster on at least one face;

-- that there be no rigid bonding or connection between the said walls, and that the space between them (3) be at least equal to:

$$d_{(cm)} \text{ greater than } \frac{100}{\text{mass of backup component (in } kg/m^2\text{)}};$$

-- that the space between the two components be coated with absorbent material incorporating mineral or vegetable fiber and that it create no rigid bond (4) between the walls. (Absorbent material is not essential provided one of the components is itself an absorbent: Fibragglo, for example).

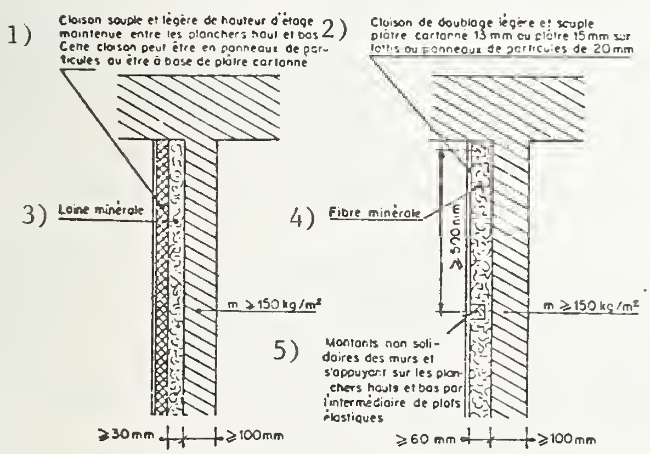


Figure 1. Cross sections. Two examples of medium-weight walls backed with a light flexible partition, designed to provide adequate noise attenuation between dwelling units.

Key:

1. Light, flexible floor-to-ceiling partition held between floor and ceiling. This partition may be of particle board or based on plaster board.
2. Light, flexible backing partition of 13-mm plasterboard or 15mm of plaster over lath of 20-mm particle board.
3. Rock wool
4. Mineral fiber
5. Uprights independent of the walls, held in place by elastic plates against the floor and ceiling.

-- that the backing wall not be a masonry partition (5)

-- that the walls adjacent to the wall in question be heavy (mass greater than 350 kg/m^2)

Two examples of this type of solution are shown in Figure 1.

3. A light double partition of plasterboard, asbestos cement, or wood, provided its impedance index, R, be on the order of 60 db(A), mounted very tightly (particularly in contact with the upper floor)) in case the floors are solid slab of reinforced concrete at least 16 mm thick. This technique is still fairly new, and it can be checked out by on-site acoustical measurements taken by an approved laboratory. (Consult the list in Cahier 72-54 bis: "Label comfort acoustique".) Considering lateral sound transmission, the thicker the slabs, the better the sound insulation will be (6).

c. Use of 3-dimensional cells

These have proved to be an excellent means for providing the desired level of sound insulation. To make quite sure you know precisely what you are doing, refer to measurements taken by an approved laboratory (consult the list in Cahier 72-54 bis, "Label comfort acoustique").

This solution offers the major advantage of providing insurance against most of the potential sound-conditioning pitfalls listed below.

You must make sure that no indirect transmission will interfere with the level of sound-conditioning you set out to achieve. Such unforeseen transmission may occur:

-- If two contiguous units are hooked up to a common ventilation duct (either gravity or forced). The best solution is to avoid such an arrangement by using common ducts only for superposed units.

Take care when designing exhaust systems not to use absorbent material which can soak up and become impregnated with grease or oil.

This situation, a very dangerous one from the point of view of fire hazard--occurs when the absorbent material has a fibrous surface and when it is not shielded against all deposits of grease or oil. The absorbent materials built into the rear face of the moving parts of exhaust vents are proof against such deposits, and are therefore acceptable.

Such hazards are particularly dangerous in the kitchen, where a buildup can contribute to the rapid and unexpected spread of a fire. To a lesser degree, this buildup can also occur in other service rooms.

-- If, as a consequence of the enclosure of one or more pipes in the chase space of a party wall, the mass of the wall is reduced;

When the mass of the wall is just sufficient for sound attenuation, pipes must be backed up or fastened to the party wall, not incorporated into it;

The same holds true for installing electrical junction boxes, for example. These must not be set facing one another, because that would considerably impair the noise attenuation provided by the party wall. To avoid this defect, we suggest that the thickness of the wall never be reduced, in the case of small junction boxes, to less than half its running thickness;

-- If there are ducts (heating ducts, for example) (7) running through the party wall (Figure 2) without an airtight seal between the rooms involved (poor seal between duct and joint, or hollows between joint and wall).

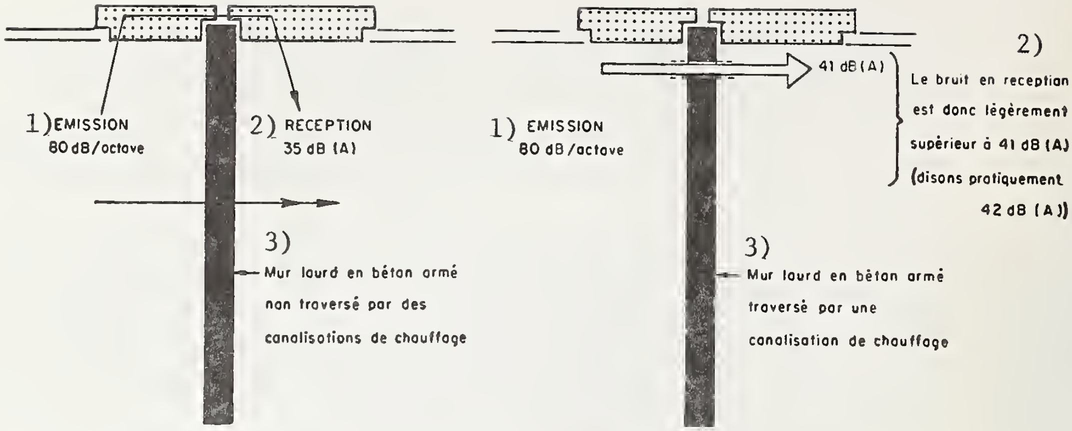
The best solution is to avoid any such run-throughs. If in a specific case they should prove to be inevitable, one remedy is to fill in the empty spaces permanently with mineral fiber or other flexible material. Another way is to use thin, flexible expansion joints of the correct diameter for the run-through ducts;

-- If the party wall is traversed by heating ducts for very lightweight heating units, such as small convectors with large lightwieght radiating surface, or radiators with large lightweight radiating surface, thus constituting a microphone/loudspeaker system. The soundest solution, as we have said, is to avoid such run-throughs.

Another is to make certain in advance, by laboratory measurement, of the isolating quality surrounding the system formed by the two heating units mounted in exactly the same way as they will be actually installed (insulation for this purpose must exceed the desired final attenuating effect by around 5 db);

-- If the garbage chute serves the kitchens of two contiguous units. Here again, you can make certain in advance, by means of laboratory measurements, of the transmission system set up by the two doors on either side of the chute (one open, one shut). If this insulation does not exceed the desired final level by at least 5 db, one remedy is to remove the garbage chutes from the kitchens altogether, and another is to shut them into a cupboard;

-- By light facades (panel facades, and particularly curtain facades) when there is continuity of the elements of the facades running in front of two juxtaposed units: Loss of noise attenuation may come from lateral transmission through the element itself (Figure 3),



Key:

Figure 2

(left)

1. Source 80 db/octave
2. Reception 35 db(A)
3. Heavy wall of reinforced concrete, with no pass-through heating ducts.

(right)

1. Source 80 db/octave
2. 41 db(A) (noise at point of reception is slightly louder than 41 db(A) (let's say for practical purposes 42 db(A)).
3. Heavy wall of reinforced concrete with one run-through heating duct.

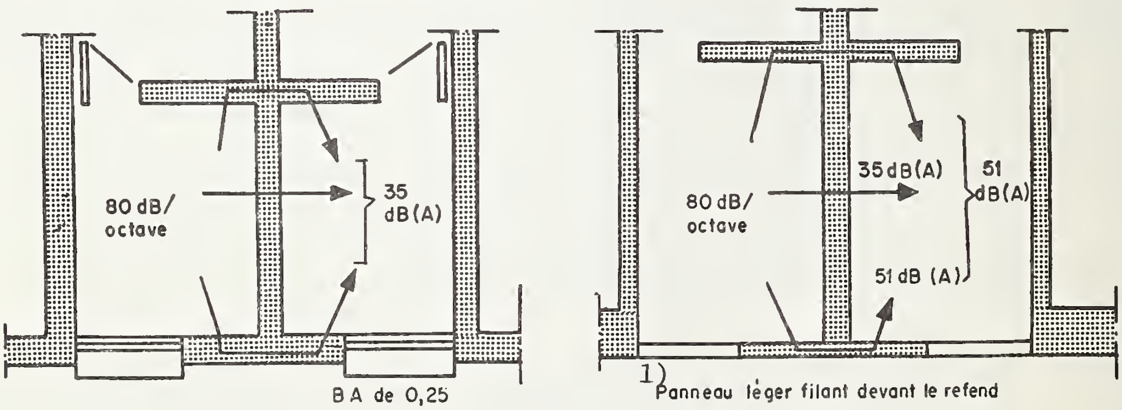


Figure 3. Example of increased airborne noise transmission between units, due to a light piece of woodwork running in front of the party wall (measurements on site).

Key:
1. Light woodwork panel running in front of party wall.

and also from faults in the seal between the facade and the party wall. Only on-site or laboratory measurements in a lab designed to study lateral transmission can show whether this type of transmission, in any given case, may be ruled out;

-- By the inside coffers of roll-up blinds serving two neighboring units (an arrangement, once again, which has drawbacks other than its deleterious effect on noise attenuation, such, for example, as fire hazard);

-- If there is a light horizontal partition (ceiling or slab, floating or fixed) running continuously through the party wall. One remedy is to design so that this partition is cut at right angles to the party wall;

-- If, as in Figure 4, there are windows on either side of the party walls whose openings are very close together (less than a few tens of centimeters). One remedy is to run the party wall out beyond the facade by a few decimeters, and to make sure the windows are tight.

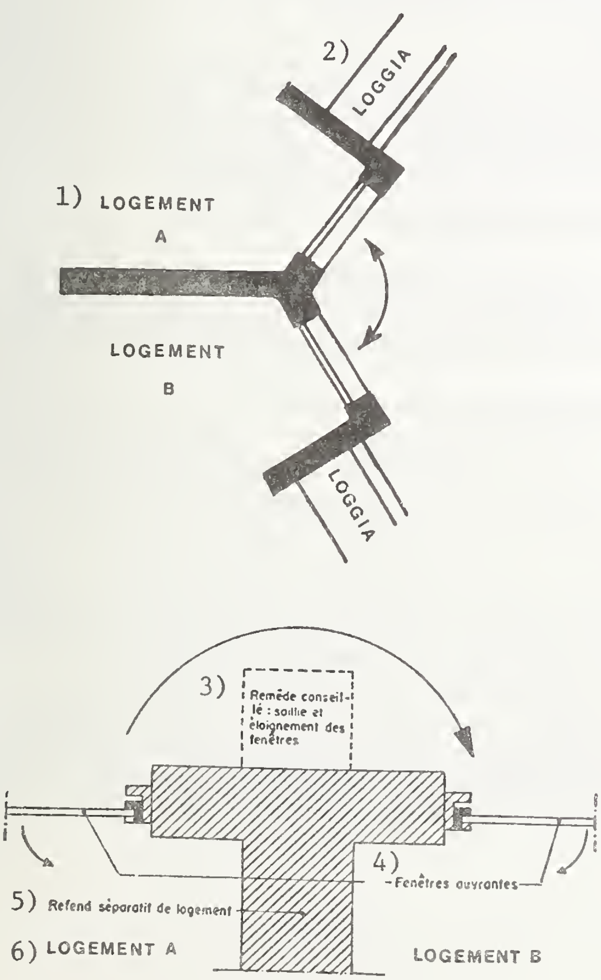


Figure 4

Key:
1. Housing units A & B
2. Loggia
3. Recommended remedy: Bay windows, with maximum separation.
4. Casement windows
5. Party wall
6. Units A & B

The presence of a building nearby which acts as a reflector, or direct view of one unit from another (which happens, for example, when you have a right-angle plan) can considerably aggravate this situation;

-- If large surfaces of light masonry walls (more than 5 m^2) are in contact with the party wall (see CSTB n° 748). The loss of the expected additional sound attenuation can run as high as S/15 to S/10 in db(A) (where S is the total surface of the light partitions in the units between which you are concerned with noise attenuation (which is cumulative in the two units and is expressed in square meters).

On the other hand, partitions with low radiation factors, such as those of plasterboard or those of high mass (at least 200 kg/m^2), create no such problems;

-- If, when the frames are removed from concrete work, the holes left are not filled in. This defect can be remedied by filling with mortar at least half the thickness of the wall.

This list of causes for loss of sound attenuation is not intended to be exhaustive.

1.3.bis Separations Between Contiguous Housing Units Meeting Acoustical Comfort Label Standards

1.3.bis.1. Semi-detached houses.

Double wall with complete separation (separate foundations), with each wall weighing at least 250 kg/m^2, the space between walls being at least 1 centimeter at all points (8). Each wall must be plastered on at least one side.

1.3.bis.2. Apartment building units.

Unless otherwise indicated, we assume that contiguous units have their party wall between rooms used for the same purpose: bedroom against bedroom, service room against service room, etc.

a. Double wall with total separation (separate foundations), each wall weighing at least 250 kg/m^2, and the space between walls being at least 1 cm at all points (8). Each wall must be plastered on at least one face. For apartment units, this solution applies to contiguous units whose party wall separates rooms used for different purposes, as well as to those having their party walls between rooms used for the same purpose.

b. An airtight wall with a mass of at least 450 kg/m^2, in the case of units in a multiple-occupancy dwelling whose party wall separates rooms used for the same purpose on either side:

Example: a wall of formed concrete 20 cm thick, set on both sides;

Example: a wall of formed concrete 21 cm thick, without openings or cracks.

c. In the case of units in a multiple-occupancy building whose party wall separates rooms used for the same purpose on either side:

An airtight wall whose mass is at least 350 kg/m^2 backed by a tight flexible partition whose mass is at least 10 kg/m^2, under the following conditions:

-- That there be no rigid bond or connection between these two partitions, and that the space, d, between them be at least

$$d_{(cm)} \text{ greater than } \frac{100}{\text{mass of backup element (in } kg/m^2\text{)}}$$

-- That the space between the elements be filled with an absorbent material, such as mineral or vegetable fiber, which cannot set up a rigid bond between the walls (absorbent material is not indispensable if one of the elements is of itself sound-absorbent: Fibragglo, for example);

-- The backup is not a masonry partition;

-- The adjacent walls are heavy (mass greater than 350 kg/m^2).

Every care must be taken to avoid any indirect transmission of sound, such for example as that cited in paragraph 1.3, the more so since the end in view is more difficult to achieve.

You will see that solutions b and c are appropriate if the contiguous portions of the units consist of rooms used for the same purpose (bedroom opposite bedroom, living-room opposite living-room). They may prove inadequate in the case of a bedroom opposite a living-room.

d. Use of 3-dimensional cells

We have seen that these can be an excellent means of achieving the desired level of sound-conditioning. To make perfectly sure you know what you are doing, get acoustical measurements performed by an approved laboratory.

The great advantage of this solution is that it is a guarantee against most of the possible sound-attenuation failures we listed at the end of section 1.3.

1.4. Acceptable Noise Barriers Between Units and Common Interior Service Systems

A great many solutions are available, both for complying with the Code (see Section 1.1.) and for reaching the performance levels stipulated for the Acoustical Comfort Label.

We distinguish two cases: the first, in which no principal room is contiguous to a common interior service system, and the second, in which one such room is so.

1.41. There is no common wall shared by a principal room and/or a kitchen or common interior service system.

We can assume that the noise path runs through the hall door and the communicating doors to each room.

This would indicate specifying noise attenuation coefficients for the hall doors, including their frames: actually, any measurement of the noise attenuation coefficient for the door alone would not tell us much about the way that door is going to perform on site, when hung in its case.

For usual room volume and separating wall surfaces, sound insulation can be achieved:

a. With a hall or entry door of very high acoustical quality, by which we mean one with a laboratory-measured noise reduction index, when hung in its frame, of at least 33 db (A) for a noise rated pink at its point of emission. (This calls for very carefully made seals, both for the door and for its frame and jamb, and between the case and the wall. This means a nicely leveled floor, and careful protection of the door and its case prior to hanging.)

b. By surrounding the entry with absorbent material giving an equivalent area of absorption (9) of at least 3 square meters, which cannot be blocked off by the furniture, and providing an entry door of good acoustical quality with a noise attenuation rating, as measured in the laboratory hung in its case, of at least 30 db(A) for a pink-rated noise at point of emission.

The same caveats as to careful sealing and protection prior to installation apply as listed above.

c. When each room in the unit has its own communicating door, and the entry door has a noise attenuation rating, as measured in the laboratory hung in its case, of at least 25 db(A).

The same caveats as to careful sealing and protection prior to installation apply as listed above.

1.42. Main room shares a wall with part of the common interior service systems.

It is preferable to have the common wall between a principal room and a circulation system a wall whose mass is at least 300 kg/m^2. Once you have that, noise transmission will come mainly, as in the case above, through the hall or entry door and the communicating doors.

1.4 bis ACL Standards for Noise Attenuation Between Dwelling Units and Common Interior Circulation Systems

If there is a common wall between a principal room and some of the service systems in the building, that wall's mass must be at least 350 kg/m^2.

Noise transmission occurring in these conditions will come mainly through the entry door, and can be cut down enough by one of the following solutions:

a. An entry door of very good acoustical quality, meaning one whose laboratory-measured noise attenuation rating when hung in its case is 35 db(A) for a pink-rated noise at point of emission. This calls for particularly careful sealing when the door is installed, both around the door proper and around its case, and again between the case and the wall. It requires a perfectly level floor and excellent storage and protection of both door and case prior to and during installation;

b. The entry is surrounded with sound-absorbent materials providing an equivalent area of absorption (9) of at least 3 square meters at all frequencies (particularly medium and high), and the entry door is of very good acoustical quality as described in paragraph 1.41a (requiring special care in sealing and protection);

c. Each room in the unit has its communicating door and the entry door is of good acoustical quality, as described in paragraph 1.41b (requiring special care in sealing and protection);

d. Each room has its own communicating door, the entry is surrounded with absorbent materials providing an equivalent area of absorption of at least 3 square meters at all frequencies (especially the medium and high ones), and the entry door meet the specifications detailed in paragraph 1.41c (requiring careful seal and protection).

1.5. Code Compliance Noise Attenuation Between Superposed Units

These may consist of simple floors or compound floors (floor over separate ceiling or with floating slab). These separations must be sealed airtight, a condition absolutely necessary to provide the required noise attenuation.

a. Simple floor

Simple floors (examples: full slab of reinforced concrete, floor laid over joists, etc.) are floors whose components are rigidly fastened together. As for simple walls, sound insulation between superposed units can be satisfactory provided the floor's mass is greater than 350 kg/m^2. (10)

This is most readily achieved with a full slab of reinforced concrete 16 cm thick, rough cast, or with a full slab of reinforced concrete 15 cm thick which has been cement-set, polished, and covered.

b. Compound floor (covering over floor).

Insulation between superposed units can be satisfactory with an airtight floor with a mass of 250 kg/m^2 or more (11), covered with a floating flooring such as parquet over floating joists or a floating slab, under the following conditions:

-- That is to be laid over material flexible enough so that static crushing under load is at least 1 mm, while still in the area of elasticity;

-- That the volume enclosed between the floating floor and the covering be, per square meter of floor, at least 1 cubic meter divided by the mass, M, in kg/m^2, of the floating floor (example: for a floating slab with a mass of 100 kg/m^2: 0.01 cubic meters per square meter of floor, which would mean a minimum distance of 1 cm between the floating slab and the covering);

-- That this volume be at least partially filled with absorbent material such as mineral or vegetable fiber;

-- That there be no rigid bond (such as plaster sealant, mortar spills, screenings, or rubbish) between the floating floor on the one hand and, on the other, the structural members, the woodwork, the plumbing, the door cases, and the sills (see REEF E 1, vol II, sections 4.41 and 4.42).

-- That the walls adjacent to the floor be massive (at least 350 kg/m^2).

c. Compound floor (suspended ceiling hung from support)

Noise attenuation between superposed dwelling units can be satisfactory with an airtight floor whose mass is at least 250 kg/m^2, backed by a flexible (12) suspended ceiling, also airtight, under the following conditions:

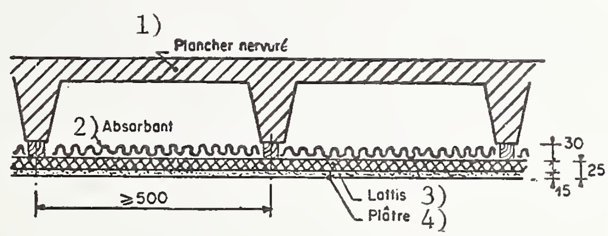
-- That there be no rigid bond or fastening between the floor and the suspended ceiling, and that the air-space, d, between the two be at least:

$$d_{(cm)} \geq \frac{100}{\text{mass of the suspended ceiling (kg/m}^2\text{)}}$$

This space must be filled, at least partially, with absorbent material, usually of vegetable or mineral fiber creating no rigid bond between floor and suspended ceiling. (The sound-absorbent material will not be required if the suspended ceiling is itself sound-absorbent);

-- That the walls adjacent to the floor be heavy (mass greater than 350 kg/m^2).

Examples of compound floors can be seen in Figure 5.



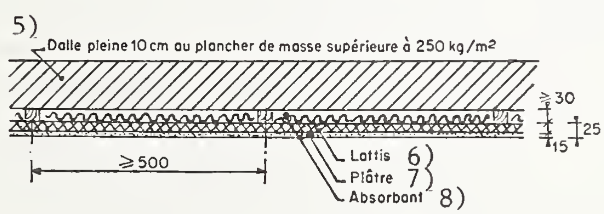


Figure 5. Compound floors providing good isolation between units

Key:
1. Floor on joists
2. Absorbent material
3. Lath
4. Plaster
5. Formed slab 10 cm thick or floor with mass greater than 250 kg/m^2
6. Lath
7. Plaster
8. Absorbent material

d. Use of 3 dimensional cells.

It has been found that these can be an excellent way to provide the desired noise reduction. To be absolutely sure of what you are doing, rely on acoustical measurements taken by an approved laboratory.

This solution's great advantage is that it provides a guarantee against most of the noise-attenuation pitfalls described below.

In all instances, care must be taken that no static transmission impairs the noise attenuation you have set out to obtain.

By way of example, there may be major static noise transmission due either to the floor plan (see first paragraphs) or to household appliances;

-- If the rooms are bounded by light masonry partitions, whose cumulative surface S (cumulative, that is, for both the sound-source and sound-receiving room), can set up very serious lateral transmission if there are many of them and if they have large surfaces, say greater than around 5 square meters. The noise reduction loss can run as high as S/15 to S/10 (see CSTB Cahier n° 748). On the other hand, partitions with a low radiation factor, such as plasterboard or high-mass partitions (at least 200 kg/m^2) do not give rise to this problem;

-- If, in the case of an expansion joint, one of the walls on either side of the joint has a mass less than 200 kg/m^2;

-- If there is an expansion joint inside a unit;

-- If there is a curtain wall common to both the superposed units.

The loss of noise attenuation can come from transmission through the element itself (Figure 6) or from faults in the seal between the element and the floor. Only measurements taken on site or in a laboratory equipped to study lateral noise transmission can show whether or not the likelihood of this kind of transmission is negligible in any given case;

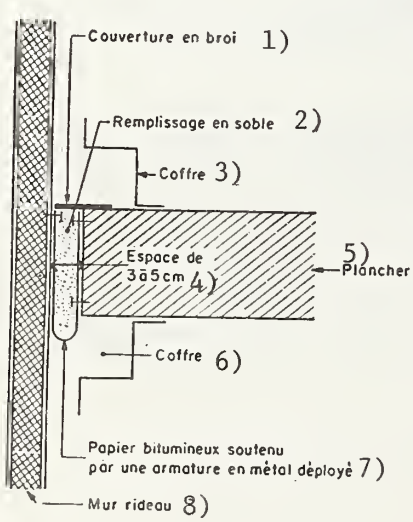


Figure 6. Major static transmission between superposed units by reason of continuity of the light curtain-wall (on the other hand, one may assume that noise transmission owing to lack of seal is negligible thanks to the heavy sand fill).

Key:
1. Tar or asphalt coating
2. Sand fill
3. Coffer
4. Space of 3 to 5 cm
5. Floor
6. Coffer
7. Tar paper supported by a spread metal grid
8. Curtain wall

-- If the garbage chute goes through the kitchens without being enclosed in a cupboard. Remedies for this are to be found in paragraph 1.3.;

-- If there is a technical sheath built of light materials without horizontal separation perpendicular to each floor (see Figure 7). The remedy here consists in cutting the sheath at each floor with a partition which must be airtight (for both acoustical reasons and others);

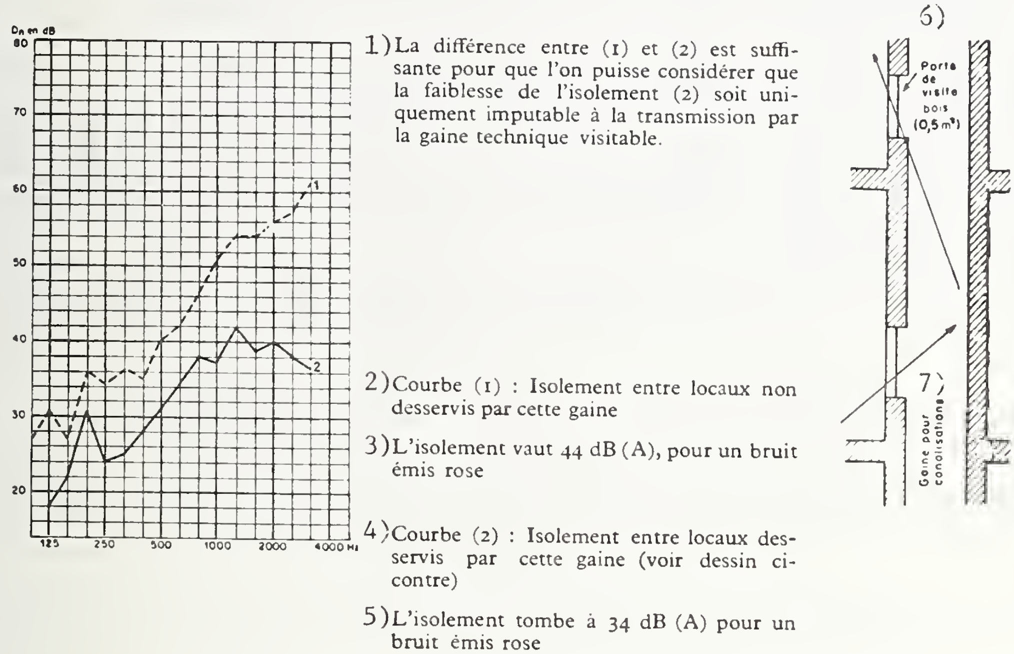
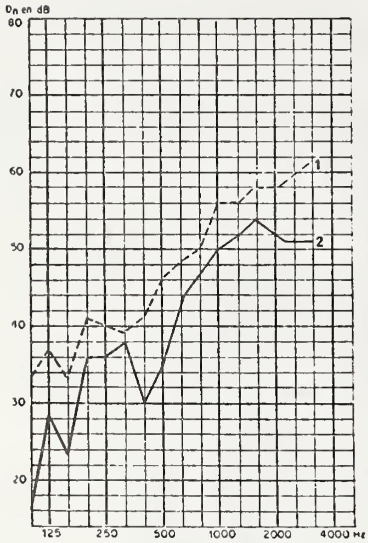


Figure 7. Airborne noise transmission through a technical sheath serving superposed units.

1. The difference between (1) and (2) is enough to allow you to assume that the inadequacy of the isolation (2) may be charged solely to noise transmission through the accessible technical sheath.
2. Curve (1): Isolation between units not served by this sheath
3. The isolation is rated at 44 db(A) for a pink noise at the source.
4. Curve (2): Isolation between units served by this sheath (see drawing at right).
5. Isolation drops to 34 db(A) for a noise rated pink at the source.
6. Access panel (wood, 10.5 m^2.)
7. Sheath for ducts.



The difference between isolations (1) and (2) is enough to permit the assumption that the inadequacy of the (2) isolation is due solely to the duct.

Curve (1): between bedrooms (no duct)

The insulation is rated at 50 db(A) for a noise rated pink at its source.

Curve (2): Between kitchens served by the same single ventilation duct whose interior surface is smooth.

The isolation is rated at 41 db(A) for a noise rated pink at its source.

Figure 8. Standardized noise attenuation between superposed units

-- If, with gravity ventilation, two rooms of the two superposed units are tied into a single collective duct whose inner surface is smooth; remedies for this may be:

install individual ducts,

ducts which are fairly flat in profile and have numerous joints can prove satisfactory from the acoustical point of view.

-- With forced ventilation, small sections of openings can, in some cases, provide the desired noise reduction between superposed units tied into the same duct. More precisely, and for a given outlet, the difference, δ, expressed in db(A) for a pink noise between the level of reverberated pressure, L_p, in the source room and the level of acoustical power transmitted to the receiving room, P, at the outlet and an increasing function of the output, Q, produced by the outlet (or we might say that δ is a decreasing function of the free section, s, of the air passage). As a rule you have: $\delta = K + 10 \log P - 20 \log Q$. Of course the idea is to make sure that K is as great as possible.

If you have measurements that give you δ directly under the airflow conditions that will prevail during normal use, you need to have a δ of at least 51 db(A), so that the effect on sound attenuation between the superposed units using the forced ventilation system will not have any adverse effect on regulation levels of noise attenuation.

If you do not have such measurements available, we suggest that you follow these recommendations:

-- Limit the section, S, to 35 cm. This will often entail a pressure drop at the outlets of at least 70 Pa;

-- Make the outlet cores sufficiently sound-absorbent. The minimum is either plain 1-mm sheet metal or a single sheet of 3-mm plastic. The insulating quality of the core is the more necessary if it is attached at a central point;

-- Make sure your ducts for individual tie-ins do not exceed 130 mm in diameter;

-- If there are ducts (for example heating ducts) running through the party wall and thus causing noise transmission, either because of their poor seal or because of their slight surface (as in downspouts or wastepipes), or again because of the slight surface of the equipment they feed (heaters, such as radiators or convection units).

To avoid these hazards, encountered in central hot-water heating systems, one remedy is to use heavy heating units or heating units that have been laboratory tested for low "intercom" rating.

One remedy, which is efficacious mainly if the transmission is caused by defective seal around the plumbing, is the use of simple, thin sleeves tightly fitted to the diameter of the rising pipes. Another remedy is to house the plumbing in a sheath (say 10-mm plasterboard or asbestos cement), and fill the space between the sheath and the pipes with mineral fiber. Still another might be to arrange the distribution ducts star-fashion around a point which is not noise-sensitive, such as a landing or a cupboard;

-- If the flue-spaces have been inadequately filled in. So as not to ruin the vertical insulation, the fill must be heavy. For example, it is a certainty that using building rubble as fill will give very poor results.

(The foregoing list of causes of noise reduction is not intended to be exhaustive.)

1.5 bis ACL Standards for Noise Attenuation Between Superposed Dwelling Units

In the case of apartment units in which the plan is identical on all floors:

-- A simple airtight floor with a mass of at least 450 kg/m^2, such as a reinforced concrete slab 20 cm thick, smoothset and covered, or a 21-cm rough-poured slab;

-- A floor whose mass is at least 350 kg/m^2, airtight, covered by wooden flooring on floating joists or by a floating slab, under the conditions listed in paragraph 1.5.b.

-- A floor with a mass of at least 350 kg/m^2, airtight, backed with a suspended ceiling under the conditions set forth in paragraph 1.5.c.

-- The solution suggested in paragraph 1.5.d., on condition that the mounting of each cell upon the one below it is elastic enough.

Most particular care will of course be taken to avoid all static sound transmissions, such, for example, as those listed at the end of paragraph 1.5.

1.6. Code Compliance Sound Attenuation Between Dwelling Units and Premises Destined for Other Use.

The noise reduction requirement is 5 db higher than that required between dwelling units. This level of noise reduction can be obtained by:

-- A wall with a mass of 350 kg/m^2, airtight, backed with a flexible (13) tight panel with a mass of 10 kg/m^2, under the following conditions:

-- that there be no rigid bond or fastening between the two walls, and the space between them be at least (14) equal to:

$$d_{(cm)} = \frac{100}{\text{mass of the backing element (in kg/m}^2\text{)}}$$

-- that the space between the elements be filled at least partially with a sound-absorbent material, preferably one with a mineral or vegetable fiber base, which cannot set up a rigid bond between the walls. (It is not necessary to have this absorbent material if one of the elements is itself absorbent)

-- that the backing wall not be a masonry wall;

-- that the adjacent walls be heavy (mass in excess of 350 kg/m^2).

-- A floor with a mass of 350 kg/m^2, airtight, and topped with a floating floor or backed by suspended floating ceiling, under the conditions set forth in paragraphs 1.5b and 1.5c.

1.6 bis ACL Standards for Sound Attenuation Between Dwelling Units and Premises for Other Use

We would cite, in the case of juxtaposition, the solution described under sub-paragraph a of paragraph 1.3 bis. For the case of superposition, we would advise the technique known as box-in-box (REEF, volume II, "Acoustics," Chapter E.1.).

2. PROTECTION AGAINST IMPACT NOISES

2.1. Review of Code Requirements (order of 14 June 1969)

The noise attenuation provided by covered floors must be such that the standard impact (tapping) machine, placed at any point in the unit, not cause a noise level in the main rooms of adjacent units in excess of 70 db(a).

2.2. Vertical and Diagonal Transmission of Impact Noises.

It must be emphasized that an impact on the floor of a room is heard on the floor below (15) not only in the room immediately beneath it, but also the rooms contiguous to it, since the transmission takes place on the diagonal.

Assuming that the floor plan of the apartments is identical on every floor, we must consider two types of impact noise transmission:

a. Impact noise transmitted from one main room to the main room directly below it;

b. impact noise transmitted diagonally, particularly from a service room to a principal room on the floor below which is contiguous to a service room.

2.3. Floor Assemblies Providing Protection Against Impact Noise

Insofar as concerns the transmission of standardized impact noise, satisfaction may be achieved with the following solutions:

1. A slab of poured concrete whose thickness, e, is at least 16 cm, with a covering whose α index of impact sound pressure improvement is at least 37 - e (example: α 19 with an 18-cm poured concrete slab); e is expressed in cm (16).

2. A floor and covering assembly for which laboratory measurements have shown that the adjusted overall level (A) of standardized impact noise,

L_n (17) which it transfers does not exceed 70 db(A). However, if the receiving area contains three light masonry partitions with large surfaces (more, say, than 5 m^2 each), the expected result may not be achieved.

3. In the case of diagonal transmission (of impact noise, coming for example from a service room and received in the main rooms), if the service room is separated from the main rooms by means of light masonry partitions, refer back to the two preceding paragraphs.

4. If the problem is one of diagonal transmission, if the service room is separated from the main rooms by a low-radiation light partition (thin sheets of plasterboard or asbestos cement panels or particle board), whose thickness, e, is at least 16 cm, topped with a covering whose α index is at least 35 - e, or a poured concrete slab at least 16 mm thick with a covering whose L_n is no more than 72 db(A).

5. In the case of diagonal transmission, if the service room is separated from the main rooms by a heavy wall (at least 250 kg/m^2), a poured concrete slab 16 mm thick with a covering whose L_n over a standard slab is less than 76 db(a).

2.3 bis Floor Assemblies to Meet ACL Standards

Label standard can be achieved with:

1. A poured concrete slab whose thickness, e (at least 16 cm), plus a covering whose index, α, of improvement of acoustical protection against impact noises is at least 39 - e (e expressed in cm).

2. A floor assembly for which laboratory measuresments have shown that the adjusted overall level (A) of standardized transmitted impact noise, L_n, does not exceed 67 db(A).

3. In the case of diagonal transmission (for example, of impact noise generated in a service room and transmitted to main rooms), if the service room is separated from the main room by a light masonry partition, refer back to the two preceding paragraphs.

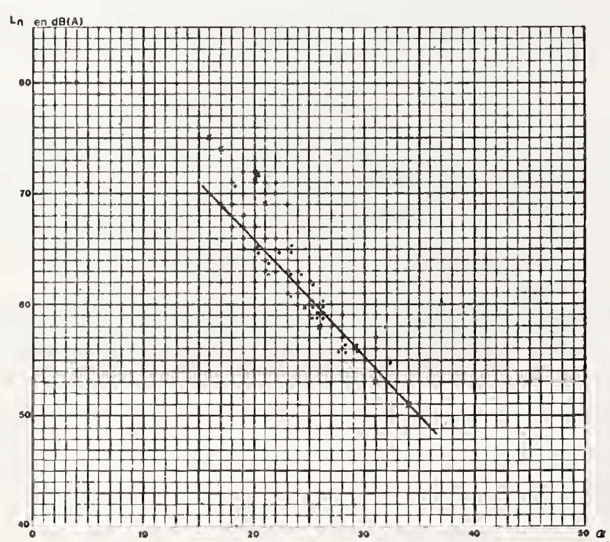
4. In the case of diagonal transmission, if the service room is separated from the main rooms by a light partition with a low reflection factor (thin sheets of plasterboard, or of asbestos cement, or of particle board), consider a poured concrete slab whose thickness, e, is at least 16 cm, coupled with a covering whose α index is at least 37 - e, or a poured concrete slab 16 cm thick coupled with a covering whose L_n does not exceed 70 db(A), or a 20-cm concrete slab covered by a ground surface whose L_n does not exceed 73 dB(A).

5. In case of diagonal transmission, if each service room is surrounded with heavy walls (at least 350 kg/m^2), a poured concrete slab 20 cm thick coupled with a covering whose L_n on a standard slab is less than 76 db(A).

6. In the case of diagonal transmission, if every service room is separated from the main room by a heavy wall (at least 250 kg/m^2), a poured concrete slab 16 cm thick coupled with a covering whose L_n on a standard slab is less than 74 db(A). This case might also apply, for instance, to noise from an outside landing heard in a principal room.

7. An expansion joint between the source of impact and the reception of impact noise. This could be the case particularly in neighboring single-family dwellings.

Ratio between index L_n and index α for floorings other than floating slabs.



Ratio between index L_n and index α, for floating slabs.

Table 1 Some Floor Coverings Tested at CSTB

Floor Coverings	Standard Impact noise Level L, in db(A) on a Full slab of Reinforced Concrete	α Index	Noise Attenuation (Standard Impact) In db(A)
1) Moquette courante sur thibaude ou sur sous-couche alvéolaire...	40 à 55	30 à 40	28 à 43
2) Tapis à velours nappé ou implanté	54 à 55	29 à 30	28 à 29
3) Tapis vinylique homogène posé par tension entre plinthes sur thibaude de feutre de 800 g/m².	52	32	31
4) Tapis aiguilleté, avec envers mousse	53 à 58	26 à 31	25 à 30
5) Dalle flottante 4 cm béton armé sur 1 cm de fibres minérales longues	55 à 60	25 à 30	23 à 28
6) Tapis caoutchouc à sous-couche cellulaire de 2 à 3 mm.........	57 à 61	24 à 27	22 à 26
7) Parquet par panneaux, flottant sur 2 cm de sciure de bois imprégnée au bitume .... 8) Parquet à lambourdes flottantes sur bandes de feutre liégé bitumé (grains de liège de 4 mm), ou sur panneaux légers de 1 cm d'épaisseur en fibres de bois imprégnées au brai 9) Parquet par panneaux, flottant sur panneaux légers de 1 cm d'épaisseur en fibres de bois imprégnées au brai	58 à 66	24 à 28	17 à 25
10) Tapis aiguilleté, sans envers mousse	58 à 68	22 à 26	15 à 25
11) Dalle flottante 4 cm béton armé sur grains de liège collés sur feutre bitumé (épaisseur de la sous-couche 13 mm)................	62	23	21
12) Tapis vinylique sur semelle alvéolaire, épaisseur totale 3 à 4,2 mm	67 à 71	20 à 25	12 à 16
13) Parquet à bâtons rompus posés directement sur le plancher ou avec interposition de sable ou de panneaux légers de fibres de bois	63 à 68	22 à 25	15 à 20
14) Tapis vinylique sur semelle alvéolaire et carton d'amiante. Épaisseur totale 3,2 à 3,5 mm...............................	67 à 69	21 à 23	14 à 16
15) Dalle flottante 4 cm en béton armé sur grains de liège collés sur feutre bitumé (épaisseur de la sous-couche 8 mm)..........	66	21	17
16) Tapis vinylique sur feutre jute 700 g/m²....................	67 à 75	16 à 22	8 à 16
17) Dalle flottante 4 cm en béton armé sur 2 cm de balle de riz liée au bitume	70	21	13
18) Dalles vinyliques de 2 mm sur sous-couche de 2,8 mm en granulés de fibres de bois......................................	71	20	12
19) Tapis vinylique sur feutre synthétique (polyester)............	69 à 72	18 à 21	11 à 14
20) Parquet à l'anglaise sur lambourdes simplement posées sur le plancher ou fixées à lui (par clouage spécial ou scellement au plâtre ou au bitume)	71	19	12
21) Chape asphalte de 20 mm sur deux cartons feutres de 360 g/m², revêtue de vinyl amiante	72	20	11
22) Parquet mosaïque collé sur panneaux légers de 1 cm d'épaisseur en fibres de bois imprégnées au brai	70 à 72	19 à 21	11 à 13

(Table continued on next page)

(Table 1 Continuation)

23) Dalles vinyliques à semelle chargée en liège, l'épaisseur de la semelle étant 2 mm 24) Parquet à bâtons rompus en chêne posé à bain de bitume 25) Dalle flottante 4 cm béton armé sur tapis de fibres végétales 1 cm 26) Parquet mosaïque collé sur liège aggloméré 2 à 4 mm 27) Tapis vinylique à semelle alvéolaire et carton d'amiante; épaisseur totale 2 à 2,2 mm	71 à 73	18 à 19	10 à 12
28) Tapis thermoplastique sur carton feutre 500 g/m²	75	15	8
29) Dalles vinyliques sur semelle chargée en liège, l'épaisseur de la semelle étant 1,5mm 30) Grès cérame collé sur sous-couche de 8 mm à base de liège réalisée in situ	76	12	7
31) Parquet mosaïque collé 32) Dalles en caoutchouc plein, épaisseur 3 à 4 mm 33) Linoléum	77 à 80	4 à 9	3 à 6
34) Tapis vinylique calandré sur support textile	76 à 78	5 à 10	5 à 7
35 Tapis ou dalles plastiques sans support textile ni sous-couche élastique incorporée	80	1 à 5	3

Erratum septembre 1976

Key:
1. Ordinary carpet over horsehair or waffle padding
2. Wall-to-wall nap velour carpet
3. Homogeneous vinyl flooring, wall to wall, laid over felt weighing 800 g/m^2
4. Foam backed knotted carpet
5. 4-cm floating slab of reinforced concrete over 1 cm of long mineral fiber
6. Rubber carpet over a 2 or 3 mm cellulose pad
7. Wood flooring panels floating on 2 cm thickness of bitumen-impregnated sawdust
8. Floor laid on floating joists over bitumenized corked felt (cork granule size 4 mm), or over light 1-cm panels of tar-impregnated wood fiber
9. Panel flooring, floating on light 1-cm panels of tar-impregnated wood fiber
10. Non foam backed knotted carpet
11. Floating slab of reinforced concrete 4 cm thick over roofing felt coated with ground cork (thickness of padding 13 mm)
12. Waffle-backed vinyl carpet, total thickness 3 to 4.2 mm
13. Herringbone wood parquet laid directly on the under-flooring or over sand or light wood fiber panels
14. Vinyl carpet on waffle and asbestos backing total thickness 3.2 to 3.5 mm
15. 4-cm floating slab of reinforced concrete over roofing felt coated with ground cork 8 mm thick
16. Vinyl carpet on jute felt, weighing 700 g/m^2
17. 4-cm floating slab of reinforced concrete over 2 cm of asphalt-bonded rice hulls
18. 2-mm vinyl tiles on 2.8 mm granulated wood fiberboard
19. Vinyl carpet on synthetic felt (polyester)
20. Plank flooring over joists either laid on the floor or attached to it (specially nailed or sealed with plaster or asphalt)

21. 20 mm asphalt covering on two 360 g/m^2 felt layers, covered with vinyl asbestos.
22. Mosaic parquet glued onto light 1-cm panels of asphalt-impregnated fiberboard.
23. Vinyl tiles on impregnated cork backing, with a backing thickness of 2mm
24. Oak herringbone parquet laid in hot asphalt
25. 4-cm floating slab of reinforced concrete over 1-cm pad of vegetable fiber
26. Mosaic parquet glued onto cork board 2 to 4 mm thick
27. Vinyl carpet with waffle and asbestos backing; total thickness 2 to 2.2 mm
28. Thermoplastic carpet on 500 g/m^2 felt backing
29. Vinyl tiles on cork-impregnated backing, with a backing thickness of 1.5mm
30. Stoneware glued on site to an 8 mm cork-based backing
31. Glued mosaic parquet
32. Rubber tiles, of 3 to 4 mm thickness
33. Linoleum
34. Vinyl carpet with textile backing
35. Plastic carpet or tiles with no woven backing or bonded flexible backing

3. PROTECTION AGAINST PLUMBING AND APPLIANCE NOISES

3.1. Review of Code Requirements (orders of 14 June 1969 and 22 December 1975)

In principal rooms, the common services in a building must not generate a noise level greater than 30 db(A), and individual equipment (outside the unit) must not generate noise levels there in excess of 35 db(A).

In kitchens, the individual or collective equipment of a building must not generate a noise level in excess of 38 db(A), and forced mechanical ventilation (meaning kitchen vents) must not generate noise levels in excess of 35 db(A) (with the vent set at LOW).

3.2. General Remarks on Room Arrangement and Fixture Design

Floor plans have a major impact on noise transmission from appliance operation. Hence you cannot hope to have good results without taking properly planned and very special precautions, if you set the kitchen, the bathroom, or the powder room of one unit next to or atop the bedroom of another, or if you set the kitchen next to the bedroom in a single unit, or if you set the bedroom opposite a stairwell or elevator shaft.

The design of plumbing, air conditioning, and heating fixtures as well as placement of household appliances is critical to noise transmission, owing to the strictness of code requirements.

It is very helpful of the manufacturers of plumbing fixtures, air conditioning, and appliances to supply the acoustical specifications of their products, particularly in case there is a testing code to determine such specifications in the laboratory (example: tap noise, AFNOR NF S 31-014 to 31-016).

3.2. bis General Remarks on the ACL Standard

The foregoing considerations are the more cogent if you plan to achieve the Acoustical Comfort Label.

3.3 (and 3.3. bis) Common Equipment and Systems

Protection against noise from this equipment depends both on the acoustical power of the equipment and on the noise impedance between it and the main rooms. This boils down to saying that building installations will be satisfactory if their distance from the principal rooms is a function of the noise they generate. So when they are particularly noisy, you can prudently relegate them either to areas which are not contiguous to the dwelling units, or, under certain conditions, to the roof. (18)

If the building equipment is tucked into the dwelling building itself, the solution will call for more careful and complete, and hence more difficult sound attenuation.

3.31 (and 3.31 bis) Elevators

Builders are advised (as noted in Section 3.2.) to consult the elevator manufacturers for information as to noise (machinery noise, noise from tracks, noise from opening doors, noise from tripping switches, etc...). Experience has shown that there are indeed manufacturers who can build absolutely silent elevators. In any case, it is indispensable that the machinery (motors, winding gear, pulleys) rest on a vibration-proof base and that the various tracks and contacts be designed to avoid audible vibrations or door-closing noise. Once in service, retention of elevator acoustical quality will be subordinate to proper operating maintenance.

3.32. Heating Installations

When the heating system is noisy, the reason may often be found in:

-- the main heating element if, for example, there are identifiable resonance frequencies for the burner and for the combustion chamber;

-- in ancillary installations, such as circulating pumps and fans;

-- in fuel-delivery noises, if the fueling chute or feed pipe is located near housing windows.

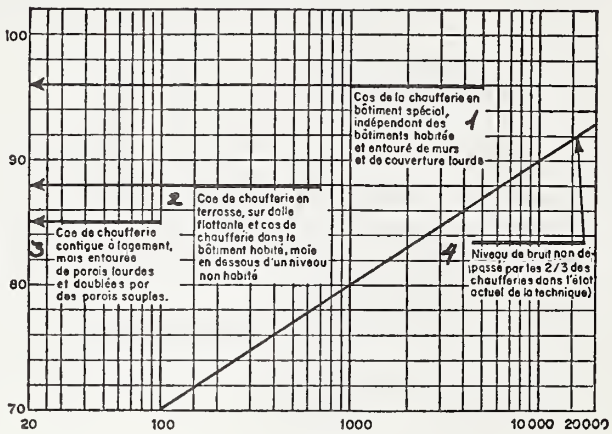
All these noises are propagated in very different ways: noise may be airborne (top and bottom ventilation), spread through walls or through the structure, and through plumbing and wiring conduits. As a result, no matter what the heating plant's location may be in relation to the housing units, the following common conditions must be met if the heating system is not to be a source of acoustical problems:

-- chimneys and flues detached from the residential buildings (although peak-load backup equipment is acceptable);

-- air intake ducts equipped with silencers which must be the more effective the larger the solid angle of overlook onto these ducts from housing units. For this purpose, clusters of sound-absorbent materials may be used, or the air intake ducts may be located toward non-occupied areas (a highly desirable design arrangement).

-- the fuel input chute or feed pipe can be placed at some distance from the facades of housing units.

Assuming that all these conditions exist simultaneously, there are possible solutions for limiting direct sound transmission from the heating system to the dwelling units (see Figure 9):



db(A) level from heating plant on premises

power rating of heating plant (kW)

Figure 9

Key: (1) Heating plant in its own special building, independent of residential units and surrounded by heavy walls and roof.

(2) Heating plant on a floating slab on the roof, and heating plant inside the residential building, but below a unit not planned for residential use.

(3) Heating plant contiguous to a residential unit, but surrounded with heavy walls backed by flexible partitions.

(4) Noise threshold not exceeded by 2/3 of the heating plants built at the present state of technology.

a. these consist either in reducing the noise at its source (19) or in placing the heating system at some distance from the housing units; for example, the main heating system may be housed in a special building with heavy walls and roof, or it may be buried beneath a heavy cover; you will note that quite often, if the building contains large expanses of window in its outer walls, the quiet of nearby dwelling units is thereby compromised.

b. others consist, in case it is impossible to adopt the foregoing arrangements, in increasing the acoustical isolation as well as taking heightened precautions against vibration between the heating plant and the dwelling units. Apparently this is possible only if the power rating of the heating system is relatively low, and under the following conditions:

b.1. Precautions against vibration noise (apartment building conditions)

-- the circulation pump is the right size and is set to operate at optimum speed; it is installed on a base separated from the floor and, upstream and down, its ducts are equipped with flexible mufflers so as to avoid propagation of vibrations through them; it is not advisable to use motors running faster than 1500 rpm.

-- all ducts are separated from the walls and floors by means of collars, studs, soffits, pegs, etc., as well as vibration damping fasteners.

If there are clusters of electric fans, they must be mounted on floating slabs or on equivalent bases such as "Silent-Blocs," and be separated from the ducts by flexible sheathing.

b.2. Insulation against airborne noises between heating systems and dwelling units.

Without prejudice to the "common" precautions cited earlier in this section, the following precautions may offer solutions to the problem posed in the following cases:

In the case of a heating system on the roof, one solution might be to mount the system on a heavy floating slab (or something equivalent, such as a floating caisson), making sure that the ceiling of the housing units underneath the heating plan has a mass of at least 350 kg/m^2.

In the case of an underground heating system, one solution is to put it beneath a floor not occupied for residential purposes (technical or commercial premises, lobby, etc.).

In the case of a heating plant located directly beneath (or contiguous to) a dwelling unit, the acoustical problem is very difficult if not impossible to solve if the heating element is noisy (noise level in the boiler greater than the order of 85 db(A); for this problem, see Figure 9.)

One solution for solving it, if the noise level at source is below the threshold level, could be to surround the heating plant area with heavy walls of at least 500 kg/m^2 and a sealed, flexible (12) suspended ceiling (for the upper covering of the space), and by flexible (13) sealed partitions (for the walls), with both ceilings and walls having a mass of 10 to 20 kg/m^2 and being at least 10 cm distant from the walls they back, the space between them being completely or partially filled with sound absorbent material. The bond between each backing partition and its parent wall should be as loose as possible (see Section 1.6). The insulation must not be vitiated by holes, fastenings, suspension brackets, or pass-through plumbing or ducts...

3.32. bis Heating Installation

The precautions listed in Section 3.32 must be the more scrupulously observed if your target is the quality called for under the Acoustical Comfort Label standard. For example, the arrangements described in the last paragraph of Section 3.32 are appropriate only if the noise level inside the heating enclosure does not exceed 80 db(A).

3.33 (and 3.33 bis) Water Pumps

If there are such devices (such as pressure-boosters), the antivibration precautions set forth in paragraph 3.32, 1 are applicable.

3.34 (and 3.34 bis) Precautions Against Expansion Noises

One solution is to allow free expansion in the hot-water pipes. This can be achieved by means of supports allowing slight longitudinal play, by curved shapes designed for the purpose (loops, elbows, goosenecks, etc.). An additional precaution is to make sure that the water temperature in the pipes is not subject to major variations.

3.35 (and 3.35 bis) Mechanical Ventilation Equipment

Remember that the usual arrangement, which changes the entire volume of air in the main rooms once an hour, involves removing the air from the service rooms and allowing fresh air to move naturally into the main rooms to fill the slight vacuum set up by the exhaust fans. However, there is no reason why you should not consider simultaneous mechanical exhaust and input of air (which will let you recover the heat from the exhaust air and send it back to the apartment through a heat exchanger via the fresh-air ducts which will have been more or less warmed in the process. This can be an excellent way to conserve energy.)

Noise sources may be:

- -- noise from the fan itself coming through a solid material (vibrations caused by the fan's turning out of true) or through the air, either through the ducts (against the airflow) or through the party wall if they do not provide enough isolation. Noise may enter the apartments in the ventilated building as well as nearby buildings exposed to direct external transmission of the ventilator noise (20).

-- Airflow through the ducts, and particularly through the outlets.

To cut down ventilator noise transmission through the structure, the preferred solution is to mount the fan on a floating slab (21), or on equivalent arrangements such as vibration-absorbing legs.

To derive full advantage from this arrangement, there will be flexible couplings between the ducts and the suspended equipment, except of course in cases where the ducts are already detached from the motor/fan complex (whether the latter be "floating" in its caisson, or placed on a floating floor or on anti-vibration legs, forming a sealed low-pressure space in which the ducts begin and end. In this case, you will need flexible couplings between this space and the fan, on the air exhaust side.)

When the flow-rate of the air through the ducts or outlets is high, it can, particularly if it encounters obstacles such as inlets, elbows, bottlenecks, or connections, cause noise due to turbulence. For acoustical reasons, but also for others (such as fire safety or load loss), the preferred solution is to cut down the air flow rate in the ducts to a level (22) of 3 to 5 meters per second, according to the diameter of the ducts and their placement (more or less distant from dwelling units).

As for the outlets, manufacturers should advise as to the acoustical power level in db(A) under the specified airflow conditions (and that level must be below 35 db(A) for minimum output in kitchens).

Lacking a measured value for the acoustical power level, we recommend limiting the operating pressure drop at the vent to around 100 Pa.

For the fan/motor assembly, it is best if the manufacturers supply the measured values (in db(A)) of the acoustical power level radiating to the outside and generated in the ducts (counter to the airflow) under the specified airflow conditions. These values must not exceed the threshold of around 60 db(A).

Otherwise, we shall assume that the fan/motor assembly is quiet in the case of regular use of motors running slower than peak speed and at a steady rate, with limitation on the absolute speed of the air as it emerges from the turbine. This will involve the necessity for simultaneously holding down its two components:

a relative speed of the blades, which requires sufficient turbine diameter (remember that the acoustical power output of a fan is inversely proportional to $\emptyset^4$, where $\emptyset$ is the diameter of the fan proper). The solution we suggest is to calculate this minimum value, expressed in meters, by means of the following formula:

$$\emptyset = \frac{\sqrt{Q}}{3} \quad \text{for two-way fans,}$$

and

$$0 = \frac{\sqrt{Q}}{2} \quad \text{for one-way fans.}$$

Q is the maximum output of the fan (expressed in cubic meters per second), meaning the output obtained when all the outlets are set for maximum output;

Q also taking leakage into account. See note (23)

b. the peripheral speed, no greater than around 12 meters per second. Note that this involves a total pressure not in excess of around 200 Pa.

The exhaust circuit must be very simple (you must rule out all unneeded elbows, both for acoustical reasons and for reasons of operating economy and fire safety), and big enough: avoid small housings with poor aerodynamic design; they cause load losses which can be disastrous from the point of view of energy consumption and from that of noise from the exhaust fan, emitted both to the outside and running counter to the airflow in the ducts, and thence into the rooms they serve.

We do not advise installing sound absorbents, even fireproof ones, in an exhaust circuit (24), for reasons of fire safety.

Setting and balancing devices are not recommended because they can cause noise. The fact is that you can always get along without them, if your circuits are properly designed to begin with.

These tips should be amended as follows for the fresh-air intake circuits:

The drawbacks involved in noise absorbent substances disappear, thanks to the relative cleanness of the air, given the express condition that they do not crumble and fall apart in the airflow; elbows with or without absorbents may be advisable, if they do not give rise to sizeable additional load losses (more than 5 Pa in all), so as to increase the noise attenuation provided by the outlets. The same attenuation obtainable with elbows can also be obtained with absorbent-lined distribution boxes.

If there are balancing controls, they should be placed at some distance from the air outlet, and sound-absorbent material should be interposed between them and the outlet.

3.36. Garbage Chutes

This convenience can be acoustically satisfactory provided it is mounted on an air column which is itself mounted on a vibration-damping base, and is not backed up against any wall of a main room in a residential unit, or against any wall which is a continuation of a main-room wall.

We recommend that individual garbage chute doors open only very slowly, without noise either on opening or on closing, and that the stopped plate at the back of the chute be flexible enough to absorb any noise from falling trash.

3.4. Built-in Individual Fixtures

These include primarily plumbing installations (sinks,washstands, toilets, bidets, bathtubs) and, sometimes, individual heating units.

3.41. Plumbing Installations

The generation and transmission of noise from these installations are complicated, and still not thoroughly understood.

Noise heard in dwelling units depends on the noise level emitted by the plumbing, the position of the service rooms in one unit in relation to the main rooms in another, and on the kind of walls surrounding the principal rooms. If you are concerned with the main rooms in a unit receiving this kind of noise, you are dealing with diagonal noise transmission in the case of multistory buildings with identical floor-plans on each level, in which the units presumably have their service rooms abutting their neighbors' service rooms, and their main rooms abutting their neighbors' main rooms.

This means that the best chances for a solution to the problem posed by noise transmission from plumbing or appliances from one unit to another consists in acting simultaneously on all the factors involved: the noise source, the structures, and the floor plan. The latter factor, if it is favorable, will make your job of bringing the rest of the premises up to code a lot easier.

a. Steps to take about noise at its source

The use of quiet fixtures is highly recommended, as is limiting incoming water pressure to a level not in excess of around 3 bar. To do this, there are regulators or governors which can be used, provided they do not themselves generate noise that can be heard in the apartments.

Noise from taps is measured in laboratories (CSTB, CEBTP), under conditions laid down in Afnor standard NF S 31-014 and NF S 31-015. A tap is classified by means of a curve representing the value D_s expressed in db(A), as a function of flow for a supply pressure of 0.3 MPa (3 bar). The higher than D_s value, the quieter the tap.

Taps which have been awarded the NF seal are, additionally, classified according to the noise they generate and according to their maximum flow. Taps whose D_s value is at least 25 db(A) are said to belong to Group 1 (meaning that these are the best), with the number I sometimes followed by the letter A, B, or C, specifying the tap flow if it is equipped with an aerator.

Taps whose D_s rating is between 15 and 25 db(A) inclusive are said to belong to Group II, with the number II followed by a letter as explained for Group I.

Taps whose D_s rating is below 15 db(A) cannot be granted the NF label.

A good solution is to use Group I taps with at most 3 bar pressure, which in practice gives good results even if you do not follow the recommendations in paragraph b.2. below. To reconcile the flow requirement with low noise, the best way is to use taps in Group I C.

The fixtures themselves must not add their own noise to that of the taps, and therefore must be even quieter than the taps. This is the case particularly of compressors, stop-cocks, and pressure reducers such as water meters. Standardization of testing procedures for these devices is currently under study.

To avoid noises from the water supply pipes, it is best to make the pipe sections ample (a water flow speed in excess of a V rating on the order of 2.5 to 3 m/sec is not recommended, since the flow rate even so will have to be modulated according to the sections and installations considered in relation to their proximity to the principal rooms).

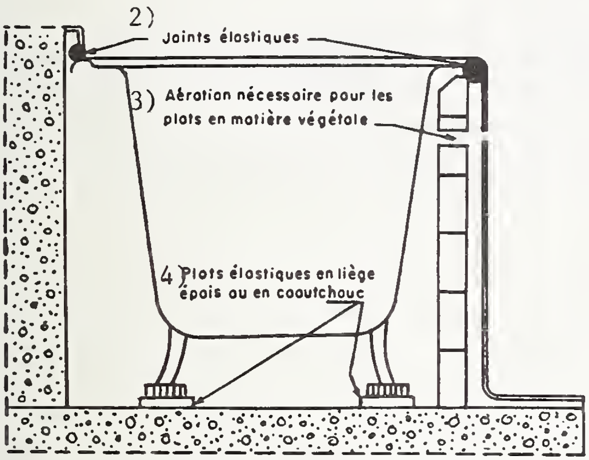
b. How to avoid noise transmission from fixtures through the structure.

b.1. Avoid installing fixtures against walls surrounding a main room or, if this is not feasible, use the recommended remedies.

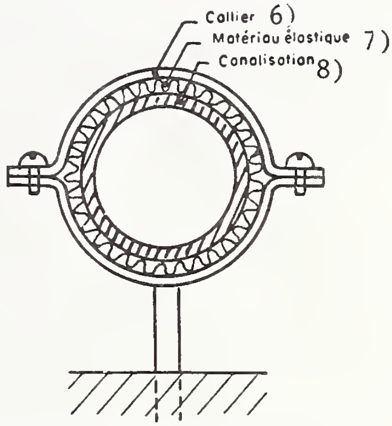
Avoid installing fixtures against or plumbing inside walls and floors adjoining a main room, unless you use properly designed devices for isolating them permanently from the structure (see Figure 10 for examples). In case you do use such devices (fill, collars, plugs, cases, fastenings, sheathing, etc. specifically designed to minimize vibrations), they must be installed on heavy walls (at least 250 kg/m^2). Another approach may be acceptable: that is to back the wall on which your fixtures are installed with a cupboard or a built-in storage space with drawers, or to put a flexible facing over the entire surface of the wall on the main room side.

b.2. Mass of walls between main rooms and bathrooms

It is advisable, in the case of a multi-story building with identical floor plans, to use walls with a mass of at least 250 kg per m^2 between rooms which are a source of fixture and equipment noises and the principal rooms. This arrangement cuts down noise transmission from the service rooms to a level, N, in the main rooms of the units to levels of N $\pm$ 1, and is helpful for other reasons as well. In this case it is possible to get satisfactory results with taps rated NG Group II, with supply pressure of less than 0.3 MPa (3 bars).



1) Baignoire encastrée par des dispositifs antivibratiles



5) Matériau élastique intercalé entre canalisation et brides de fixation

Figure 10. Devices for isolating plumbing fixtures from the structure.

Key: (1) bathtub surrounded by anti-vibration devices
(2) flexible joints
(3) air vents required for blocks of vegetable fiber
(4) Flexible plates of thick cork or rubber
(5) Flexible material interposed between pipes and clamps
(6) Collar (7) Elastic material (8) Pipes

3.41 bis Plumbing Installations Meeting Acoustical Comfort Label Standards

Increasing the level of acoustical quality over the required levels heightens the need for choosing quiet fixtures and holding water pressure down. In addition to the recommendations already made in paragraph 3.41, it is advisable to cluster the service rooms and to surround the cluster with walls whose mass is at least 350 kg/m^2.

3.42. Individual Heating Installations

If these are installed without proper anti-vibration precautions on a floor or against a party wall, they may very often prove to be a source of excessive noise in the adjoining apartments, owing to vibration set up in the floor beneath them. Simple precautions against vibration make it possible to reduce this serious nuisance, but will do nothing about the noise level in the unit where they are installed.

3.42 bis Noise in a Unit From Its Own Equipment

Cutting down such noises to acceptable levels makes it necessary to keep acoustical factors in mind when selecting equipment such as individual heating installations. Sound isolation may be made doubly sure by placing such equipment in appropriate locations (laundry-room, storage room, landing, etc.)

4. BIS SPECIAL REQUIREMENTS FOR THE ACOUSTICAL COMFORT LABEL: PROTECTION AGAINST OUTSIDE NOISES

Protection against a noisy location can be approached in several ways, either by improving the site (using screens, for example), or by careful building design.

When possible, the best solution for protection against a specific outside noise source is to set up a full screen (25) between the noise source and the facades to be protected (26). We know that when the view of all noise sources is cut off from the entire facade of a building, the drop in noise levels inside is about 7 db(A) from what it was before the screen was provided. This diminution is generally even greater for units on levels well below this limit of visibility (it is sometimes said that these units are in the "shade zone."). This can be determined with CSTB Cahier No. 952.

Solutions in which protection is provided by the building itself may be one of a combination of the following:

- Use of balconies with full guard walls, or of loggias, lowers the noise level by around 2 db(A) inside the units, provided the view of the noise source is cut off along the entire bay, clear up to the lintel.

The noise level inside the units can, under these conditions, be cut down by around 2 db(A), if the reflection of incident sound waves on the underside of the balcony (or loggia) of the floor above can be attenuated by means of absorbers (see CSTB n° 901 for increasing sound isolation through the use of balconies and loggias);

- In case of units with two exposures, placing the service rooms on the side toward the noise source and the principal rooms on the quiet side: in many cases, these rooms are practically protected already, since noise can reach them only by traversing the unit, and will be diffracted around the building or reflected off nearby obstacles if there are any (REEF, part E 1, Volume II, section 4.11). This solution may be advantageous if the noise-exposed facade is in Zone II of the ACL standard. We would further note that forced ventilation of such units is highly recommended.

-- Use of acoustically insulating facades: however, you must bear in mind the fact that application of this solution raises a fundamental problem, in that windows have two functions usually performed only one at a time, rarely simultaneously:

when closed, they will in certain cases (see below) provide excellent acoustical protection against outside noises;

when open, they still constitute the basic means for providing comfortable temperatures inside the units in spring, summer, and fall, but during those seasons they afford practically no acoustical protection.

This means that the comfort of the people living in housing built in a noisy location will depend on the way in which comfortable temperatures are maintained in spring, summer, and fall, since the windows have been placed so as to provide protection against outside noises. In any case, this will involve effective protection against the sun (except on North or Northeast exposures), forced ventilation, and standby heating with individual thermostats in case the main heat source is in the floor and/or ceiling.

One way to deal with this problem is by the use of forced air, either at a high rate of flow (provided you have taken the precautions outlined in Section 3.35), or pre-cooled by any one of several procedures (air from underground ducts, heated in winter and cooled in summer, or by heat exchange with air almost saturated with humidity). See the examples of solutions in Section 1.3 of II.

Once these precautions are taken, the noise attenuation effect of a facade becomes a significant factor in protection against outside elements, in relation to human requirements in the way of noise levels and comfortable temperatures, particularly in summer.

From the acoustical point of view, you will note that facades are made up of glazed portions, opaque portions, and sometimes an air intake. Assuming that the opaque portions are far more of a sound barrier than the glazed portions, either because of their mass or because they act as a double wall (and here we insert a reminder of the essential criterion of the mechanical independence of such walls). Under these conditions, when the glazed surface amounts to 1/4 of the ground surface of the building, whose height to ceiling is assumed to be 2.5 meters and whose reverberation interval is 0.5 seconds, you can achieve the following insulation levels in db(A) against source levels of street traffic (measurements taken in the CSTB or CEBPT laboratory):

All these insulation levels are lowered by 1 db(A) if the ratio between glazed and ground surface becomes 0.30, by 2 db(A) if the ratio becomes 0.40, and by 3 db(A) if it becomes 0.50.

All these insulation levels are increased by 1 db(A) if the glazed surface is only 1/5 of the ground surface, and by 2 db(A) if the glazed surface is no more than 1/6 the ground surface.

	Glass thickness (mm)	Window frames	Isolement (15) dB (A)	Air entry
Single pane	3	Fenêtre bois (1)	24	NO
	3	Fenêtre bois enrobé PVC, avec joints (2)	28	NO
	8	Fenêtre oscillobattante, avec joints (3)	29	NO
	8	Fenêtre bois enrobé PVC, avec joints (4)	31	NO
Multiple panes	3 + 5 + 3	Fenêtre bois enrobé PVC, avec joints (5)	27	NO
	3 + 2,5 + 3 + 2,5 + 3	Fenêtre bois enrobé PVC, avec joints (5)	27	NO
	6 + 12 + 6	Cadre fixe bois (6)	29	NO
	8 + 21 + 4	Fenêtre bois enrobé PVC, avec joints (5)	33	NO
	4 + 40 + 6	Fenêtre bois Acotherm avec ou sans volet roulant (7)	35	NO
	5,5 + 36 + 8	Fenêtre bois Acotherm avec ou sans volet roulant (7)	35	NO
	4 + 45 + 6	Fenêtre PVC Acotherm avec ou sans volet roulant (8)	35	NO
	5 + 45 + 8	Fenêtre bois Acotherm avec ou sans volet roulant (7)	36	NO
	4 + 6 + 4 + 28 + 6	Fenêtre bois Acotherm avec ou sans volet roulant ( )	35	NO
	5 + 45 + 5	Fenêtre bois comportant deux ensembles de verres parallèles, coulissants ou fixes (9)	31 (sans joints)	NO
			37 (avec joints)	NO NO
	8 + 51 + 4	Fenêtre bois Acotherm (10)	37	NO
	8 + 65 + 5	Fenêtre coulissante aluminium (dormant bois) Acotherm (11)	35	NO
Double window	8 + 150 + 8	Fenêtre bois enrobé PVC, avec joints (12)	44	NO
	4 + 150 + 4	Fenêtre prototype CSTB (« nouveau composant façade ») (13)	44	OUI débit de 30 m³/h sous 15 Pa (14)
	12 + 110 + 8	Fenêtre bois Acotherm avec ou sans volet roulant (7)	45	NO
	10 + 160 + 8	Fenêtre bois Acotherm avec ou sans volet roulant (7)	47	NO

Note 1. Bold-face numbers indicate air space between panes.
2. Acotherm windows listed are casements, unless otherwise indicated.
3. These noise attenuation ratings were laboratory-measured.
4. Rollup shutters with Acotherm windows were subjected to acoustical studies and research.

Key:
(1) Wooden frame
(2) PVC-coated wooden frame, jointed
(3) Casement window, jointed
(4) PVC-coated wood, jointed
(5) PVC-coated wooden frame, jointed
(6) Fixed wooden frame
(7) Acotherm wooden window with or without rollup shutter
(8) Acotherm PVC window with or without rollup shutter
(9) Wooden window with two parallel glass assemblies, sliding or fixed
(10) Acotherm wooden frame
(11) Aluminum sliding window with fixed Acotherm wooden frame
(12) PVC-coated wooden window, jointed
(13) CSTB prototype window ("new facade component")
(14) YES Air entry 30 m^3/hr under 15 Pa.
(15) Noise attentuation (db(A))

These ratings hold only if no major indirect noise transmission markedly diminishes the isolation thus obtained. Such transmission may exist:

-- because of unimproved seal, or if seal is provided by materials which are too light or not properly joined over too large a surface;

-- because of opaque walls (27) if their acoustical isolation index is no more than 10 or so db(A) better than that defined above (or even 12 db(A) or so if the glazed surfaces are small: example: less than 1/5 the ground surface);

-- because of the rollup shutter cases if they are visible both from inside and outside. One solution is to place the cases entirely outside the facade wall; another is to surround them with adequately isolating walls and to pack absorbent material (mineral fiber) inside the cases; in the latter case, they can, if properly designed, serve as air intakes without any excessive increase in noise levels:

-- because of air intakes in the facade, unless these are equipped with appropriate silencers (absorbent baffles, for example). The air intakes themselves must provide about 5 db(A) more sound isolation than the target level. The problem is the more intractable in that, if the building is in a noisy location, comfortable temperatures are difficult to achieve in summer with the windows shut (to keep out the noise), which implies very heavy flows through the air intakes; there are solutions, though, both for Zone II and Zone I : soundproofed ducts, with or without branching; soundproofed shutter cases, etc. See Cahier No 1308 and another forthcoming.

A straight duct, surrounded by suitable absorbent material, 300 mm long and enclosing a 20-mm air intake, will be adequate in Zone II of the standard.

A straight duct surrounded by suitable absorbent material, 550 mm in length and including two elbows, containing an air intake 20 mm in diameter, will be adequate for Zone II of the standard.

Figures 11 and 12 show schematic cross sections of the ducts described here, using as their absorbent materials perforated sheets of bonded rock wool with a bulk mass of 375 kg/m^3.

Other solutions are possible (shutter cases packed with absorbent material such as concrete mixed with wood chips).

-- because of fresh air intakes, if the intake mouth is exposed to noise and if there are no absorbent materials in the circuit.

-- because of the roofing, if it is not heavy enough and if some of the incident acoustical energy falls on it from above.

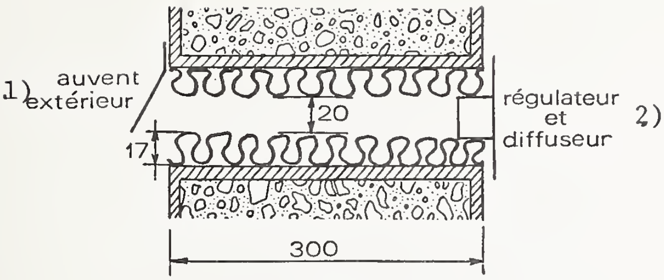


Figure 11

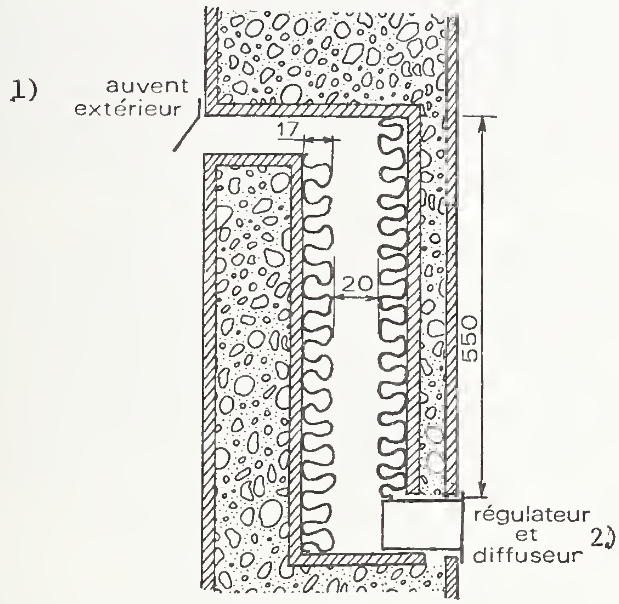


Figure 12

Key to Figures 11 and 12: (1) Exterior hood
(2) Regulator and diffuser

5. BIS SOUND CONDITIONING INSIDE A UNIT BETWEEN BEDROOMS AND OTHER ROOMS

Such sound conditioning, whose Label specification calls for 41 db(A) for a pink noise at the source, depends on the impedance capacity of the separating wall between daytime and nighttime parts of the unit, if they are contiguous, and on sound transmission through the corridor (or entry), which will depend on the acoustical quality of the communicating doors. The resulting isolation cannot but be less than the lowest level of impedance in each of these transmission channels, taken separately. It is less by around 3 db(A) for the lowest of these impedance levels if there is only a very slight difference between them.

a. Case of non-contiguity between day and night sides.

The only noise transmission comes through doors; one solution is to provide three successive doors between the rooms in question (this, for example, is the case if there is a door in the corridor), and another solution is to put absorbent material on the ceiling of the corridor between the rooms whose noise level you are trying to lower (an area of at least 3 m^2 for medium and high frequencies), with the space between each door and its surrounding walls having a cumulative surface of less than 150 cm^2.

b. Contiguity between day and night sides.

In addition to the aforementioned precautions, it is recommended that the separating wall between the day and night sides provide adequate impedance itself. To achieve this you can use:

- -- a wall with a mass of 200 kg/m^2 (example: 8-cm reinforced concrete);
- -- a wall with an acoustical impedance rating of 43 db(A). Some models of cupboard walls offer this level;
- -- a wall made up of two sheets of plasterboard, separated by at least 6 cm with mineral fiber nailed to studs spaced at least 60 cm apart;
- -- a wall with a mass of 150 kg/m^2, with at least half its surface backed with built-in storage cupboards that can be closed.

APPENDIX I

SPOTTING ACOUSTICAL DEFECTS IN A UNIT BY LOOKING AT FLOOR PLANS AND DESCRIPTIVE SPECIFICATIONS

A. Inadequate protection against airborne noise transmission outside the building if the building site is noisy.

-- Unit heated only by heavy radiating partitions (floor, ceiling, and perhaps walls as well).

-- Unit without controlled forced ventilation.

-- Facade containing large glazed expanses which do not meet the Acotherm standard or light filler panels not specifically designed for acoustical properties.

-- Thickness and nature of glazed expanse designed solely for mechanical or thermal purposes. (Presumption of inadequate sound attenuation quality).

-- External woodwork meeting neither the A.3 UEAtc tightness specification nor the Acotherm standard.

-- Air intake on the facade through openings which have not been soundproofed.

-- Rollup shutter cases built of light materials with no sound absorbent packing.

-- Lightweight roofing (in case all or some of the noise sources radiate toward the roof).

B. Inadequate protection against airborne noise transmission inside the building

Coming from contiguous units:

-- Party wall not heavy enough (less than 350 kg/m^2) when it is a simple wall.

-- Bedroom of one unit backed against a living-room or, even worse, a service room in an adjoining unit. (Presumption of inadequate protection.)

-- In the case of a medium-weight wall backed with a light partition:

- the medium wall is not heavy enough (less than 150 kg/m^2);

- the distance between the two walls is too short:

$$d_{cm} \text{ less than } \frac{100}{\text{mass of the backing partition } (kg/m^2)}$$

- no absorbent material between the two walls;

- backing or main walls of masonry.

-- In the case of a light double wall (unless demonstrated by laboratory tests to have an adequate sound attenuation rating):

- wall (or walls) of masonry

- walls of identical thickness

- floors weighing less than 400 kg/m^2

- distance between walls too short

- d_{cm} less than $\frac{200}{\text{mass of the backing element } (kg/m^2)}$

- no absorbent material in the space between the two walls.

-- Simple or compound wall of light masonry partitions with large surface, unless the wall is thickened to compensate.

-- Party wall of mass less than 400 kg/m^2 backed on both sides with plaster sprayed over expanded polystyrene.

Other construction systems not warranted by acoustical isolation measurements.

-- Transom or light facade panels running in front of party walls.

-- Facade panels whose seal with the end of the party wall is poor (doubtful tightness).

-- Windows on either side of the party wall whose openings are very close together.

-- Floating slab on which a party wall rests.

-- Pipes passing through a party wall in a chase space which has not been properly sealed.

-- Common ventilation duct serving the contiguous rooms of two units.

Noise from common service systems inside the building:

-- Wall separating a room in the unit from the service system not heavy enough (less than 300 kg/m^2).

-- Very light entry door without tight joint, when each room has its own communicating door.

-- Entry door whose total noise attenuation rating is less than 35 db(A), when not every room has its own communicating door.

Noise from units above or below:

-- Floors not heavy enough (less than 350 kg/m^2).

-- Floor plans not identical on all floors, giving rise to annoying superpositions such that the bedroom of one unit is in the same vertical plane as a living-room or service room, unless of course the floors have been reinforced to compensate for this.

-- Floor over which a floating surface is planned (slab or wood over joists) or a suspended ceiling, when the mass of the floor is less than 250 kg/m^2.

-- Ceiling rigidly suspended, or not tight.

-- Rooms bounded by large surfaces of light masonry.

-- Expansion joint running through a unit.

-- Expansion joint abutting a unit, one of whose walls on either side of the joint has a mass less than 200 kg/m^2.

-- Light light curtain wall running in front of the floor, not checked out with on-site measurement of vertical sound projection.

-- Pipes or ducts running through the floor in an imperfectly sealed conduit, or a flue space left open during construction and not subsequently filled in (case of technical shields).

-- Common gravity ventilation duct built of prefabricated story-high modules.

-- Forces exhaust intakes whose free section for airflow, s, is greater than 35 cm^2.

C. Inadequate protection against impact noise transmission from the floors of units above

From principal rooms:

-- Floor with an α less than 21 if the floor's mass is 350 kg/m^2.

-- Floor with α less than 19 if the floor's mass is 350 kg/m^2 to 400 kg/m^2, but less than 400.

-- Floor with an α less than 17 if the floor's mass is between 400 and 450 kg/m^2.

-- Floor with an α less than 25 if the floor's mass is less than 300 kg/m^2.

-- Floating floor whose specifications did not call for its installation in compliance with the rules of the art, that is, installation is calculated to avoid any possibility of movement by the floor.

From service rooms:

-- Floor whose α is not those cited above when the service rooms are separated from the main rooms by light partitions.

-- Main rooms situated beneath service rooms, unless the floors of the latter have the same α as those of the main rooms.

-- Floating floor which has been integrated into the walls and floors by service room plumbing or appliances, or by baseboards, or by any other means.

In all cases where there are large surfaces of light masonry walls in solid contact with the floors, unless the floors' α has been adequately increased.

D. Inadequate protection against transmission of operating noise from fixtures and appliances.

HEATING PLANT

-- Heating plant housed in the building and abutting on units without special precautions (an arrangement which is not as a rule recommended). Putting Fibragglo against the lower face of the floor, encased in the chase space, is never adequate.

-- Heating plant housed inside the building but not abutting on any units, although:

- the circulation pumps are in solid contact with the main walls and foundations.

- the flue is inside the building.

-- The heating plant is close to the building and has exhaust vents directed toward building facades.

-- Heating plant close to the building and surrounded by light walls with large surfaces (example: glazed walls).

-- Unsheathed ducts running through the walls.

FORCED VENTILATION INSTALLATION

-- Blowers in solid contact with main walls and/or foundation.

-- Blowers too small.

-- Flow rate of air too fast (over around 5 m/sec). (This also applies to ducts on the roof.)

-- Exhaust vents whose free section, s, for air passage is greater than 35 cm^2.

PLUMBING

-- Pressure too high (over 3 bar)

-- Plumbing fixtures, including pipes, attached to light masonry walls.

-- Taps not NF rated.

GARBAGE DISPOSAL CHUTES

Chute backed up to a bedroom wall or--not quite so bad--to a wall of a living-room or to a wall of light masonry in solid contact with a bedroom wall (unless, of course, the chute has been installed with special anti-vibration precautions).

ELEVATORS

--Cage backed up against a bedroom, unless there is adequate reinforcement of the wall between the cage and the bedroom.

E. Inadequate protection against airborne noise from in-building business premises or parking garages

-- Garage or commercial premises located directly beneath or beside dwelling units, without any reinforcement of the party wall.

-- Party walls of inadequate mass (less than 450 kg/m^2), and not backed.

-- Suspended ceiling or backing partition poorly mounted (example: a ceiling that is porous or rigidly mounted).

-- Light adjacent structures (less than 350 kg/m^2).

-- Access ramp to parking garage located directly below dwelling unit windows.

APPENDIX II. INFLUENCE OF WORK BY THE VARIOUS BUILDING TRADES ON COMPLIANCE WITH ACOUSTICAL REQUIREMENTS (with references to pertinent paragraphs)

A Isolement aux bruits aériens entre

	Façades (1)	(2) Murs intérieurs au bâtiment (excepté cloisons de distribution)	Cloisons de distribution (3)	Joint de dilatation (4)	Planchers (5)	Porte palière (6)	Revêtements de sol situés au-dessus de (7) pièces: principales (8)	Revêtements de sol situés au-dessus de (7) pièces: autres (9)	Équipements (10): Électricité (11)	Équipements (10): Chauffage (12)	Équipements (10): Ventilation (13)	Équipements (10): Vide-ordures (14)	Équipements (10): Ascenseurs (15)	Équipements (10): Robinetteries (16)
locaux juxtaposés (17)	transmission de flanc (18) § 1,3 (fin)	(19) § 1,3 *abc*	transmission de flanc (20) § 1,3 (fin)	(21) § 1,3*b* 1er alinéa	transmission de flanc (22) § 1,2 (tableau)	[1] (23)	En cas de dalle flottante celle-ci ne doit pas être commune à des logements différents (24) § 1,3 (fin)		(25) § 1,3 (fin)	traversée de canalisation (26) § 1,3 (fin)	transmission du son dans les conduits § 1,3 (fin) (27)	(28) § 1,3 (fin)	(15)	(16)
locaux superposés (29)	transmission de flanc (30) § 1,5 (fin)	transmission de flanc § 1,2 (tableau) (31)	transmission de flanc § 1,5 (fin) (32)	§ 1,3 *b* [3] § 1,5 (33)	§ 1,5 *ab cd* (34)		§ 1,5*b* (35)	§ 1,5*b* (36)		traversée de canalisation § 1,5 (fin) (37)	transmission du son dans les conduits § 1,5 (fin) (38)	§ 1,5 (fin) (39)		
circulation intérieure mais commune et logement (40)		§ 1,42 (41)	influence généralement faible ou nulle (42)			§ 1,4 (43)					[3] (44)			
extérieur et logement (45)	(46) § 4 *bis*	[4] (47)	[4] (48)		[4] (49)		[4] (50)	[4] (51)		chauffage par le sol sans appoint à prohiber § 4 *bis* (52)	il est nécessaire que la ventilation soit mécanique § 4 *bis*-3,35 (53)			
partie jour et partie nuit d'un même logement (54)		influence généralement faible ou nulle (55)	(56) § 5 *bis*		influence généralement bénéfique pour les pavillons à étage (57)						à cause des fentes sous les portes, 2 portes sont nécessaires entre jour et nuit (58)			

[Key on following page]

[Key to chart on preceding page]

(1) Facades
(2) Interior walls (except chase spaces)
(3) Chase spaces
(4) Expansion joint
(5) Floors
(6) Entry door
(7) Covering of floor above
(8) Main rooms
(9) Other rooms
(10) Equipment
(11) Electricity
(12) Heating
(13) Ventilation
(14) Garbage chute
(15) Elevators
(16) Plumbing
(17) Juxtaposed premises
(18) Side transmission Sec. 1.3 (end)
(19) Section 1.3 abc
(20) Side transmission Section 1.3 (end)
(21) Section 1.3b, first indent
(22) Side transmission (section 1.2 (table))
(23) Footnote (1)
(24) Floating slab must not be shared by two or more units. Section 1.3 (end)
(25) Section 1.3 (end)
(26) Run-through ducts Section 1.3 (end)
(27) Noise transmission through ducts Section 1.3 (end).
(28) Section 1.3 (end)
(29) Superposed units
(30) Side transmission Section 1.5 (end)
(31) Side transmission Section 1.2 (table)
(32) Side transmission Section 1.5 (end)
(33) Section 1.3.b (2), Section 1.5
(34) Section 1.5 abcd.
(35) Section 1.5 b
(36) Section 1.5 b
(37) Run-through ducts Section 1.5 (end)
(38) Noise transmission through ducts Section 1.5 (end)
(39) Section 1.5 (end)
(40) Common interior circulation systems and housing unit
(41) Section 1.42
(42) Overall influence slight or nil
(43) Section 1.4
(44) Footnote (3)
(45) Outside and dwelling unit
(46) Section 4 bis
(47-51) Footnote (4)
(52) Sun heating without backup cooling Section 4 bis
(53) There must be forced ventilation Section 4-bis - 3.35
(54) Daytime and nighttime sides of a unit
(55) Influence generally slight or nil
(56) Section 5 bis
(57) Influence generally benign for 2-story detached houses
(58) Because of slits under the doors, two doors are needed between day-side and night-side.

A. Protection against airborne noises between

		Façades (1)	Murs intérieurs au bâtiment (excepté cloisons de distribution) (2)	Cloisons de distribution (3)	Joint de dilatation (4)	Planchers (5)	Porte palière (6)	Revêtements de sol situés au-dessus de pièces (7)		Équipements (10)					
								principales (8)	autres (9)	Electricité (11)	Chauffage (12)	Ventilation (13)	Vide-ordures (14)	Ascenseurs (15)	Robinetteries (16)
B Bruits de choc normalisés			(17) § 2,3 alinéas 2, 3, 4, 5	(18) § 2,3 alinéas 2, 3, 4, 5		(20) § 2,3		(21) § 2,3 alinéas 1 et 2	(22) § 2,3 alinéas 3, 4 et 5						
C Bruit d'équipement	Vide-ordures (V. O.) (23)	(24) influence pouvant être bénéfique si le V.O. est sur loggia	(25) influence probable mais peu connue	(26) influence probable mais peu connue	(19) Supprime pratiquement tout bruit de choc ou d'équipement dans un local séparé de l'émission par le joint de dilatation.	influence probable mais peu connue (27)							(28) § 3,36		
	Ascenseurs (29)		influence probable mais peu connue (30)	influence probable mais peu connue (31)		influence probable mais peu connue (32)								(33) § 3,31	
	V.M.C. (34)	voir remarque 20 (35) (§ 3,3)	influence dans le cas où la machinerie est contiguë à un logement (36)	influence probable mais peu connue (37)		influence probable mais peu connue (38)						(39) § 3,35			
	Chauffage (40)	influence dans le cas où la chaufferie est extérieure (41)	influence dans le cas où la chaufferie est contiguë à un logement. § 3.3.2 b2 (42)	influence probable mais peu connue (43)		§ 3,3 2 et notamment 3,3 2 b2 (44)					(45) § 3,35 § 3,42 au § 3,42 *bis*				
	Robinetterie (46)			(47) influence notable § 3,41 *b*		(48) influence probable mais peu connue									(49) § 3,41 au § 3,42 *bis*

Empty squares: Empty squares mean that the influence is nil, slight or unknown

1. No influence, at least if the landing-unit isolation is in compliance itself.
2. The reason why Section 1.3.b cites only vertical walls weighing at least 200 kg/m^2 is that only such walls are proof against excessive side transmissions between floors.
3. Benign effect in the case of VMC (requiring a good seal on the entry door).
4. No direct /acoustical/ effect but some influence on thermal inertia. Summertime comfort is helped by strong thermal inertia, and so it must be ensured without opening the windows in situations where there is continuous loud noise outdoors.

[Key to chart on preceding page]

(1) Facades
(2) Interior walls (except chase spaces)
(3) Chase spaces
(4) Expansion joint
(5) Floors
(6) Entry door
(7) Covering of floor above
(8) Main rooms
(9) Other rooms
(10) Equipment
(11) Electricity
(12) Heating
(13) Ventilation
(14) Garbage chutes
(15) Elevators
(16) Plumbing
(17) Section 2.3, indents 2,3,4,5
(18) Section 2,3, indents 2,3,4,5
(19) Abolishes practically all impact or equipment noise in a room separated from the noise source by an expansion joint.
(20) Section 2.3
(21) Section 2.3, indents 1 and 2
(22) Section 2.3, indents 3, 4 and 5
(23) Garbage chute (V.O.)
(24) Influence might be benign if the garbage chute is on a loggia.
(25) Influence probable but little known
(26) Influence probable but little known
(27) Influence probable but little known
(28) Section 3.36
(29) Elevators
(30) Influence probable but little known
(31) Influence probable but little known
(32) Influence probable but little known
(33) Section 3.31
(34) VMC.S. (forced ventilation and heating
(35) See observation 20. Section 3.3
(36) Influence if the machinery is contiguous to a housing unit.
(37) Influence probable but little known
(38) Influence probable but little known
(39) Section 3.35
(40) Heating
(41) Influence if the heating is outside the building
(42) Influence if the heating plant is contiguous to a dwelling unit. Section 3.3.2.b.2.
(43) Influence probable but little known
(44) Section 3.3.2, and particularly 3.3.2.b.2.
(45) Section 3.35, 3.42 to 3.42 bis.
(46) Plumbing
(47) Very considerable influence
(48) Influence probable but little known
(49) Section 3.41 to 3.42 bis.

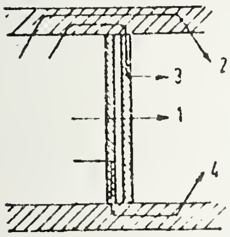
NOTES

1. See page 70 of Part E, Volume II, of the REEF (Building Sciences) on the effect of permeability on the acoustical impedance of a partition.

2. A flexible wall is one whose critical frequency is above 2,000 Hz. We shall be using this definition throughout this text. Example: plasterboard 10 to 18 cm thick, or particle board 20 to 50 mm thick.

3. If, for example, the backup component weighs 13 kg/m^2, as plasterboard does, the distance between the interior faces of the two components must be at least 8 cm.
The reason for this linkage between wall mass and spacing is that the resonance frequency of the mass-elasticity system, made up of the mass and its imprisoned air, must not exceed around 60 Hz (see pp 71 and 72 of Part E, Vol II, REEF.).
Quite often, a closet or cupboard will make good backing, provided of course that it covers the entire wall surface between the rooms to be isolated.

4. For example, such a rigid bond might be set up by too stiff a material between the medium-weight wall and the backup wall. This is one of the reasons why expanded polystyrene is undesirable for the purpose, unless it is selected from among the most flexible varieties. The other reason is that this material is not an acoustical absorbent.

5. 

A double wall of light masonry, for example, each of whose components weighs less than 150 kg/m^2, whatever the material may be, usually falls far short of providing the required levels of isolation, owing to side transmissions. The only way to deal with these is to take very special precautions and, given the present state of the art, these are not overly compatible with structural stability.

As a general rule, the best thing to do with such a bad bargain is to combine the two walls into a single partition.

Another bad example of the multiple partition is a wall with a mass of 300 kg/m^2 backed on both sides with plaster sprayed over expanded polystyrene.

6. There are several helpful parameters in addition to the theoretical low sound radiation ratings of these particular walls, which may allow you to specify party walls with a slightly lower R index:
   a) Emplacement in a heavy structure (full concrete slabs weighing at least 400 kg/m^2;
   b) A good ratio between partition surfaces and room volume.

When you have these on your side, you can expect to see your R - D_n values drop to 5 db(A).

7. It should be noted that such heating duct runthroughs have disadvantages other than spoiling your sound-conditioning, not the least of which is the fire hazard they pose. This means that a good, airtight seal between contiguous units is necessary, both for reasons other than sound insulation (e.g., fire protection), and for acoustical reasons.

8. In order to maintain the separation, care must be taken to screen the space against any falling objects such as pebbles or gravel. One way would be to fill the space with some flexible material such as expanded polystyrene, specially chosen for low density and low rigidity, so that the resulting mass/spring/resonance frequency does not exceed 50 Hz. or so, allowing for the fact that the polystyrene will act as a spring or shock absorber between the two walls.

9. This equivalent area of absorption could become "inoperative" were it to be masked by furniture. Locating the area of absorption on the ceiling makes this less likely to happen.

10. In the case of hollow floors, it is not certain (see REEF., vol 2, part E, p 70, section 3.321.6) that a mass of 350 kg/m^2 is adequate to provide the desired level of isolation.

11. This is more mass than is indicated in Section I.3.b. This is due in part to the fact that it is harder to dissociate the supplementary ceiling or the floating floor from the supporting slab than it is to dissociate two vertical partitions: it is hard to see, in fact, how to hold a floor or ceiling in place independent of the supporting slab; the floor tends to crush the underlayment, whereas on the face of it, the only way to hold up the ceiling is to hang it from the supporting slab.

12. A flexible partition is one whose critical frequency is greater than 2,000 Hz. Examples: plasterboard 10-18 mm thick, or particle board 20 to 50 mm thick.

13. A flexible partition is one whose critical frequency is over 2,000 Hz. This automatically rules out any plaster wall and any masonry component.

14. If, for example, the backup component weighs 13 kg/m^2 (say plasterboard), the distance, d, between the inner surfaces of the two components must be at least 8 cm.

15. In conventional as in heavy pre-fabricated construction, the only impact noises considered are those originating on higher levels. With light pre-fab construction, you will in all likelihood have to consider impact noise from neighboring rooms as well.

16. If you have hollow floors, you cannot be sure that a covering with an α index of 21 is going to do the job. Tests may be needed to remove all doubt. And the tests may show, for example in the case of a hollow floor topped with a floating floor, how effective the assembly is against both airborne and impact noise.

17. The figures on page twenty-four show the relation between the impact noise, L_n, transmitted by a floor over a standard slab and the α index of that particular type of floor. The standard slab is a poured slab of reinforced concrete with a mass of 350 kg/m^2.

18. To wit: to mount the equipment on a heavy floating slab or floating caisson, in a compartment lined with absorbent material, and to have the ducts or conduits interrupted by flexible sleeves perpendicular to the party wall between the compartment and the neighboring unit or units.
It will also be noted that, despite the absence of regulations, such equipment may in some cases (heating or ventilation plants) emit acoustical energy toward neighboring units. These units would be exposed to particular nuisance if the only way they could get ventilation or comfortable summer temperatures were to open the windows. If this is the case, the recommended solution is to hold the acoustical pressure 2 meters away from the exposed facades down to 40 db(A) at most.

19. It has been found that some gas burners, particularly those operating in ambient air, are far quieter than the curves in Figure 9 would indicate.

20. See note 18.

21. If your mounting has 2-way elasticity, take care that the two resonance frequencies are not identical:

-- resonance frequency between the ventilating system and its own anti-vibration mountings, and
-- resonance frequency between the floating slab (or floor) and the layer beneath it.

22. Remember that at equal output, the acoustical power, W, sent into the ducts is proportional to the 4th power of the air-flow: $W = k V^4$.

23. This leak flow is very rarely less than 10 percent. See: Examples of solutions, titled I - Hygrothermic and II - Ventilation.

24. When absorbent materials, even though not themselves combustible, become impregnated with grease and oil, they constitute a fire hazard. This hazardous situation occurs when the absorbent material has a fibrous surface and when it is not so placed as to be protected from any deposits of grease or oil. The absorbent materials built into the moving parts of exhaust vents are shielded from such deposits, and are therefore acceptable.
These hazards are particularly serious in kitchens, where the buildup of such inflammable deposits can help spread a fire with startling rapidity. To a lesser degree, the same hazard may arise in other service rooms.

25. We are using the term "screen" here in the broad sense: a screen may be a wall built for the purpose (of concrete, wood, asbestos cement, etc), or a group of buildings designed to be noise-proof (air-conditioned) or indifferent to noise because of their use (shops or commercial premises, parking garages, etc.), or again it may be a (reinforced) berm, or even

an array of solar heating receptors. Living (green) screens, to which special virtues are often ascribed, are not really very efficient in practice.

26. This point of view may be summed up in the statement that, insofar as possible, such protection should be kept "without the walls," meaning as far as may be from the building and as close as may be to the noise source. This approach also embraces the concern with providing outdoor recreation space, such as children's playgrounds.

27. Light facades may thus afford an inadequate noise attenuation index (Cahier n° 1260), to the degree to which the two facings are bonded together by thermal insulation which was never intended to provide a barrier against noise.

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This report offers methods of providing levels of residential acoustical comfort which meet French specifications contained in the French order of June 1969, and some methods which may facilitate meeting the more stringent requirements of the Acoustical Comfort Standard.

Two levels of solutions are thus identified: first, those which meet the basic French building code regulations; and, second, those which can bring dwelling units up to the French Acoustical Comfort Standard.

Recent advances in acoustical knowledge as applied to residential construction created a need for this revision to the earlier edition to provide new examples of solutions which meet building code requirements as well as solutions qualifying for the Acoustical Comfort Standard Label.

17. KEY WORDS *(six to twelve entries; alphabetical order; capitalize only the first letter of the first key word unless a proper name; separated by semicolons)*

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