RESEARCH PROJECT
ON THE QUALIFICATION OF THE DEGREE OF ACOUSTIC COMFORT PROVIDED BY MULTI-FAMILY BUILDINGS
PHASE II

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QUALIFICATION OF THE DEGREE OF ACOUSTIC COMFORT PROVIDED BY MULTI-FAMILY BUILDINGS – PHASE II

EXECUTIVE SUMMARY PRODUCED BY CMHC

In the report entitled Qualification Of The Degree Of Acoustic Comfort Provided By Multi-Dwelling Buildings - Phase 1 submitted to CMHC on July 10, 1996, MJM Acoustical Consultants Inc. proposes a method of monitoring and evaluating the isolation of noise produced by human activity, plumbing and mechanical equipment in multi-family buildings to be sold as condominiums. The overall objective of this study is to provide the construction industry with a reliable tool to evaluate the level of acoustic comfort in a housing complex. The Phase II report of the study submitted on December 17, 2002 describes the process of validating on site the criteria that had been proposed during Phase I, based on theoretical studies subsidized by CMHC between 1980 and 1996. It also proposes a protocol for assessing the degree of acoustic comfort provided by dwelling units located in multi-family residential buildings.

Ambient noise level criteria selected for mechanical and environmental noise

The ambient noise data collected by MJM since its creation in 1984, suggests that NC 20 is an appropriate design criteria for the isolation of the airborne and solid borne noise produced by the building's common mechanical and electrical equipment, and transmitted into the main rooms (bedroom, living room, etc.) of a apartment. This criteria also applies for living rooms and bedrooms with regards to plumbing noise originating from the use of plumbing fixtures inside adjacent dwellings.

As a noise criteria, it is preferable to use NC curves rather than a global level in dB(A) to take into account the frequency content of the disturbing noise. As illustrated in the case of elevator noise, a barely measurable increase in the global level (dB(A)) due to the operation of an elevator can correspond to a large increase in the noise level at a particular frequency, which makes it clearly perceptible.

The criteria selected for the noise produced by the heating/cooling mechanical equipment located within the apartments (in bedrooms, living rooms and dining rooms) is NC 25[1].

To characterize the outdoor noise associated with the urban where a building is constructed, it is proposed that the residual urban noise sampled during the day for a length of 10-minutes ($L_{95(10min)}$), at the façade of the building under study, should be less than or equal to 55 dB(A). This criteria is meant to give an idea of the steady background noise of the area in which a building is located; it is not meant to characterize specific noise sources in the area unless the source's operation is continuous in nature.

SOUND ISOLATION CRITERIA

Noise isolation provided by the envelope

The noise reduction target for the envelope of the building is 25 dB(A) which corresponds to the difference between the outdoor ambient noise level of $L_{eq(24\ hours)}$ = 55 dB(A) set by CMHC as the upper noise limit considered "normally acceptable" for a residential project and the target ambient noise inside an apartment when the heating/ cooling system is not in operation: either NC 20 or approximately 30 dB(A).

Airborne noise isolation

Based on the results of the sound isolation tests available when this report was published, performed on interdwelling partitions and floor/ceiling assemblies most frequently used in the construction industry, it appears that the indirect or flanking transmission of sound from one apartment to another limits the acoustic performance of the partitions and floor/ceiling assemblies to FSTC 58 in wood structures and FSTC 60 in concrete structures. The analysis of the data plotted on **graphs 7 to 10** confirms that the objective for airborne sound isolation of FSTC 55 with a minimum acoustic separation of at least 38 dB at low frequencies (third-octave bands with centre frequencies of 125 Hz and 160 Hz) established in Phase I of this research study is realistic and achievable in the majority of cases.

1 Note: In spaces other than bedrooms a slightly higher background noise (NC 30-35) is generally well tolerated for air conditioning systems

Impact noise isolation

As everyone knows, carpet is the floor covering which provides the best impact noise isolation, and the only covering, when installed on a concrete slab or on a floor of a wood-structure, capable of attenuating to near inaudibility the footstep noise produced by most people.

All thin acoustic isolation membranes destined for installation under an engineered wood floor have one thing in common: they provide little to no isolation of impact noise at low frequencies. The isolation that they provide becomes noticeable at frequencies greater than 250 Hz and varies from one membrane to another depending on the firmness of the support that the membrane provides: the firmer the membrane, the less impact noise isolation it provides at medium and high frequencies.

In summary:

- the IIC 65 criterion is easy to achieve when a floor covering of carpet and under-carpet are used.

- in the case of a wood floor installed on a 200 mm to 250 mm thick concrete slab, it seems relatively easy to achieve the IIC 55 criterion by using an appropriate acoustic membrane 3.5 to 7 mm thick.

- as for ceramic, due to the firm support required for this type of flooring, a harder membrane is required and the achievable impact noise transmission target is set to IIC 50. The installation of ceramic is thus not recommended for rooms other than entrance halls, kitchens and bathrooms where maintenance of floor surface is a priority.

SUGGESTED PROCEDURES FOR CONDUCTING ACOUSTICAL MEASUREMENTS

Various suggested procedures can be found in the body of the report for conducting measurements of ambient, transient or fluctuating noise within units, and measurements of urban noise outside the building. A rapid method is also described for the measurement of FSTC and FIIC scores provided by block partitions and inter-unit floor/ceiling assemblies.

Building acoustic comfort assessment grids

Tables 1 and 2 summarize the measures to be used and the criteria to which the results of these measurements must be compared in order to assess the degree of acoustical comfort provided by a unit which is already built. The comfort provided by a unit is described under three categories, using a scoring system that is explained in the report itself:

- isolation from mechanical noise;
- isolation from exterior noise;
- isolation from noise produced by human activity inside neighbouring units.

Table 3 proposes an evaluation method based on the plans of units not yet constructed.

Contribution to the construction sector

The first phase of this research project was an attempt to develop a method of evaluating the degree of acoustic comfort afforded by multi-family residential buildings during which the knowledge available on the subject has been collected and expressed into sound insulation objectives to be achieved in multi-family structures. An evaluation protocol to economically classify each housing unit that is part of a multi-family complex was also developed. Phase II of this project made it possible to validate/amend the proposed evaluation protocol performed in buildings with wood and concrete structures. In the opinion of the authors, the Research Study on the Qualification of the Degree of Acoustic Comfort Provided by Multi-Family Buildings is a reliable way of measuring the degree of acoustic comfort afforded by housing complexes.

Project Manager: Luis de Miguel

Research Consultant: MJM Acoustical Consultants Inc.

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Housing research at CMHC

Under Part IX of the National Housing Act, the Government of Canada provides funds to CMHC to conduct research into the social, economic and technical aspects of housing and related fields, and to undertake the publishing and distribution of the results of this research. This fact sheet is one of a series intended to inform you of the nature and scope of CMHC's research.

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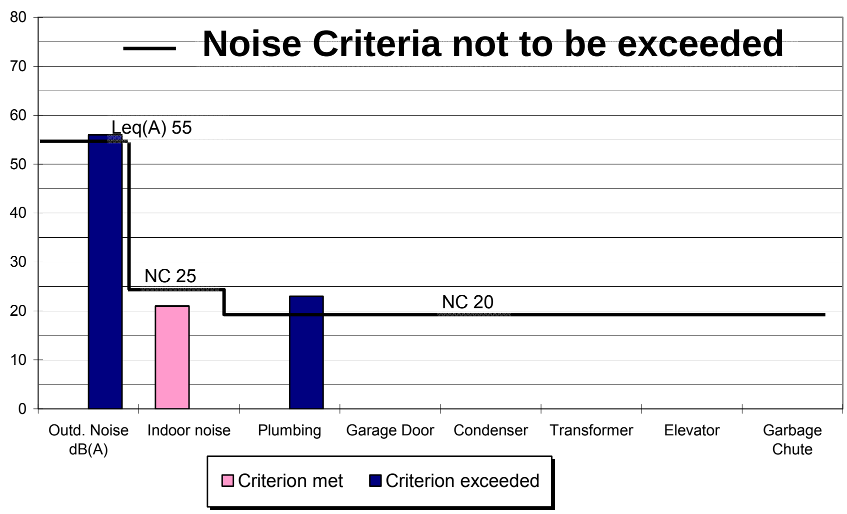
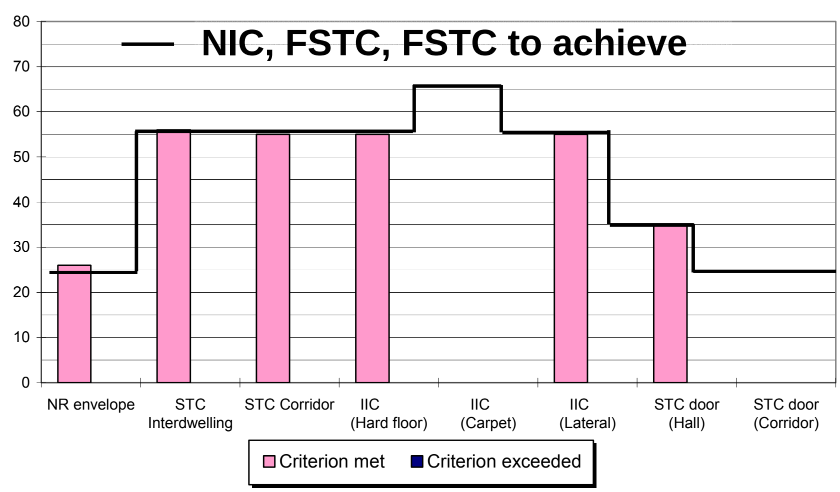
MEASUREMENTS TO PERFORM	SOUND LEVEL OR RATING MEASURED	TARGETTED OBJECTIVE
Outdoor residual noise L95(A)(10 min) :	56 dB(A)	L95 ≤ 55 dB(A)
Outdoor noise, Leq(A)(10min) :	57 dB(A)	Leq(out)-Leq(in) > 25 dB(A)
Indoor ambient noise, Leq(A)(10min) :	31 dB(A)	
Indoor ambient noise, L95(10min) :	21 NC (L95)	NC20 ≤ L95 ≤ NC25
FSTC, interdwelling wall/floor :	56	≥ 55 (with NR at 125 and 160 Hz ≤ 38)
FSTC, corridor wall, exit stairwell :	55	≥ 55
FIIC (hard floor) interdwelling :	55 IIC	≥ 55 (FIIC)
FIIC (carpet) interdwelling :		≥ 65 (FIIC)
FIIC (lateral transmission, exit stairwell) :	55 IIC	≥ 55 (FIIC)
FSTC access door :	35 hall	≥ 25 or ≥ 35 if the door is facing an entrance hall or an elevator hall
Leq(20 sec) plumbing main rooms :	23 NC	≤ NC 20
L(5 cycles) garage door :	x NC	≤ NC 20
Leq(20 sec) condenser or cooling tower :	x NC	≤ NC 20
Leq(10 sec) transformer :	i NC	≤ NC 20
L(Max)35ms elevator :	i NC	≤ NC 20
L(Max)35ms garbage chute :	x NC	≤ NC 20

x: non-existant; i: inaudible





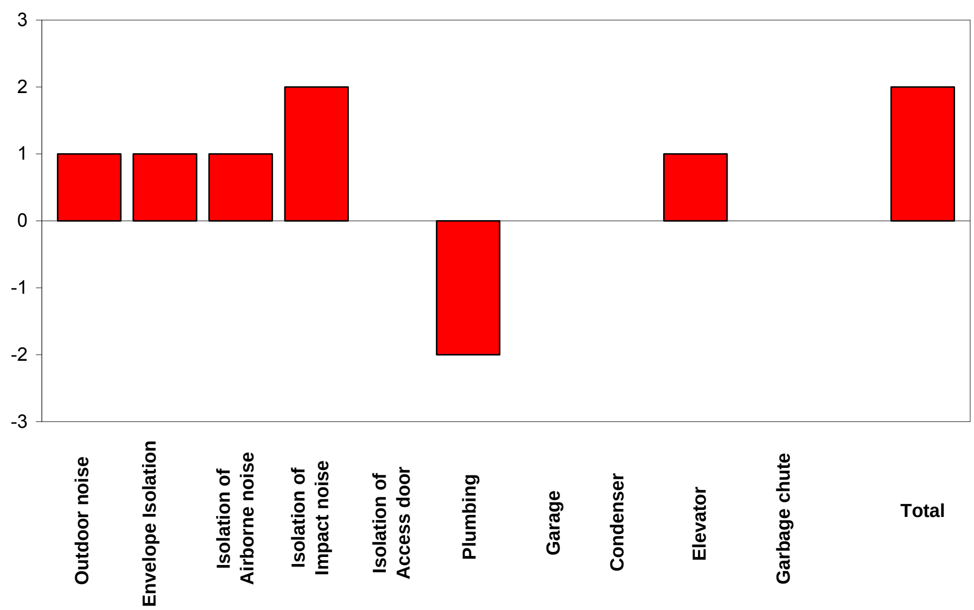
ACOUSTIC COMFORT OF CONSTRUCTED BUILDINGS

Table 1

CATEGORIES	POINTS ATTRIBUTED	SCORING METHOD	
AMBIENT NOISE			
Residual outdoor noise	-1	L95(A)out - 55 if L95(A)out > 55 and 0 otherwise	
Residual indoor noise	1	L95 -NC20 if L95 ≤ NC 20, 1 if NC20 < L95 < NC25 otherwise NC 25 - L95	
Envelope attenuation :	1	(Leq(A)ext - Leq(A)int) - 25 dB(A)	
NOISE PRODUCED BY HUMAN ACTIVITY			
Interdwelling acoustic separation :			
Airborne noise :	1	(FSTC-55) total for all FSTC	
Impact noise :	0	(FIIC-55) total for all FIIC	
Access door :	0	FSTC - 35, if the door is located near an elevator or an entrance hall	
		FSTC - 25 and 0 otherwise	
MECHANICAL, ELECTRICAL, PLUMBING NOISE			
Plumbing :	-2	0 if Leq< NC20 and NC20 - Leq otherwise	+1 if inaudible
Garage :	0	0 if Leq< NC20 and NC20 - Leq otherwise	+1 if inaudible
Condenser or cooling tower :	0	0 if Leq< NC20 and NC20 - Leq otherwise	+1 if inaudible
Transformers :	1	0 if Leq< NC20 and NC20 - Leq otherwise	+1 if inaudible
Elevator :	1	0 if Lmax< NC20 and NC20 - Lmax otherwise	+1 if inaudible
Garbage chute :	0	0 if Lmax< NC20 and NC20 - Lmax otherwise	+1 if inaudible

CLASSIFICATION OF THE UNIT

Isolation of outdoor noise:	**1**
Isolation of noise produced by human activity:	**1**
Isolation of mechanical, electrical, plumbing noise:	**0**
Total:	**2**



SINGLE NUMBER RATING OF THE ACOUSTIC COMFORT
PROVIDED BY A DWELLING IN A CONSTRUCTED BUILDING

Table 2

PENALTY POINTS AS A FUNCTION OF THE LOCATION OF THE UNIT IN RELATION TO NOISE SOURCES

POTENTIAL NOISE SOURCES	Present: (Y): Yes (N): No	Mitigation (Y): Yes (N): No	Number of penalty points* Present	Mitigation	Score
	A	B	C	D	D-C
Sources adjacent to the unit:					
- Entrance Hall	N		0	0	0
- Elevator	N		0	0	0
- Garage door	Y	Y	5	3	-2
- Mechanical/electrical room	Y	Y	5	2	-3
- Exit stairwell (2 first and 2 last floors)	N		0	0	0
- Other exit stairwells	N		0	0	0
Source inside the unit:					
- Garbage chute	N		0	0	0
- Plumbing and ventilation	Y	Y	0	0	0
- Ventilation shafts	Y	Y	5	3	-2
Sources above or below the unit:					
- Terrasse/Sun deck	N		0	0	0
- Pool	N		0	0	0
- Cooling tower and condensers on the roof	N		0	0	0
- Garage fans	N		0	0	0
- Hard floor	Y	Y	5	5	0
Outside noise sources:					
- Plane : NEF > 25	N		0	0	0
- Train : Leq ≥ 55 dB(A)	N		0	0	0
- Highway : Leq ≥ 55 dB(A)	N		0	0	0
- Main artery : Leq ≥ 55 dB(A)	N		0	0	0
Noise produced by human activity:					
- Interdwelling partition with an STC < 55	N		0	0	0
- Floor/ceiling assembly with an STC < 55	Y		0	0	0
- Floor/ceiling assembly with an IIC < 55	N		0	0	0
		TOTAL:	25	18	**-7**

SCALE OF PENALTY POINTS SUBTRACTED AS A FUNCTION OF THE NOISE TREATMENT ESTABLISHED

MITIGATION: SCALE	Number of penalty points to subtract Max	Min
Sources adjacent to the unit:		
- Entrance hall	5	2
- Elevator	5	3
- Garage door	3	2
- Mechanical/electrical room	5	3
- Exit stairwell (2 first and 2 last floor)	2	2
- Other exit stairwells	5	3
Sources inside the unit:		
- Garbage chute	3	3
- Plumbing and ventilation	5	5
- Ventilation shafts	5	2
Sources above or below the unit:		
- Terrasse/Sun deck	2	0
- Pool	2	0
- Cooling tower and condensers on the roof	5	3
- Garage fans	5	3
- Hard floor	0	0

Note :

This table is to be used for final comparison of units of the same building or same type of building, to classify units according to the acoustic comfort in which they provide

*Note: The penalty suggested in the cases of conflictual adjacencies is 5 points; this penalty was established arbitrarily. The points allocated to take into account mitigation remain to be defined precisely by additional research: those appearing in table 3 are provided as an example only. In the case of the criteria expressed in terms of STC and IIC, one must take into account the flanking noise transmission and other field conditions in the case of IIC; this was not possible with the data available at the time this research report was produced.

ACOUSTIC COMFORT OF BUILDINGS TO CONSTRUCT

Table 3

ACKNOWLEDGEMENTS

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RESEARCH PROJECT ON THE QUALIFICATION OF THE DEGREE OF ACOUSTIC COMFORT PROVIDED BY MULTI-FAMILY BUILDINGS - PHASE II

TABLE OF CONTENTS

QUALIFICATION OF THE DEGREE OF ACOUSTIC COMFORT PROVIDED BY MULTI-FAMILY DWELLINGS – PHASE II

1.0 INTRODUCTION

In the report entitled "Qualification of the degree of acoustic comfort provided by multi-family dwellings – Phase I" submitted to the Canada Mortgage and Housing Corporation (CMHC) on July 10th, 1996, MJM Acoustical Consultants Inc. proposed a method for controlling and evaluating the isolation of noise produced by human activity, plumbing and mechanical equipment inside multi-family condominium buildings. This evaluation method was developed using the knowledge contained in several research projects and studies subsidized by the CMHC available at the time Phase I was completed, as well as the content of existing standards and regulations.

In Phase II of this research project, the classification criteria developed in Phase I are reviewed and validated, and a protocol to evaluate objectively the degree of acoustical comfort provided by multi-family dwellings is proposed. To do so, the results of several hundred acoustic measurements performed by MJM Acoustical Consultants Inc. since July 1984, the date which the consulting firm was founded, were analyzed and compared. The following paragraphs describe the validation process which was followed, given the available research budget, and the recommended protocol for evaluating the acoustic comfort provided by apartments located within an existing or future multi-family dwelling building.

Notes: a) Several notes have been added and corrections have been made during the translation of this report to English from its original French version in an effort to update its content. However the reader must bear in mind that this report was first published in 2002 and that it is not all its content that has been revised/updated during its translation in 2012.

b) The nomenclature FSTC (Field Sound Transmission Class) was replaced by Apparent Sound Transmission Class (ASTC) during the revision of the ASTM E 366 standard in 2005 for field measurements where sound flanking is not controlled. In most cases where FSTC is used in this report, it is referring to ASTC.

c) **Tables 1 to 3** at the end of this report have been substantially modified/ annotated, to make their content more consistent and to facilitate their use.

2.0 NOISE CRITERIA FOR MECHANICAL AND ELECTRICAL EQUIPMENT CONSIDERATIONS RELATIVE TO NOISE CLIMATE ON A SITE, AND RESIDUAL NOISE INSIDE APARTMENTS

2.1 Validation of the selected ambient noise criteria

The ambient noise level in the absence of human activity was evaluated by averaging ambient noise measurements performed by MJM Acoustical Consultants Inc. in bedrooms, living rooms and dining rooms of 107 apartments located in the Montreal area. During these measurements, the ambient noise level was generally at its lowest (windows closed, refrigerators off, etc.). These average ambient noise levels are plotted on **graph 1** and are compared to the average ambient noise levels measured by the National Research Council of Canada[1] (NRC) in 602 Canadian homes. One notes that up to 250 Hz, the measured levels are similar to those measured by the NRC; however, starting at 500 Hz the two curves diverge substantially with differences between 4 and 8 dB. The global level of the average ambient noise measured is 29 dB(A)[2], which is 4 dB(A) less than the

1 Bradley, J.S.: "Acoustical Measurements in some Canadian Homes", Canadian Acoustics, Vol. 14, No 4, pp 19-25.

2 "A"Weighting: The sensitivity of the human hear to the noise it receives varies in function with the frequency. The ponderations A, B, and C were developed to adjust the objective values of sound pressure according to the sensitivity of the human ear: for each frequency band, the poderation factors are added or subtracted to the measured sound pressure levels. The values corrected for each frequency band are then summed logarithmically to obtain a single value called global sound level. The most common of these weightings is the "A" weighting and is used to estimate the likelihood of hearing damage in industry and to reflect the degree of nuisance caused by environmental noise. This is the same level found in most texts of noise regulations. All global sound levels appearing in this report are expressed with the "A" weighting; the noise levels by third octave bands or octave are not weighted.

average level measured by the NRC; the corresponding ambient noise criterion is NC[3] 20 whereas it is NC 25 with the data collected by the NRC.

With a low ambient noise level within the apartments, any noise transmitted, be it produced by human activity or by mechanical and electrical equipment, will be more perceptible and hence more likely to result in reduced acoustical comfort for the occupants of the apartment. The criterion set during Phase I of this research project was based on the NRC data of 33 dB(A) or NC 25. On the basis of the data obtained by MJM in over 100 Montreal dwellings, it seems more realistic for the purpose of evaluating the acoustical comfort of a dwelling, to use NC 20 instead of NC 25 or 33 dB(A) as the noise level not to be exceeded in the main rooms of an apartment (bedroom, living room, etc.) by common electrical and mechanical equipment. As a matter of fact, NC 20 is the ambient noise criterion used by the U.S. Department of Housing and Urban Development (HUD), the American counterpart of Canada Mortgage and Housing Corporation (CMHC).

2.2 Elevator noise criteria

Noise measurements have been performed in several apartments in which the residents complained of elevator noise. For every case in which complaints arose due to elevator noise, the vibration isolation of the hoisting mechanism was either deficient or nonexistent. Generally, when the hoisting mechanisms of elevators are installed on appropriate vibration devices, the noise that they transmit to the apartments is, in most instances, inaudible.

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3 NC: Noise Criteria curves: The NC curves are the background noise criteria most often used in North America to specify the levels which the noise produced by Heating, Ventilating and Air Conditioning (HVAC) systems should not exceed in inhabited spaces, as a function of the use for which these spaces are destined. These curves were developed in 1957 by Leo Beranek: they vary from NC 15 to NC 65. Since the NC curves were criticized for being too rumbly and too hissy, Beranek introduced in 1971 a series of modified NC curves which he called PNC curves (Preferred Noise Criteria). The spectrum of the PNC curves is identical to that of the NC curves for the mid frequencies but is lower at high and low frequencies. Because implementing the PNC criteria meant additional silencing costs to meet more stringent requirements at 63 and 125 Hz, the PNC criteria were never adopted by the HVAC industry. In 1981, Blazier empirically developed RC curves in an attempt to provide an alternative to the NC curves. The RC curves were gradually introduced in the noise and vibration control section of the ASHRAE Handbook, and, despite complaints from mechanical engineers and acoustical consultants, are now completely replacing the NC curves in this publication, as criteria to specify the background noise in inhabited spaces. In response to Blazier=s RC curves, Beranek created the NCB curves (Noise Criteria Balanced), which is a combination of the NC, PNC, and RC criteria.

To the best of our knowledge, the NC curves are still the noise criteria most often used by the HVAC industry to specify HVAC noise levels not to be exceeded in inhabited spaces.

Graphs 2A and 2B illustrate two examples of the evolution in time of the ambient noise in the bedroom of an apartment in which the occupants complained of the noise produced during the operation of the elevator; the integration time used for these measurements is 35 milliseconds (the time window which best correlates to the perception of sound by the human ear). The curves plotted on these graphs show the importance of performing an octave band analysis to evaluate the disturbance caused by elevator noise. When performing an octave-band analysis, one notices that the global (wide band) level increases only slightly during the operation of the elevator (see peak #2 on **graph 2A**) whereas for certain octave-bands the increase can be greater than 10 dB which makes the noise due to the operation of the elevator clearly perceptible. For this reason, we believe that the NC criteria are more appropriate than a global "A" Weighted level (dB(A))[2] to specify the level not to be exceeded by elevator noise inside inhabited spaces during the operation of elevators: the selected criterion not to be exceeded is NC 20.

2.3 Transformer noise criteria

Transformer noise is continuous in nature and is characterized by a pure tone whose fundamental frequency is 120 Hz; it can also contain harmonics at multiples of the fundamental frequency such as 240 Hz, 360 Hz, etc. Octave band analysis does not allow for easy detection of harmonics, contrary to third-octave band analysis, where peaks at 120 Hz, 240 Hz, etc. are clearly visible. This is illustrated in **graphs 3 and 4** which show the results of octave band measurements made in apartments where in both cases the occupants complained of transformer noise. In the case of **graph 3**, the transformer noise corresponds to NC 30; in the case of **graph 4**, the transformer noise measured was in the range of NC 20-25 and still was deemed unacceptable. Looking at the curves on these graphs one cannot easily detect peaks corresponding to pure tones associated to transformer noise. **Graph 5** shows the results of a third-octave band analysis of the transformer noise plotted on **graph 4**, the peaks are now clearly identifiable at frequency bands 125 Hz, 250 Hz and 500 Hz. The pure tone nature of transformer noise demonstrated on **graph 5** is what makes it easily detectable even if it is of the same order as the ambient noise, and thus likely to generate complaints among occupants.

In the majority of cases, when the vibration isolation of transformers is adequate, the noise that they emit is generally inaudible in the apartments. For the reasons mentioned above, the 33 dB(A) global level which was suggested in Phase I of this research project seems to no longer be adequate as a criterion for the transformer noise level transmitted to the main rooms of an apartment: it is recommended that it be replaced by NC 20, a criterion which is not perfect as demonstrated above, but which is somehow frequency dependent to take into account the pure tone nature of transformer noise.

2.4 Criteria for noise produced by mechanical equipment located inside apartments

In the case of mechanical equipment located inside each apartment such as Heating, Ventilating Air Conditioning (HVAC) systems, it is suggested that the noise which they produce be neutral (no pure tones) and not exceed NC 25[4]. When the noise produced by this type of equipment is constant in nature and doesn't contain any pure tones it constitutes a neutral ambient noise which is generally well tolerated mainly because its source is beneficial to the physical comfort of the apartment's occupants. In the case of an apartment with a very low ambient noise (less than NC 15), even the slightest noise is audible and a source of discomfort. Selecting a background noise criteria slightly greater than NC 20 for the HVAC equipment in each dwelling will likely result in masking noise produced in the adjacent apartments, providing a greater interdwelling acoustical privacy. The masking power provided by a higher background noise is illustrated in **graph 6**: the measured noise level generated by opening and closing the neighbouring apartment's patio door was between NC 15 and NC 20 except at 125 Hz where the noise transmitted was 10 dB higher than the ambient noise in the apartment, which made it clearly audible. With an ambient noise corresponding to the average ambient noise measured by MJM (also shown on **graph 6**), the noise produced by the opening and closing of the neighbour's patio door would have been of the same order as the ambient noise and thus much less perceptible.

4 Note: According to the author's experience, it is very rare that a ventilation system producing a level in the order of or less than NC 30 in the main rooms of an apartment will be the source of complaints from the occupants. The NC 25 criterion is thus representative of an ambient noise level comfortable for nearly all owners or apartment occupants. The limits suggested by ASHRAE for residential spaces is NC 25 to 35.

2.5 Plumbing noise criteria

Ideally, the noise level due to plumbing should be less than the residual ambient noise in order for it to be undetected in the main rooms of an apartment. For this reason, when evaluating the acoustical comfort of a multi-family building, the criterion selected for plumbing noise transmitted to the main rooms of a dwelling during the use of the plumbing fixtures of the adjacent apartment has been reduced from NC 25 recommended in Phase I, to NC 20[5].

2.6 Noise criteria for common mechanical equipment noise

As in the case of plumbing, transformers, etc. the noise level produced by mechanical equipment commonly found in a building and transmitted to the main rooms of an apartment should not exceed NC 20.

2.7 Considerations relative to the noise climate on the site where the building is located

The noise climate of the site where a building is located will also influence the level of acoustical comfort of its units; generally, the calmer the noise environment in which the building is situated, the greater its perceived acoustical comfort. Correctly evaluating the outdoor sound climate can be complex if all outdoor noise sources are being considered. This would require that measurements be performed over one or several 24 hour periods, which defeats the purpose of this study which is to provide a quick and low cost method for evaluating the global acoustical comfort of a dwelling.

A quick measurement of the exterior noise is not a complete representation of the sound climate since it doesn't account for intermittent noise sources such as trains, trucks, emergency vehicles, airplanes, etc. nor the variations in noise as a function of time (day and night). However, a measurement of the residual ambient noise (L_{95})[6] over a 10-minute period at the façade of a building during daytime allows for a characterization of

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5 When tested in individual rooms, the author still recommends NC 25 or 33 dB(A) as level not to be exceeded by plumbing noise produced by the plumbing fixtures of the adjacent apartments. The NC 20 criteria recommended in **item 2.5** above has been selected as part of a global rating which takes into account all other aspects influencing the perception of the acoustical comfort provided by a particular dwelling inside a building.

6 $L_{1, 10, 99(duration)}$: Sound pressure level exceeded 1%, 10%, 99% of the sampling period or duration indicated between parenthesis. These quantities corresponds to the highest sound pressure level measured during the sampling period in the case of the L_1 and L_{10}, and to the lowest levels in the case of the L_{99}.

the stable component of urban noise on the site. This parameter allows for a comparison of the residual urban noise context in which a building is located: the L_{95} measured at the façade of a building facing a major highway will be greater than the L_{95} measured at the façade of a building located on a calm street.

In an attempt to characterize the sound climate of a building site, it is proposed that the L_{95}, which represents the stable component of urban noise, when measured during the day (9am to 6pm) for a period of 10-minutes should not exceed 55 dB(A). In other words, the L_{95} measured during the day around the exterior of the building under study shouldn't exceed the ($L_{eq(24\ hours)}$)[7] criteria set forth by the CMHC for urban sites destined to residential occupation. As mentioned earlier, the L_{95} integrated over a 10-minute sample period should be used only to compare different urban contexts where buildings are located and not to characterize the noise climate of a site since the noise due to transient noise sources such as trucks, trains or planes, etc. are not taken into consideration in this criteria even if they can be causes for complaints.

2.8 Residual ambient noise inside apartments in the absence of human activity

As mentioned previously, the perception that an apartment is acoustically comfortable depends greatly upon the level of residual ambient noise (L_{95}) inside. If the ambient noise level is too low (less than NC 20) the noise transmitted from outside or from other units in the building will be more perceptible; therefore a very low ambient noise level in an apartment does not necessarily provide higher degree of acoustic comfort nor does a residual ambient noise level which is too high (greater than NC 25). For these reasons it is suggested that the residual ambient noise level inside an apartment in the absence of human activity should be between NC 20 and NC 25, dependent on whether the heating/ventilation/ cooling system of the unit is in operation.

7 $L_{eq(duration)}$: Equivalent sound pressure level. The sound pressure level of a steady state noise having the same acoustical energy as a fluctuating noise measured during the sample period, which is indicated in parentheses. For example, an $L_{eq(20\ min)}$ is an equivalent sound level integrated over a 20-minute period and an $L_{eq(24\ hours)}$ is an equivalent sound level integrated over a 24 hour period.

2.9 Summary of the ambient noise criteria selected for mechanical and environmental noise

The ambient noise data collected by MJM since its creation in 1984, suggests that NC 20 is an appropriate design criteria for the isolation of the airborne and solid borne noise produced by the building's common mechanical and electrical equipment, and transmitted into the main rooms (bedroom, living room, etc.) of a apartment. This criteria also applies for living rooms and bedrooms with regards to plumbing noise originating from the use of plumbing fixtures inside adjacent dwellings.

As a noise criteria, it is preferable to use NC curves rather than a global level in dB(A) to take into account the frequency content of the disturbing noise. As illustrated previously in the case of elevator noise, a barely measurable increase in the global level (dB(A)) due to the operation of an elevator can correspond to a large increase in the noise level at a particular frequency, which makes it clearly perceptible.

The criteria selected for the noise produced by the heating/cooling mechanical equipment located within the apartments (in bedrooms, living rooms and dining rooms) is NC 25[8].

To characterize the outdoor noise associated with the urban environment where a building is constructed, it is proposed that the residual urban noise sampled during the day for a length of 10-minutes ($L_{95(10min)}$), at the façade of the building under study, should be less than or equal to 55 dB(A). This criteria is meant to give an idea of the steady background noise of the area in which a building is located; it is not meant to characterize specific noise sources in the area unless the source's operation is continuous in nature.

3.0 SOUND ISOLATION CRITERIA

3.1 Attenuation provided by the building envelope

The attenuation provided by a building's envelope is determined by calculating the noise reduction between the exterior noise measured at the façade of the building and the noise measured inside the building. The noise reduction target for the envelope of the building

8 Note: In spaces other than bedrooms a slightly higher background noise (NC 30-35) is generally well tolerated for air conditioning systems.

is 25 dB(A) which corresponds to the difference between the outdoor ambient noise level of $L_{eq(24\ hours)}$ = 55 dB(A) set by the CMHC as the upper noise limit considered “normally acceptable” for a residential project and the target ambient noise inside an apartment when the heating/cooling system is not in operation: either NC 20 or approximately 30 dB(A).

3.2 Interdwelling airborne and impact noise isolation

To validate the interdwelling acoustic separation criteria expressed in terms of FSTC[9] and FIIC[10] in **tables 2 and 3**, it was necessary to establish whether these criteria could be achieved in real conditions given the architectural, spatial, structural and economic constraints inherent to all construction projects. To achieve this, the authors compared the results of acoustical measurements performed by MJM on partitions and on floor/ceiling assemblies with nominally the same composition and built by reputable builders who are recognized for the quality of the projects they construct. The results of these comparisons are shown on **graphs 7 to 16**.

3.2.1 Validation of the interdwelling airborne noise isolation criterion

A comparison of the transmission loss measured on seven concrete slabs of nominal thickness varying between 200 mm (8 in) and 250 mm (10 in) is presented on **graph 7**. The average transmission loss measured is displayed on the graph, which corresponds to a Field Sound Transmission Class (FSTC) of 61. Also displayed on **graph 7** is the interval between the highest and the lowest measured transmission loss values which correspond respectively to FSTC 55 and FSTC 64.

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9 FSTC: Field Sound Transmission Class; single number rating obtained by classifying as per ASTM E 413, the sound transmission loss of a building element measured in field conditions as per ASTM E 336 entitled ΑStandard Test Method for Measurement of Airborne Sound Insulation in Buildings". When the Sound Transmission Class measurement is performed in laboratory the ASTM E 90 standard is used. Generally for high performance partitions the STC rating performed in laboratory is substantially higher than the FSTC rating measured on site.

Note: In 2005 the ASTM E 336 standard has been reviewed and from that date the FSTC rating is reserved for measurements made in field conditions where the flanking paths are controlled and all the other conditions of the standard (such as volume, background noise, partition and room dimensions, etc.) are met. As of 2005, for measurements in field conditions where sound flanking paths are not controlled (which was the case for the measurement quoted in this research), one must use the term ASTC for Apparent Sound Transmission Class.

10 FIIC: Field Impact Insulation Class; single number rating obtained by classifying as per ASTM E 989, the normalized impact sound pressure levels measured in field conditions as per ASTM E 1007 entitled ΑField Measurement of Tapping Machine Impact Sound Transmission Through Floor-Ceiling Assemblies and Associated Support Structures@.

Graph 8 shows a similar comparison using the results of fourteen airborne noise isolation tests performed on floor/ceiling assemblies in wood structures with the composition shown in **figure 1** below:

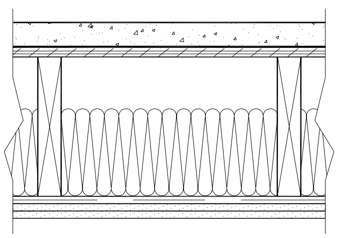

Figure 1

The average Field Sound Transmission Class obtained is FSTC 58; the range between the lowest and the highest sound transmission loss measured is FSTC 53 to FSTC 63.

Graph 9 is a summary of the results obtained from measuring nine double stud/double gypsum board interdwelling partitions having the composition as shown on **figure 2** below:

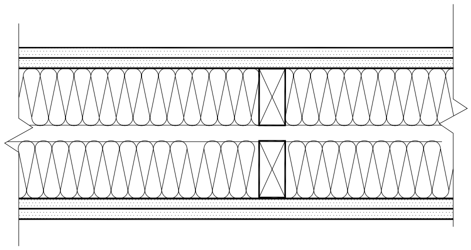

Figure 2

Precautions were taken during construction of the interdwelling partitions in order to limit the lateral flanking transmission via the floor and the ceiling as well as the transmission by the electrical outlets. The Field Sound Transmission Class corresponding to the average of the sound transmission loss measured is FSTC 58, with a range of FSTC 53 to FSTC 61 between the lowest and the highest transmission loss values measured.

The transmission loss obtained for five interdwelling partitions built with double steel studs instead of wood studs is illustrated on **graph 10**. The FSTC derived from the average transmission loss values is FSTC 60, with a minimum and a maximum of FSTC 56 to 61.

An analysis of **graphs 7 to 10** illustrates that:

- When comparing the field measurements performed by MJM ACOUSTICAL CONSULTANTS INC. to those performed in the laboratory by the National Research Council of Canada (NRC) on steel (STC 64) and wood stud (STC 66) partitions of comparable composition, one can deduce that the average degradation to be expected between the sound transmission class obtained in the field and those measured in laboratory conditions is of the order of 4 points in the case of steel stud partitions installed in a concrete structure, and of the order of 8 points in the case of wood stud partitions generally used for buildings of four storeys or less.

- As for floors constructed from wood joists with a 38 mm (1½") thick concrete topping and a ceiling composed of two layers of gypsum board on resilient furrings, the degradation between the ratings obtained in laboratory conditions (STC 67 to 70) and those obtained in the field (FSTC 58) can reach 9 to 12 points depending on the floor covering used. The Field Sound Transmission Class obtained on a concrete slab between 200 and 250 mm thick is comparable to that obtained in laboratory conditions on a floor having a similar composition.

In conclusion, based on the results of the sound isolation tests available when this report was published, performed on interdwelling partitions and floor/ceiling assemblies most frequently used in the construction industry, it appears that the indirect or flanking transmission of sound from one apartment to another, limits the acoustic performance of the partitions and floor/ceiling assemblies to FSTC 58 in wood structures and FSTC 60 in concrete structures. The analysis of the data plotted on **graphs 7 to 10** confirms that the objective for airborne sound isolation of FSTC 55 with a minimum acoustic separation of at least 38 dB at low frequencies (third-octave bands with centre frequencies of 125 Hz and 160 Hz) established in Phase I of this research study is realistic and achievable in the majority of cases.

3.2.2 Validation of the interdwelling impact noise isolation criterion

The floor coverings most often found in living rooms and bedrooms of multi-family dwellings are carpet on a carpet underlay, and hardwood floors that are either pre-varnished or varnished on site. In entrance halls, bathrooms and kitchens, the most commonly found floor coverings are ceramic tiles, marble or granite and less often vinyl tiles or linoleum.

As everyone knows, carpet is the floor covering which provides the best impact noise isolation, and the only covering, when installed on a concrete slab or on a floor of a wood-structure as shown in **figure 1** above, capable of attenuating to near inaudibility the footstep noise produced by most people.

However, for aesthetics, health, and maintenance reasons, hardwood floors are now requested by a vast majority of condominium occupants even if the impact noise isolation provided by these floors is much inferior to that provided by carpet. The hardwood coverings currently in style in condominiums are engineered floors with a thickness between 9 and 12 mm, installed on a thin "acoustic" membrane generally having a thickness between 3.5 and 7 mm. A wide variety of thin acoustic membranes are available; they are made of cork, recycled rubber, felt and other materials whose exhaustive enumeration would be useless since many new membranes are introduced to the market every year while other are being withdrawn. All thin acoustic isolation membranes destined for installation under an engineered wood floor have one thing in common: they provide little to no isolation of impact noise at low frequencies. The isolation that they provide becomes noticeable at frequencies greater than 250 Hz and varies from one membrane to another depending on the firmness of the support that the membrane provides: the firmer the membrane, the less impact noise isolation it provides at medium and high frequencies.

3.3 Acoustic performance of floor coverings

Graph 11 illustrates the Normalized Impact Sound Pressure Levels (NISPL)[11] measured by MJM on eight bare concrete slabs of varying nominal thickness from 200 to 250 mm. It can be seen on this graph that the average Impact Insulation Class is FIIC 32 and that the variation of the measured NISPL is greater than 10 dB for certain frequency bands[12]. The addition of floor coverings of various compositions generally increases the impact noise isolation that the floor/ceiling assembly provides. NISPL curves have been plotted on **graphs 12 to 15** corresponding to an average of five or six measurements performed on concrete floors of 200 to 250 mm thickness covered respectively with ceramic tile on cork, 9mm wood parquet on cork, wood parquet on a 5 mm recycled rubber membrane and carpet on an under-carpet. The FIIC 55 criterion for floors with hard surfaces and FIIC 65 for floors covered with carpet were achieved in all cases with an exception of the ceramic tile on cork for which the Field Impact Insulation Class corresponding to the average NISPL measured is FIIC 46. Our experience with ceramic floors is that they require a firmer underlay than hardwood floors to avoid cracking, which reduces significantly the impact noise isolation that can be obtained with this type of floor surface. For this reason, we believe it necessary to reduce the impact noise isolation objective to FIIC 50 for ceramic tile floors installed in entrance halls, kitchens and bathrooms where sanitary and maintenance constraints are priorities. The impact noise isolation target in living rooms, dining rooms and bedrooms remains unchanged (FIIC 55), with the consequence that apartments in which ceramic, granite or marble are installed in these rooms (unless it is demonstrated that the ceramic floor underlayment used can provide a FIIC rating of 55) will have their score negatively affected.

Our measurement data bank contains very few results for identical floors installed on floor/ceiling assemblies of wood structures as shown in above **figure 1**. In fact, the only comparable data available are those obtained from four measurements performed on carpet and under-carpet (**graph 16**) for which the average FIIC is 79, which is close to what was obtained for carpet installed on a concrete slab: FIIC 85 (**graph 15**).

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11 NISPL: Nomalized Impact Sound Pressure Levels

12 In an article from M. Michel Morin published in the Journal of the CAA July 2009 entitled "*Assessing the Field Impact Sound Insulation provided by floor coverings on concrete condominium building*", the NISPL measured on thirty-five 200 to 250 mm thick concrete slabs are compared: the FIIC rating corresponding to the minimum, average and maximum NISPL measured are respectively FIIC 24, FIIC 33 and FIIC 39.

In summary, an analysis of **graphs 12 to 16** reveals that:

- the IIC 65 criterion is easy to achieve when a floor covering of carpet and under-carpet are used.

- in the case of a wood floor installed on a 200 mm to 250 mm thick concrete slab, it seems relatively easy to achieve the IIC 55 criterion by using an appropriate acoustic membrane 3.5 to 7 mm thick.

- as for ceramic, due to the firm support required for this type of flooring, a harder membrane is required and the achievable impact noise transmission target is set to IIC 50. The installation of ceramic is thus not recommended for rooms other than entrance halls, kitchens and bathrooms where maintenance of floor surface is a priority.

4.0 PROPOSED METHOD FOR THE EVALUATION OF THE DEGREE OF ACOUSTICAL COMFORT OF DWELLINGS[13]

Tables 1 and 2 summarize the measurements to be performed in order to evaluate the acoustical comfort that an existing dwelling provides. For dwellings not yet constructed, **table 3** provides a rating method which needs further development, to take into account research data that was not available at the time this report was originally published.

4.1 Residual outdoor ambient noise and attenuation provided by the building envelope

4.1.1 The residual outdoor ambient noise (L_{95}out) is to be measured during the day (9am to 6pm) for a minimum of ten minutes at a distance of two meters from the exterior façade of the building. Points are lost if the residual outdoor ambient noise (L_{95}out) is greater than 55 dB(A).

13 Note: The point attribution method proposed to qualify the degree of acoustical comfort of a dwelling is somehow arbitrary. More research is needed to correlate the subjective perception of acoustical comfort with the results of objective measurements proposed in this report and to better qualify the overall acoustical comfort provided by a specific dwelling.

4.1.2 While the statistical measurement described in **paragraph 4.1.1** is performed, a simultaneous measurement (L_{95}in) is performed inside the building in the absence of human activity for a minimum of ten minutes; the difference in dB(A) between the outdoor and indoor noise levels represents the urban noise attenuation provided by the envelope of the building (essentially exterior walls and windows in most cases). The set objective of 25 dB(A) is subtracted from the value obtained. The objective of 25 dB(A) was obtained by calculating the difference between the indoor and outdoor noise level objectives (55 dB(A) outside and 30 dB(A) inside). If the objective attenuation of the building envelope is exceeded (i.e. greater than 25 dB(A)), the points attributed are positive; inversely, if the attenuation of the building envelope is less than 25 dB(A), the points are negative. The greater the difference between the two measured noise levels, the less the outdoor noise will be audible and as a result, the dwelling occupants should benefit from greater acoustical comfort.

The loss of points due to a high outdoor noise level can be compensated by an increased building envelope attenuation; for example, if the residual outdoor ambient noise is 58 dB(A), 3 points are lost that could be recuperated if the building envelope attenuation is 28 dB(A). However, no points will be awarded if the residual outdoor ambient noise is less than 55 dB(A).

4.2 **Residual ambient noise inside the dwelling**

Residual ambient noise inside the dwelling (L_{95}in) was measured in **item 4.1.2** above for a minimum of ten minutes. One point is attributed if the residual ambient noise (when the ventilation system is not operating) is within NC 20 and NC 25. If the residual ambient noise is greater than NC 25, the number of points removed is equal to the difference between the measured NC level and NC 25. If the measured NC level is less than NC 20, the slightest noise may be audible which does not favour acoustic comfort; therefore, the number of points equal to the difference between the measured NC level and the NC 20 criterion will be negative and will adversely affect the total of points attributed to the dwelling.

4.3 Acoustic separation between units

For airborne noise, the FSTC rating provided by interdwelling partitions and floors and whenever possible, by the dwelling/corridor partitions (no doors) and dwelling/exit stairwell partitions, are measured. For each partition, the measured FSTC rating is subtracted from the set objective FSTC 55.

For impact noise, the calculation is identical to that for airborne noise except that the objective is set to FIIC 55 for floors with hard surfaces and FIIC 65 for carpet-covered floors.

For access doors, if they are facing an elevator or an entrance hall, the FSTC rating is measured for the door or doors (two doors separated by a vestibule) at the entrance of the dwelling using the method described in **item 7.6.3 of Phase I**; this value is subtracted from the FSTC 35 objective. In the case of other access doors, the measured FSTC rating is subtracted from the objective FSTC 25.

4.4 Noise due to common building equipment

The noise due to various equipment common to a building (plumbing, elevator, garbage chute, garage doors, etc.) is measured. The scoring consists in attributing a point if the noise from the equipment is inaudible. If the noise due to certain equipment is audible in the dwelling but does not exceed NC 20, there is no penalty and no points are removed; if the noise due to common equipment is greater than NC 20, the number of points attributed is negative and corresponds to the difference between the measured noise and the NC 20 criterion.

4.5 Total points attributed

The total number of points attributed within each category is summed up. To achieve a comfort level deemed adequate, the total of the points (outdoor, human activity noise and mechanical) should be equal to or greater than 0; the greater the total, the greater the level of acoustical comfort provided by the apartment will be and vice versa.

5.0 SUGGESTED PROCEDURES FOR PERFORMING ACOUSTICAL MEASUREMENTS

5.1 Indoor continuous noise measurement

Equivalent octave band sound pressure levels integrated over a minimum period of 20 seconds measured in the middle of the room ($Leq_{(20sec)}$).

5.2 Fluctuating or transient noise measurement

In the case of measuring fluctuating or transient noise or other brief noises with levels that vary with time, the maximum level attained with a 35 ms integration time during the measurement is taken; this measurement is performed in the middle of the room. This type of measurement is used in the case of the noise produced by elevators, garbage chutes or plumbing (water hammer). In the case of the noise produced by the operation of garage doors, it is suggested that one performs an A-weighted Leq measurement for the duration of 5 complete operation cycles of the door.

5.3 Urban noise measured outside the dwelling and measurement of the exterior noise reduction provided by the envelope

Statistical noise measurement performed simultaneously outdoors at 2 m of the façade of the building or on a balcony, and indoors for a duration of 10 minutes.

5.4 Quick FSTC and FIIC measurements[14]

5.4.1 Presentation

The FSTC and FIIC ratings are calculated respectively based on the noise reduction and measured sound pressure levels which are normalized as a function of the amount of absorption (which is directly related to the reverberation time) within the receiving room. Currently, frequency analyzers allow for the calculation of the FSTC and FIIC rating but evaluating the reverberation time remains long and tedious since it needs to be evaluated for several measurement positions and for each of the sixteen octave bands taken into account in the calculation of the rating. The goal is to propose a quick method for evaluating the FSTC and FIIC ratings of interdwelling partitions and floors with adequate precision.

14 Note: This “quick” method becomes less relevant as it was when the report was originally published in 2002, as technology progresses and allows for a much faster data treatment.

The quick method being proposed herein is based on the hypothesis that the reverberation time in a reasonably furnished main room varies very little as a function of the frequency which indicates that the normalization relative to the quantity of absorption is nearly constant as a function of frequency. On the basis of this hypothesis, it is not necessary to calculate the reverberation time for each third-octave band. The FSTC rating can thus be calculated from the NIC rating (evaluated based on the noise reduction) and the FIIC rating can be calculated from the non-normalized Impact Sound Pressure Levels (ISPL) using the following equations:

$$FSTC = NIC + 10\log\left(\frac{S}{A}\right)$$

$$FIIC = FIIC_{ISPL} + 10\log\left(\frac{A}{10}\right)$$

where $FIIC_{ISPL}$: FIIC rating calculated based on the non-normalized Impact Sound Pressure Levels (ISPL)

A : amount of absorption in the receiving room

S : surface area of the assembly tested

The NIC and $\text{FIIC}_{\text{ISPL}}$ measurements are performed in accordance to the procedures outlined below. To evaluate the amount of absorption, an evaluation of the reverberation time based on the decay of the global sound pressure level at a single point in the room is proposed.

5.4.2 Validation

Based on the data from sixty-four FSTC and FIIC tests performed by MJM in the main rooms of various apartments, the variation of the reverberation time with respect to frequency represents an average variation of 2 dB for the 10 log(S/A) or 10 log(A/10) correction terms between 100 Hz and 4000 Hz with a standard deviation of 1 dB; the error of the FSTC or FIIC rating measurement should be of the same order as the variation of the correction terms as a function of frequency.

To verify this, a comparison was made with the results of fourteen FSTC and FIIC measurements performed in accordance to the ASTM E 336 and ASTM E 1007 standards against the results obtained using the proposed quick method. Essentially, the comparisons apply only to the 10 log(S/A) or 10 log(A/10) correction terms since the NIC or ISPL remain unchanged. The comparisons were performed using the following for the reverberation time measurement:

- a pink noise[15] source where the decay of the global A-weighted sound level (spectrum contained between 50 Hz and 5000 Hz) is calculated.

- a pink noise source for which frequencies below 100 Hz were removed and the decay of the global level in dB is calculated.

- a pink noise source for which frequencies below 200 Hz were removed and the decay of the global level in dB is calculated; this last configuration is meant to simulate the frequency spectrum of a .22 caliber starter pistol.

The maximum spread observed was 3 IIC or STC points and the results obtained using the quick method were always greater than those obtained in accordance with the ASTM standards, which can be explained by the fact that the global reverberation time is greater than the reverberation time for each third-octave band. On average, by using the global dB(A) signal decay, the 10 log(S/A) or 10 log(A/10) term is over estimated by 1.5 dB and by using either of the global dB signals, the terms are over estimated by an average of 1 dB; the standard deviation calculated for each of these results is 1 dB.

Therefore, slightly better precision is obtained when using the global level in dB; assuming that the spectral content of the noise source below 100 Hz or even 200 Hz is negligible. If the spectral content of the noise source contains frequencies below 100 Hz it is then necessary to evaluate the reverberation time using the global A-weighted level

15 Pink Noise: Noise that possesses equal energy in each 1/3 octave or octave band.

in order to reduce the effect of the low frequency content which has a tendency of impeding the shape and prolonging the slope of the sound decay.

The methodology and procedure of the quick FSTC and FIIC rating measurements are presented below. The precision of the results obtained using the quick method should be comparable by one point more or less to the result that would be obtained by performing the test in accordance to the ASTM standards.

5.4.3 Quick FSTC measurement

This measurement procedure is for a quick evaluation of the STC rating of an interdwelling partition or floor. The method consists in performing an NIC measurement to which a correction factor is applied that takes into account the global reverberation time of the receiving room in dB or dB(A). The procedure is as follows:

.1 NIC calculation

- perform a measurement in the source room (Lps); a spatial average
- perform a measurement in the receiving room (Lpr); a spatial average
- perform a measurement of the ambient noise in the receiving room; a spatial average
- calculate the NIC rating using the analyzer

.2 Correction factor

- in the middle of the receiving room, measure the global reverberation time (RT) in dB or dB(A) according to the type of noise source used
- measure the surface area of the sample (S) and the volume (V) of the receiving room
- calculate $K = 10 \log(S/A) + C = 10 \log[S \cdot RT/(0.16V)] + C$

  $C = -1.5$ if measured in dB(A) or -1 if measured in dB;

.3 Quick FSTC rating

Calculate FSTC = NIC + K

5.4.4 Quick FIIC measurement

.1 $FIIC_{ISPL}$ calculation

- perform one measurement (Lpr) per position of the impact machine; a spatial average
- perform an ambient noise measurement; a spatial average
- calculate the $FIIC_{ISPL}$ rating from these measurements (Lpr) using the analyzer

.2 Correction factor

- in the middle of the receiving room, measure the global reverberation time (RT) in dB or dB(A) according to the type of noise source used
- measure the volume of the receiving room
- calculate $K = 10 \log(A/10) + C = 10 \log(0.16V/10RT) + C$

  $C = -1.5$ if measured in dB(A) or -1 if measured in dB

.3 Quick FIIC rating

Calculate $FIIC = FIIC_{ISPL} + K$

Respectfully submitted December 17, 2002

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Revised and translated June 5th, 2012 by
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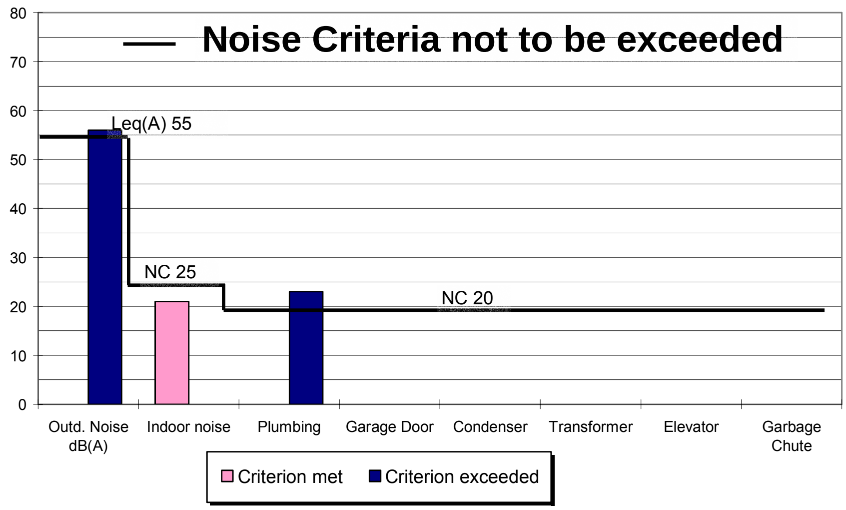
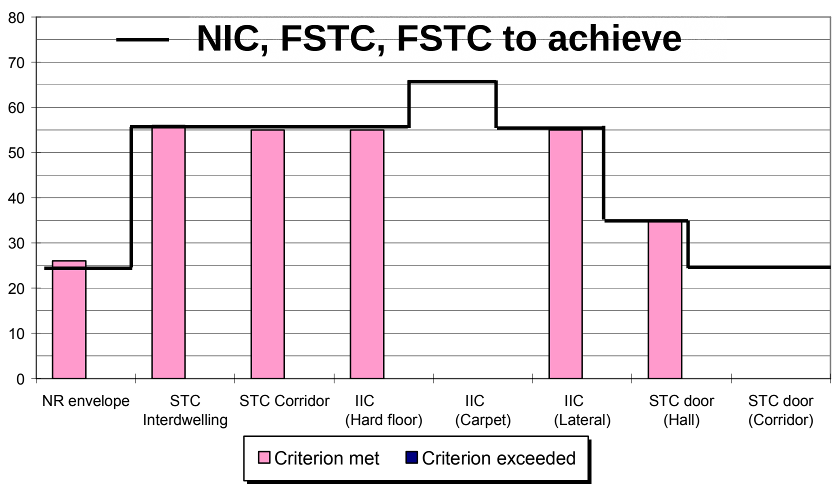
MEASUREMENTS TO PERFORM	SOUND LEVEL OR RATING MEASURED	TARGETTED OBJECTIVE
Outdoor residual noise L95(A)(10 min) :	56 dB(A)	L95 ≤ 55 dB(A)
Outdoor noise, Leq(A)(10min) :	57 dB(A)	Leq(out)-Leq(in) > 25 dB(A)
Indoor ambient noise, Leq(A)(10min) :	31 dB(A)	
Indoor ambient noise, L95(10min) :	21 NC (L95)	NC20 ≤ L95 ≤ NC25
FSTC, interdwelling wall/floor :	56	≥ 55 (with NR at 125 and 160 Hz ≤ 38)
FSTC, corridor wall, exit stairwell :	55	≥ 55
FIIC (hard floor) interdwelling :	55 IIC	≥ 55 (FIIC)
FIIC (carpet) interdwelling :		≥ 65 (FIIC)
FIIC (lateral transmission, exit stairwell) :	55 IIC	≥ 55 (FIIC)
FSTC access door :	35 hall	≥ 25 or ≥ 35 if the door is facing an entrance hall or an elevator hall
Leq(20 sec) plumbing main rooms :	23 NC	≤ NC 20
L(5 cycles) garage door :	x NC	≤ NC 20
Leq(20 sec) condenser or cooling tower :	x NC	≤ NC 20
Leq(10 sec) transformer :	i NC	≤ NC 20
L(Max)35ms elevator :	i NC	≤ NC 20
L(Max)35ms garbage chute :	x NC	≤ NC 20

x: non-existant; i: inaudible





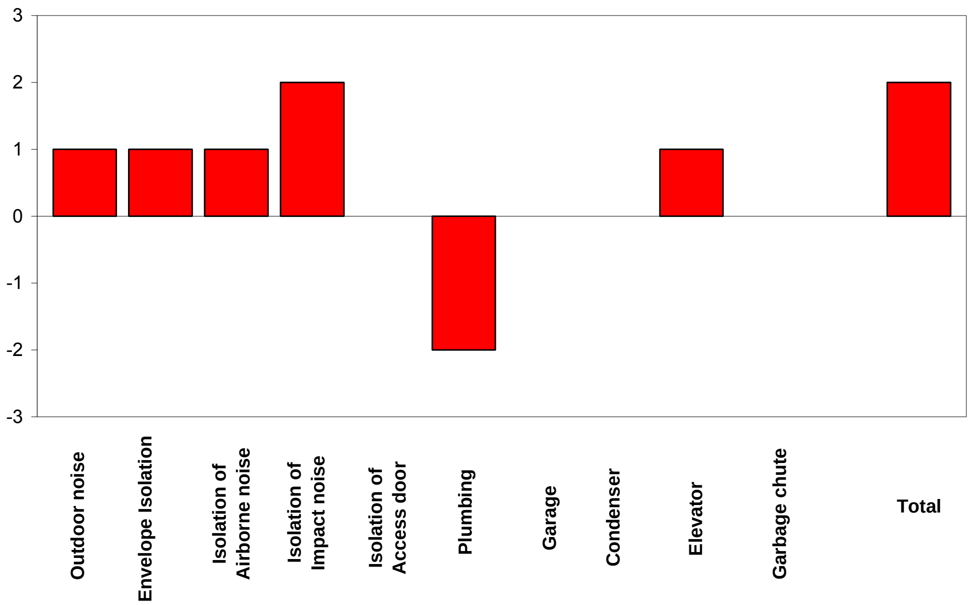
ACOUSTIC COMFORT OF CONSTRUCTED BUILDINGS

Table 1

CATEGORIES	POINTS ATTRIBUTED	SCORING METHOD	
AMBIENT NOISE			
Residual outdoor noise	-1	L95(A)out - 55 if L95(A)out > 55 and 0 otherwise	
Residual indoor noise	1	L95 -NC20 if L95 ≤ NC 20, 1 if NC20 < L95 < NC25 otherwise NC 25 - L95	
Envelope attenuation :	1	(Leq(A)ext - Leq(A)int) - 25 dB(A)	
NOISE PRODUCED BY HUMAN ACTIVITY			
Interdwelling acoustic separation :			
Airborne noise :	1	(FSTC-55) total for all FSTC	
Impact noise :	0	(FIIC-55) total for all FIIC	
Access door :	0	FSTC - 35, if the door is located near an elevator or an entrance hall FSTC - 25 and 0 otherwise	
MECHANICAL, ELECTRICAL, PLUMBING NOISE			
Plumbing :	-2	0 if Leq< NC20 and NC20 - Leq otherwise	+1 if inaudible
Garage :	0	0 if Leq< NC20 and NC20 - Leq otherwise	+1 if inaudible
Condenser or cooling tower :	0	0 if Leq< NC20 and NC20 - Leq otherwise	+1 if inaudible
Transformers :	1	0 if Leq< NC20 and NC20 - Leq otherwise	+1 if inaudible
Elevator :	1	0 if Lmax< NC20 and NC20 - Lmax otherwise	+1 if inaudible
Garbage chute :	0	0 if Lmax< NC20 and NC20 - Lmax otherwise	+1 if inaudible

CLASSIFICATION OF THE UNIT

Isolation of outdoor noise:	**1**
Isolation of noise produced by human activity:	**1**
Isolation of mechanical, electrical, plumbing noise:	**0**
Total:	**2**



SINGLE NUMBER RATING OF THE ACOUSTIC COMFORT PROVIDED BY A DWELLING IN A CONSTRUCTED BUILDING

Table 2

PENALTY POINTS AS A FUNCTION OF THE LOCATION OF THE UNIT IN RELATION TO NOISE SOURCES

POTENTIAL NOISE SOURCES	Present: (Y): Yes (N): No	Mitigation (Y): Yes (N): No	Number of penalty points* Present	Mitigation	Score
	A	B	C	D	D-C
Sources adjacent to the unit:					
- Entrance Hall	N		0	0	0
- Elevator	N		0	0	0
- Garage door	Y	Y	5	3	-2
- Mechanical/electrical room	Y	Y	5	2	-3
- Exit stairwell (2 first and 2 last floors)	N		0	0	0
- Other exit stairwells	N		0	0	0
Source inside the unit:					
- Garbage chute	N		0	0	0
- Plumbing and ventilation	Y	Y	0	0	0
- Ventilation shafts	Y	Y	5	3	-2
Sources above or below the unit:					
- Terrasse/Sun deck	N		0	0	0
- Pool	N		0	0	0
- Cooling tower and condensers on the roof	N		0	0	0
- Garage fans	N		0	0	0
- Hard floor	Y	Y	5	5	0
Outside noise sources:					
- Plane : NEF > 25	N		0	0	0
- Train : Leq ≥ 55 dB(A)	N		0	0	0
- Highway : Leq ≥ 55 dB(A)	N		0	0	0
- Main artery : Leq ≥ 55 dB(A)	N		0	0	0
Noise produced by human activity:					
- Interdwelling partition with an STC < 55	N		0	0	0
- Floor/ceiling assembly with an STC < 55	Y		0	0	0
- Floor/ceiling assembly with an IIC < 55	N		0	0	0
		TOTAL:	25	18	**-7**

SCALE OF PENALTY POINTS SUBTRACTED AS A FUNCTION OF THE NOISE TREATMENT ESTABLISHED

MITIGATION: SCALE	Number of penalty points to subtract Max	Min
Sources adjacent to the unit:		
- Entrance hall	5	2
- Elevator	5	3
- Garage door	3	2
- Mechanical/electrical room	5	3
- Exit stairwell (2 first and 2 last floor)	2	2
- Other exit stairwells	5	3
Sources inside the unit:		
- Garbage chute	3	3
- Plumbing and ventilation	5	5
- Ventilation shafts	5	2
Sources above or below the unit:		
- Terrasse/Sun deck	2	0
- Pool	2	0
- Cooling tower and condensers on the roof	5	3
- Garage fans	5	3
- Hard floor	0	0

Note :

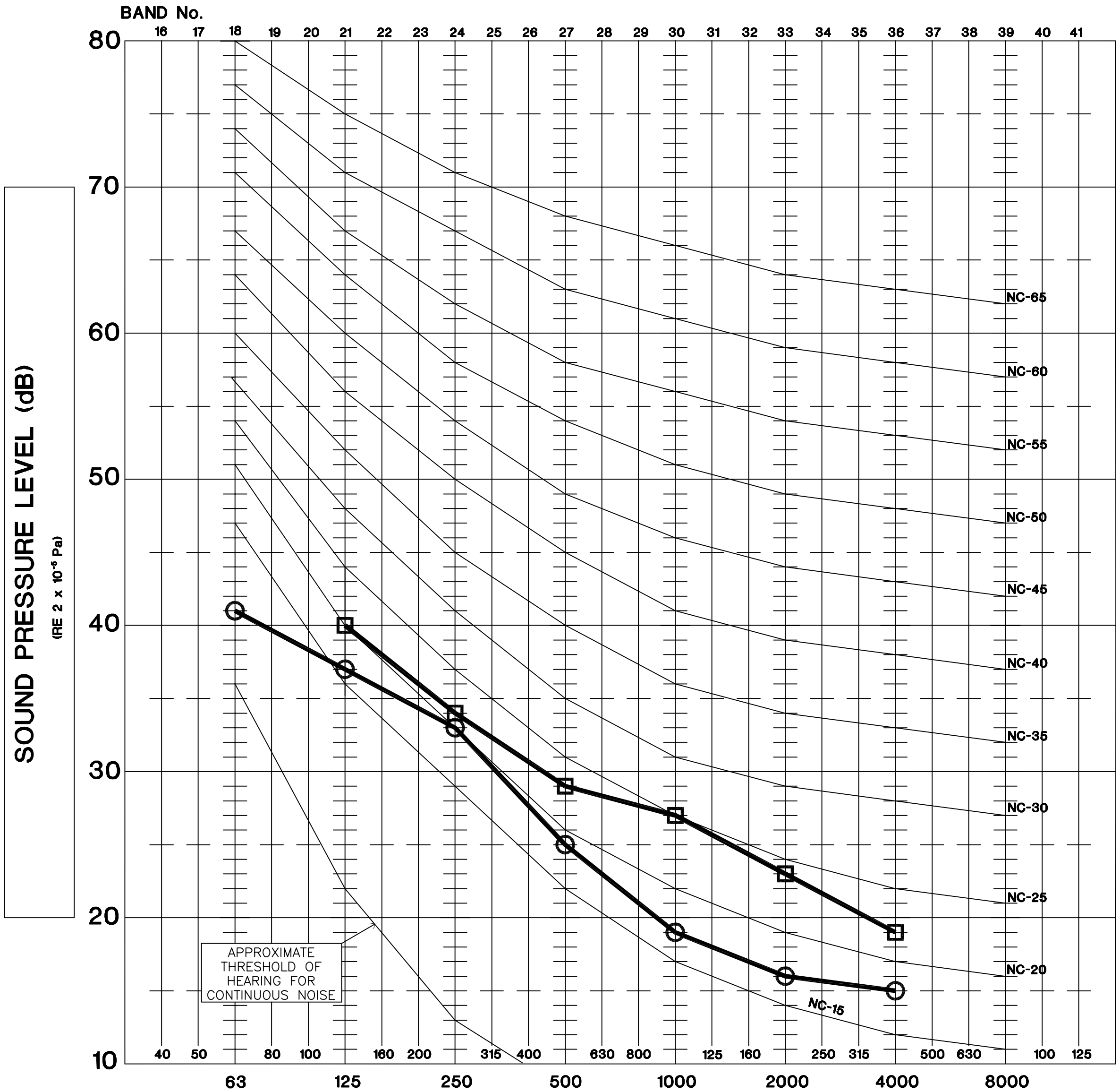
This table is to be used for final comparison of units of the same building or same type of building, to classify units according to the acoustic comfort in which they provide

*Note: The penalty suggested in the cases of conflictual adjacencies is 5 points; this penalty was established arbitrarily. The points allocated to take into account mitigation remain to be defined precisely by additional research: those appearing in table 3 are provided as an example only. In the case of the criteria expressed in terms of STC and IIC, one must take into account the flanking noise transmission and other field conditions in the case of IIC; this was not possible with the data available at the time this research report was produced.

ACOUSTIC COMFORT OF BUILDINGS TO CONSTRUCT

Table 3

NOTE: THIS GRAPH ALONE DOES NOT REPRESENT A COMPLETE REPORT



LEGEND

AMBIENT NOISE LEVELS MEASURED IN DWELLINGS

□——□ ACCORDING TO A STUDY PERFORMED BY THE NRCC IN 602 CANADIAN HOMES (33 dB(A))

○——○ BY MJM ACOUSTICAL CONSULTANTS; AVERAGE OF 107 MEASUREMENTS PERFORMED IN BEDROOMS, LIVING ROOMS AND DINING ROOMS (29 dB(A)) OF DWELLINGS LOCATED IN THE GREATER MONTREAL AREA

PROJECT DESCRIPTION

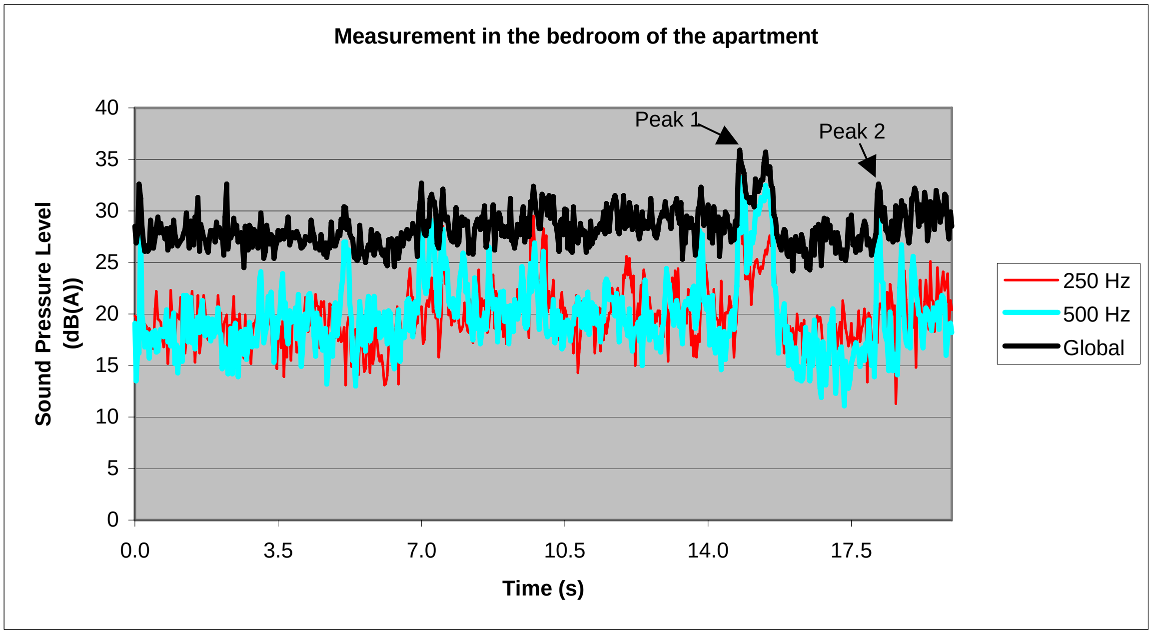
QUALIFICATION OF THE DEGREE OF ACOUSTIC COMFORT – PHASE II

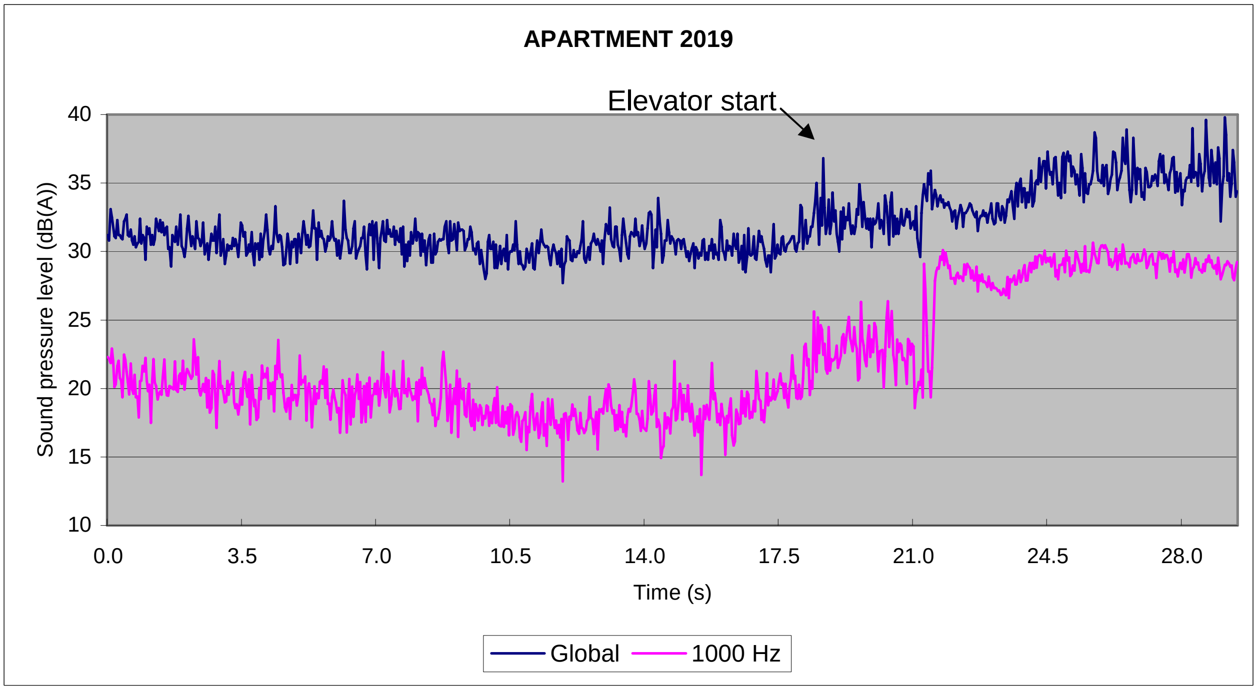
GRAPH TITLE

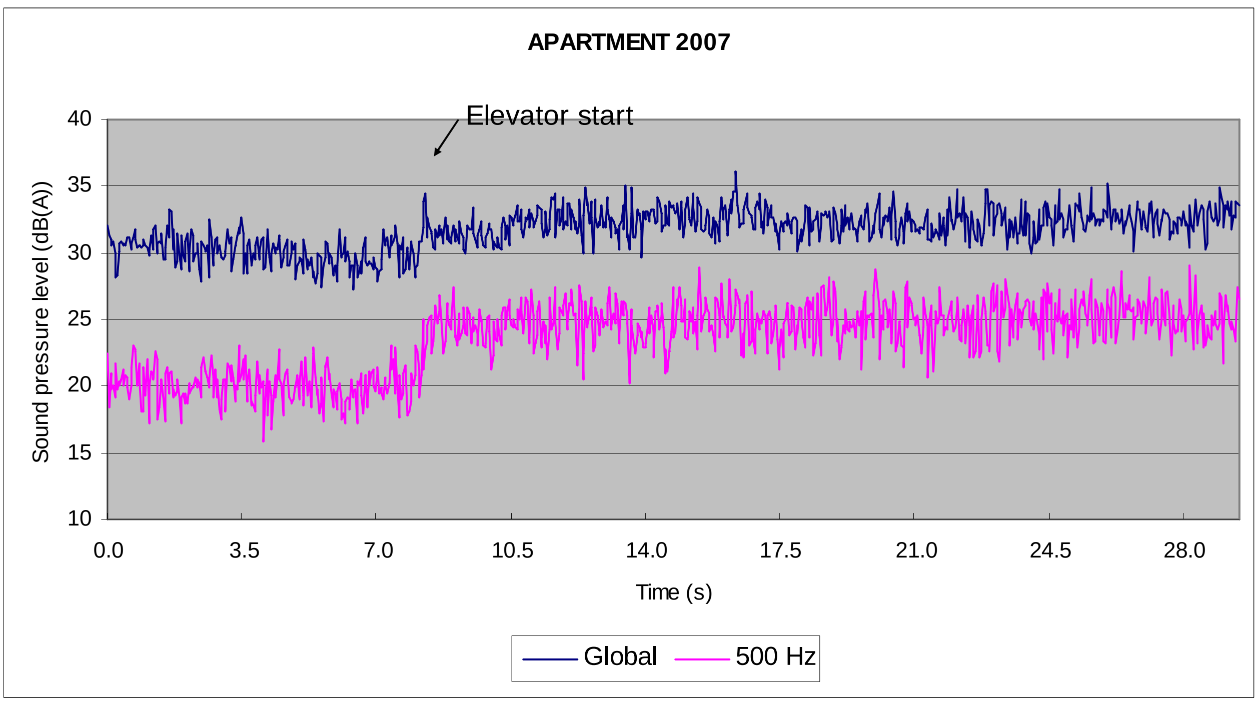
AMBIENT NOISE MEASURED IN DWELLINGS

GRAPH NUMBER 1	**FILE NAME:** 177GRA1
PROJECT NUMBER 177.021	**DATE** 2002 10

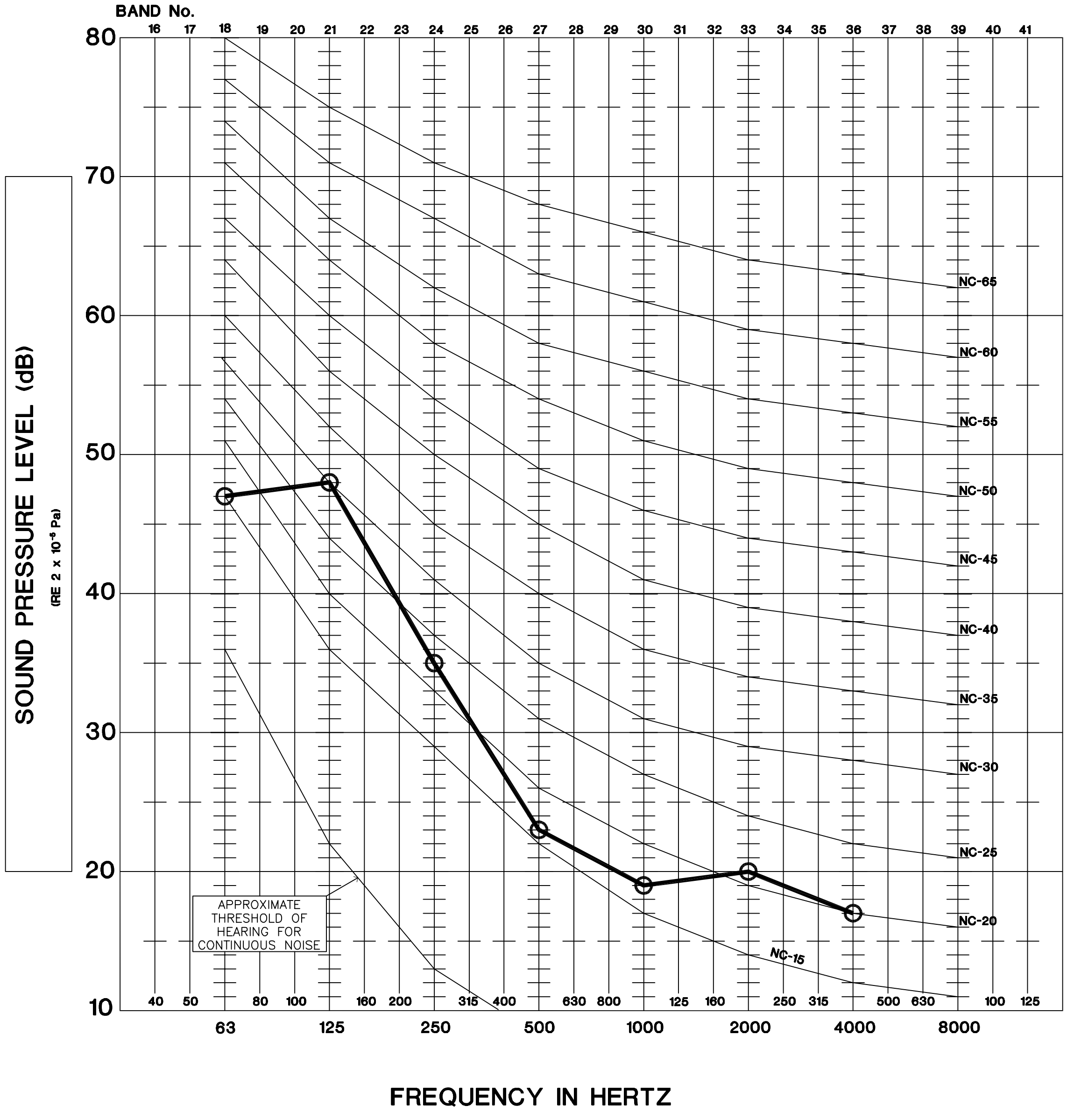
mjm


Measurement in the bedroom of the apartment
Sound Pressure Level (dB(A))
Time (s)
Peak 1
Peak 2
250 Hz
500 Hz
Global
0
5
10
15
20
25
30
35
40
0.0
3.5
7.0
10.5
14.0
17.5


APARTMENT 2019
Elevator start
Sound pressure level (dB(A))
40
35
30
25
20
15
10
0.0
3.5
7.0
10.5
14.0
17.5
21.0
24.5
28.0
Time (s)
Global
1000 Hz


APARTMENT 2007
Elevator start
Sound pressure level (dB(A))
40
35
30
25
20
15
10
0.0
3.5
7.0
10.5
14.0
17.5
21.0
24.5
28.0
Time (s)
Global
500 Hz

NOTE: THIS GRAPH ALONE DOES NOT REPRESENT A COMPLETE REPORT



LEGEND

AUDIBLE TRANSFORMER NOISE MEASURED BY OCTAVE BANDS INSIDE THE BEDROOM OF A DWELLING
GLOBAL LEVEL = (34 dB(A))

PROJECT DESCRIPTION

QUALIFICATION OF THE DEGREE OF ACOUSTIC COMFORT – PHASE II

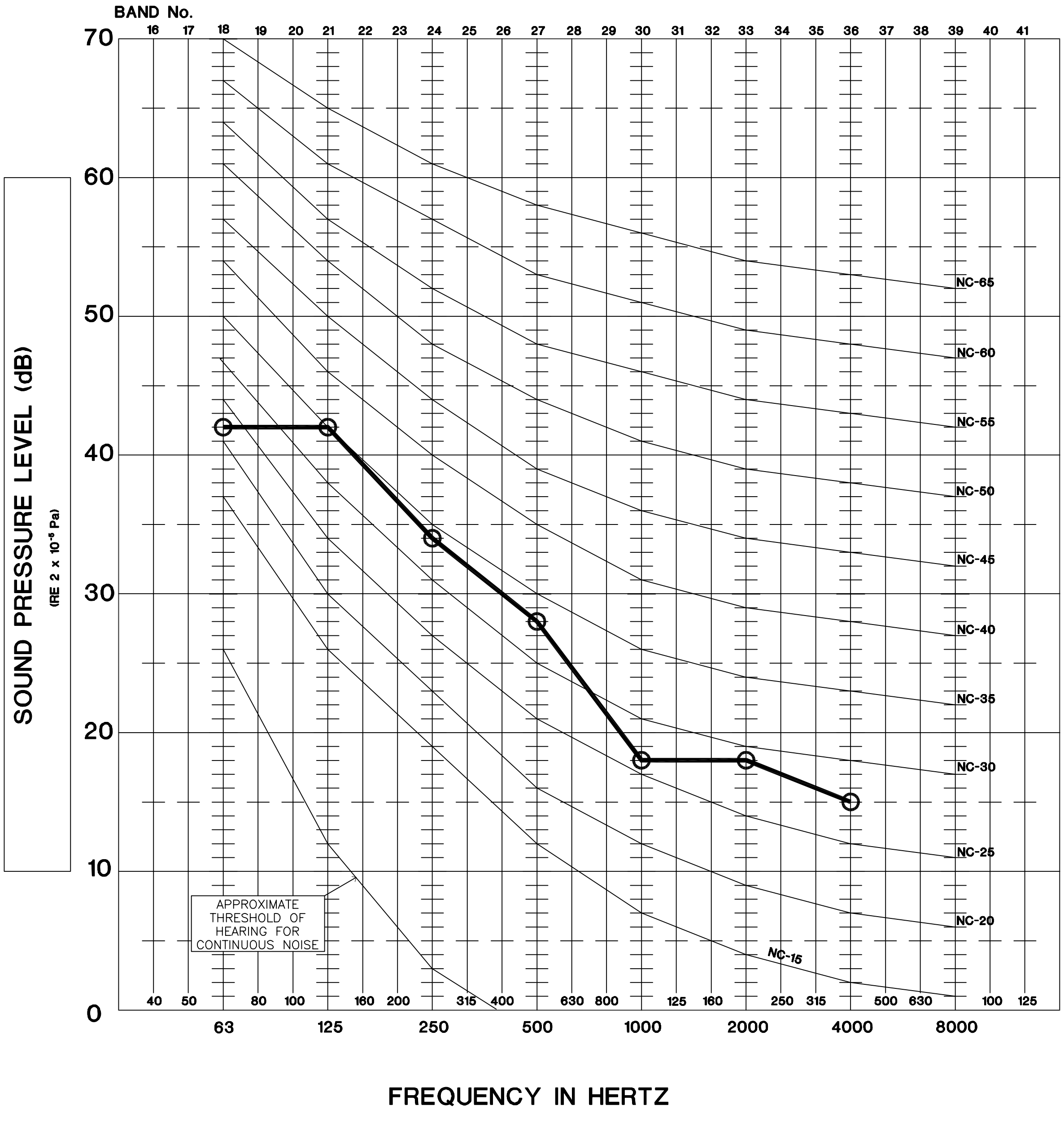
GRAPH TITLE

AUDIBLE TRANSFORMER NOISE MEASURED BY OCTAVE BANDS IN THE BEDROOM OF A DWELLING

GRAPH NUMBER 3	**FILE NAME:** 177GRA3
PROJECT NUMBER 177.021	**DATE** 2002 11

mjm

NOTE: THIS GRAPH ALONE DOES NOT REPRESENT A COMPLETE REPORT



LEGEND

AUDIBLE TRANSFORMER NOISE MEASURED BY OCTAVE BANDS INSIDE THE BEDROOM OF A DWELLING
GLOBAL LEVEL = (31 dB(A))

PROJECT DESCRIPTION

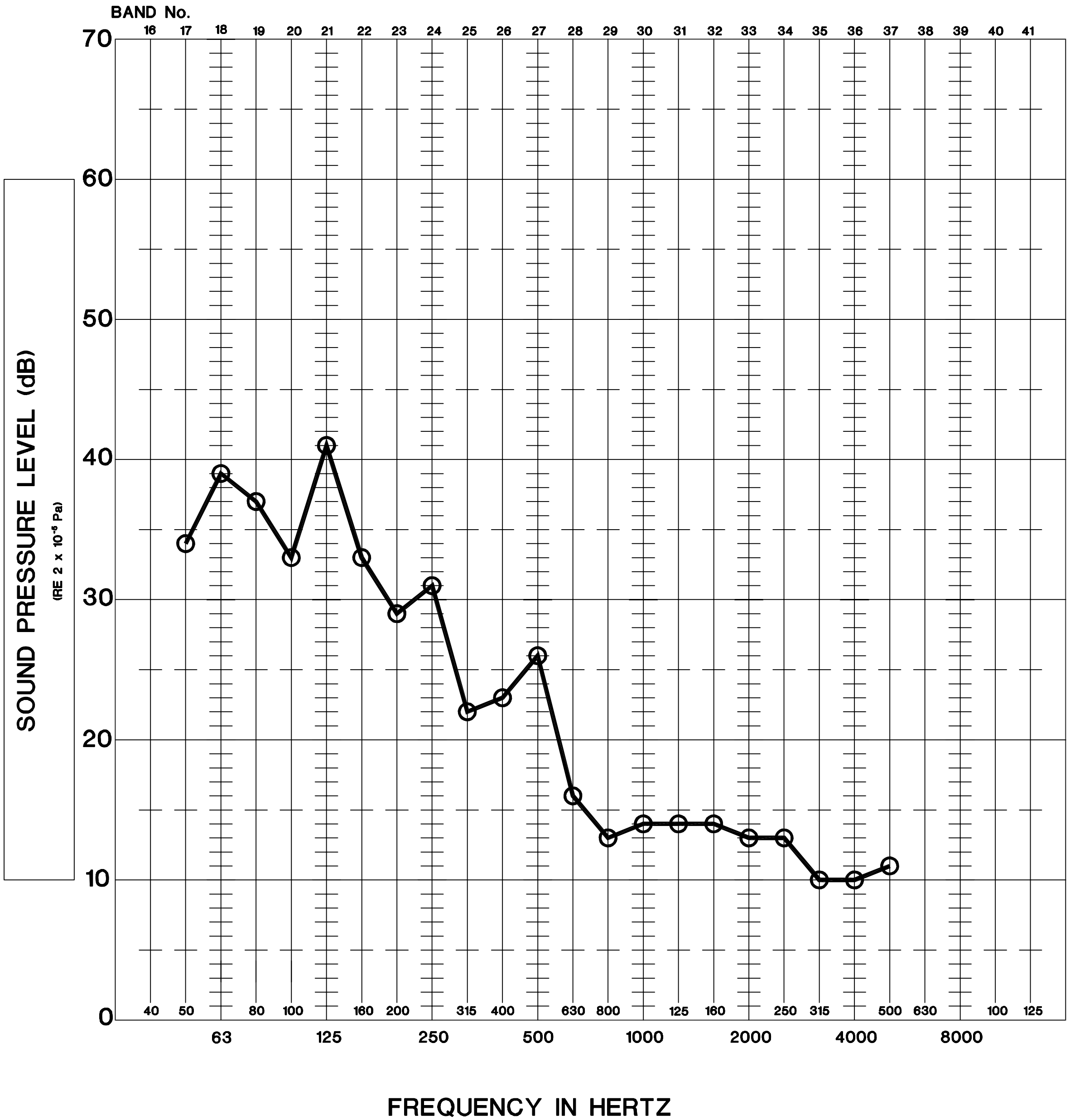
QUALIFICATION OF THE DEGREE OF ACOUSTIC COMFORT – PHASE II

GRAPH TITLE

AUDIBLE TRANSFORMER NOISE MEASURED BY OCTAVE BANDS IN THE BEDROOM OF A DWELLING

GRAPH NUMBER 4	**FILE NAME:** 177GRA4
PROJECT NUMBER 177.021	**DATE** 2002 11

NOTE: THIS GRAPH ALONE DOES NOT REPRESENT A COMPLETE REPORT



LEGEND

AMBIENT NOISE LEVEL MEASURED BY THIRD–OCTAVE BANDS CORRESPONDING TO THE PLOT SHOWN IN GRAPH 4

GLOBAL LEVEL = (31 dB(A))

PROJECT DESCRIPTION

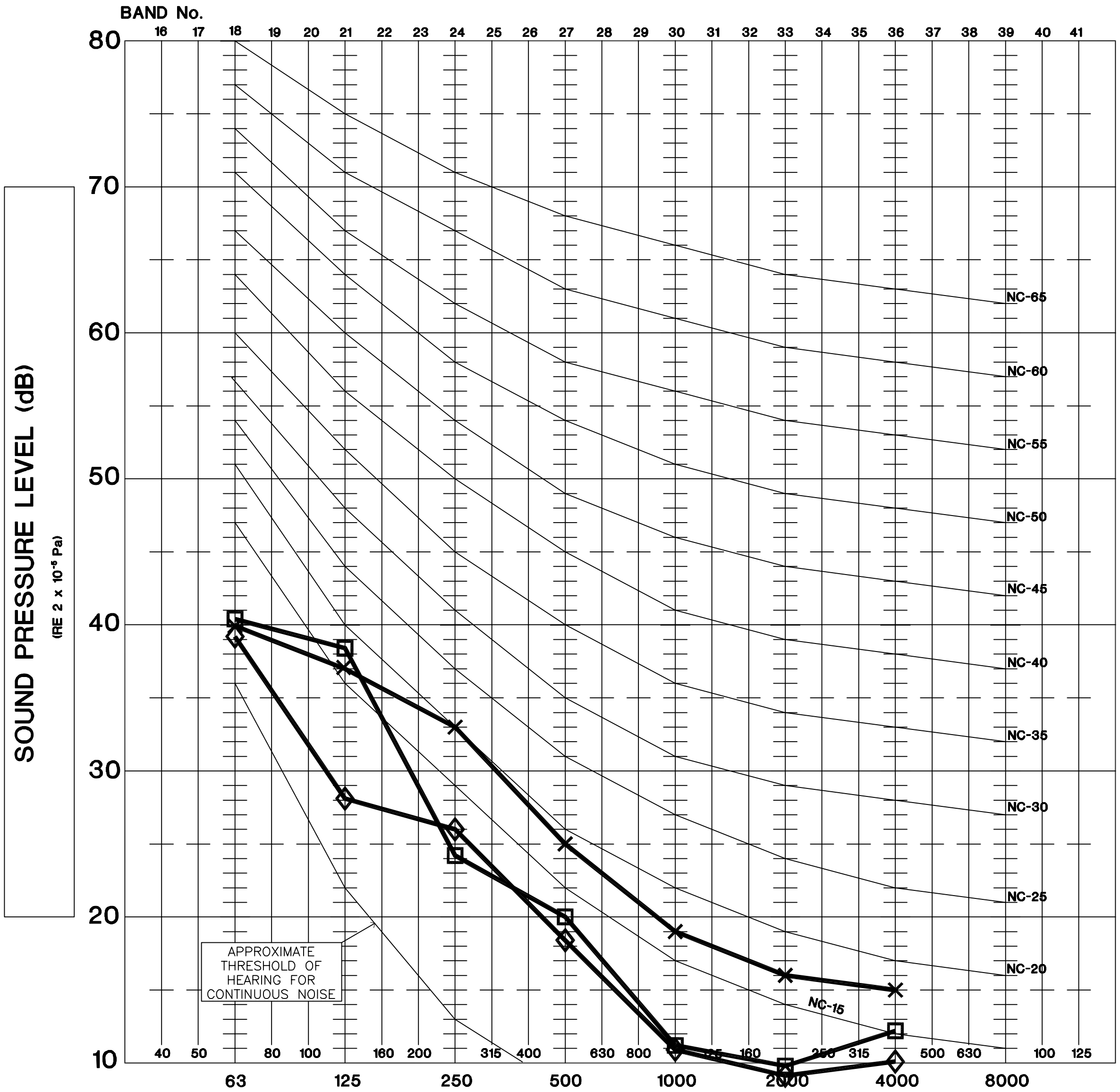
QUALIFICATION OF THE DEGREE OF ACOUSTIC COMFORT – PHASE II

GRAPH TITLE

TRANSFORMER NOISE LEVELS OF GRAPH 4 PLOTTED IN 1/3 OCTAVE BANDS

GRAPH NUMBER 5	**FILE NAME:** 177GRA5
PROJECT NUMBER 177.021	**DATE** 2002 11

NOTE: THIS GRAPH ALONE DOES NOT REPRESENT A COMPLETE REPORT



LEGEND

MEASUREMENT PERFORMED IN THE MAIN BEDROOM OF APARTMENT 55 WHILE THE PATIO DOOR OF THE ADJACENT APARTMENT WAS CONTINUOUSLY OPENED AND CLOSED (25 dB(A))

AMBIENT NOISE MEASURED IN THE MAIN BEDROOM OF APARTMENT 55 (22 dB(A))

AVERAGE AMBIENT NOISE MEASURED BY MJM IN 107 DWELLINGS (29 dB(A))

PROJECT DESCRIPTION

QUALIFICATION OF THE DEGREE OF ACOUSTIC COMFORT – PHASE II

GRAPH TITLE

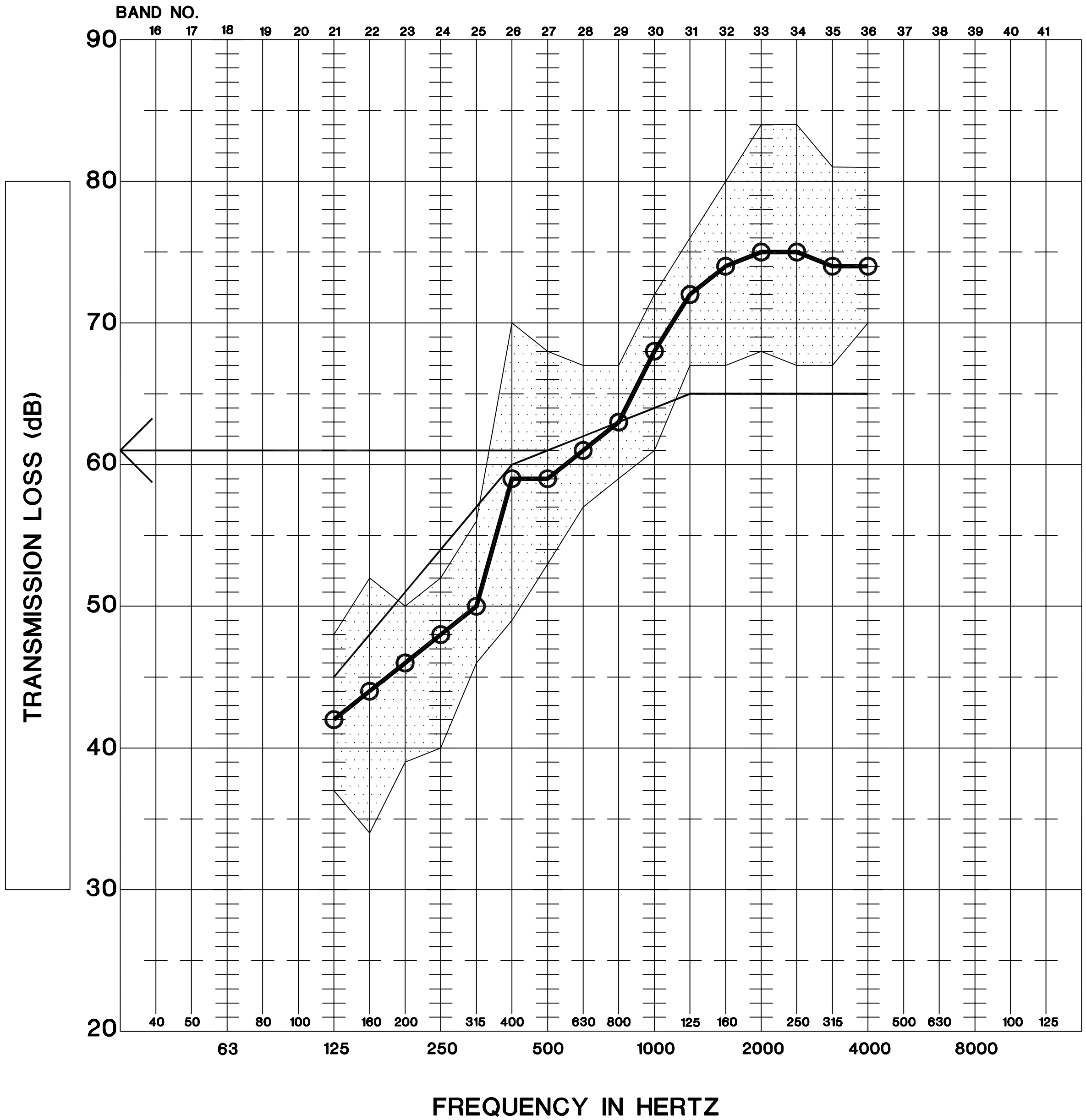
SOUND MASKING OF HUMAN ACTIVITY NOISE PROVIDED BY RESIDUAL AMBIENT NOISE LEVELS

GRAPH NUMBER 6 **FILE NAME:** 177GRA6

PROJECT NUMBER 177.021 **DATE** 2002 11

mjm

NOTE: THIS GRAPH ALONE DOES NOT REPRESENT A COMPLETE REPORT



LEGEND

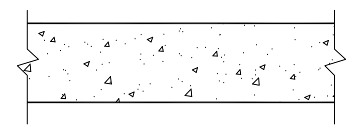
Average transmission loss based on 7 field measurements

Classification curve (ASTM E 413–87)

Interval between the lowest and the highest sound transmission loss measured

AVERAGE STC = 61
MINIMUM STC MEASURED = 55
MAXIMUM STC MEASURED = 64

DESCRIPTION



8" TO 10" THICK CONCRETE SLAB

PROJECT DESCRIPTION

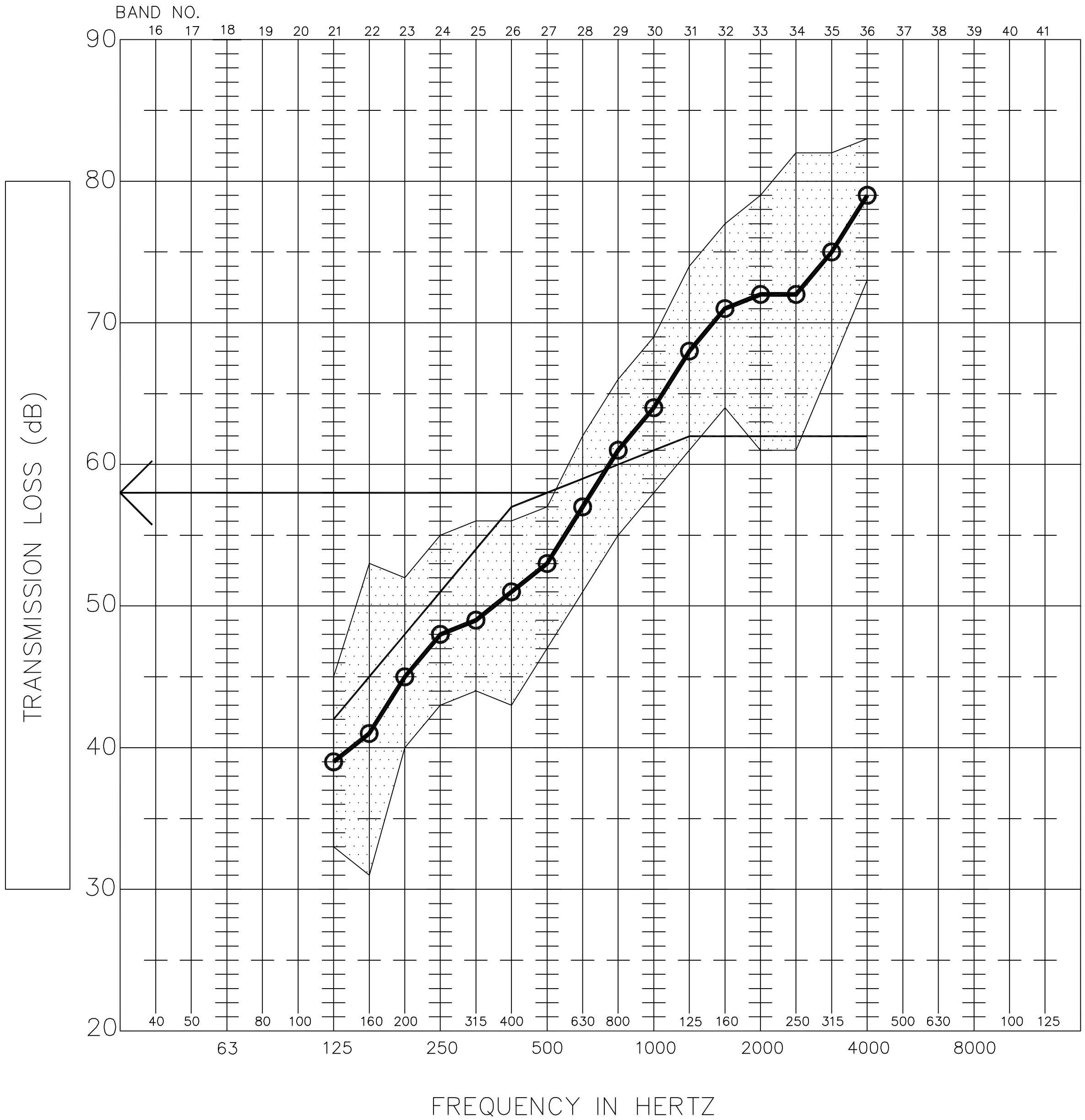
QUALIFICATION OF THE DEGREE OF ACOUSTIC COMFORT – PHASE II

GRAPH TITLE

AIRBORNE NOISE TRANSMISSION LOSS CONCRETE STRUCTURE

GRAPH NUMBER 7	**FILE NAME:** 177GRA7
PROJECT NUMBER 177.021	**DATE** 2002 09

NOTE: THIS GRAPH ALONE DOES NOT REPRESENT A COMPLETE REPORT



LEGEND

Average transmission loss based on 14 field measurements

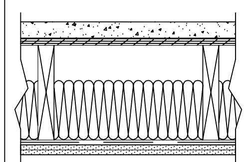
Classification curve (ASTM E 413–87)

Interval between the lowest and the highest sound transmission loss measured

AVERAGE STC = 58
MINIMUM STC MEASURED = 53
MAXIMUM STC MEASURED = 63

DESCRIPTION

FLOOR/CEILING ASSEMBLY WITH A WOOD STRUCTURE

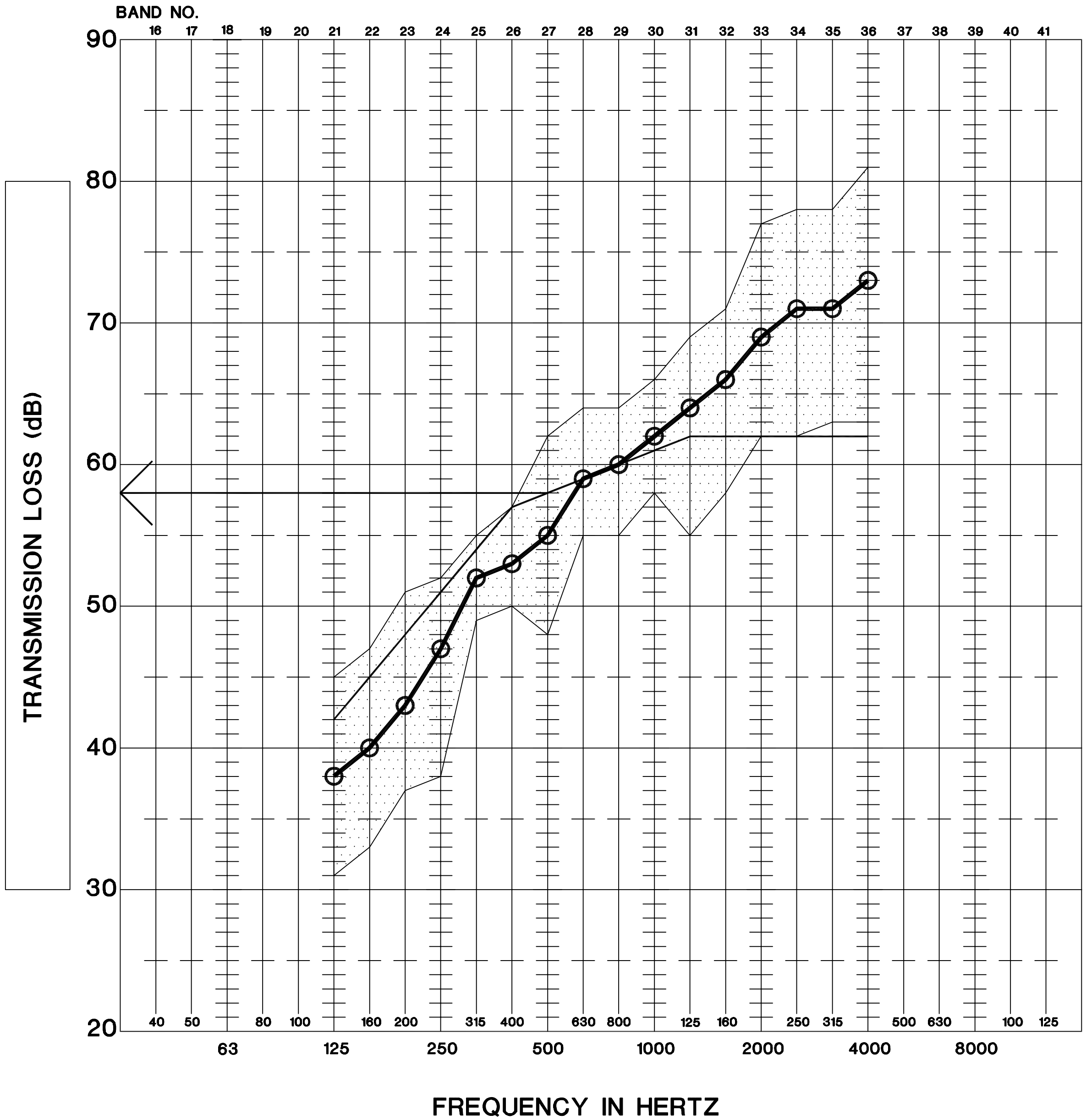


- 38mm (1⅝") CONCRETE SUB–FLOOR
- 15lbs BUILDING PAPER;
- 16mm (⅝") PLYWOOD OR ASPENITE;
- JOISTS SPACED AS REQUIRED STRUCTURALLY;
- 150mm (6") THICK GLASS FIBER BATTS BETWEEN THE JOISTS;
- RESILIENT FURRINGS SCREWED AT 400mm c/c UNDERNEATH THE JOISTS;
- TWO 13mm (½") TYPE "X" GYPSUM BOARDS SCREWED DIRECTLY TO THE RESILIENT FURRINGS.

PROJECT DESCRIPTION	
QUALIFICATION OF THE DEGREE OF ACOUSTIC COMFORT – PHASE II	
GRAPH TITLE	
AIRBORNE NOISE TRANSMISSION LOSS WOOD STRUCTURE	
GRAPH NUMBER 8	FILE NAME: 177GRA8
PROJECT NUMBER 177.021	DATE 2002 09

mjm

NOTE: THIS GRAPH ALONE DOES NOT REPRESENT A COMPLETE REPORT



LEGEND

Average transmission loss based on 9 field measurements

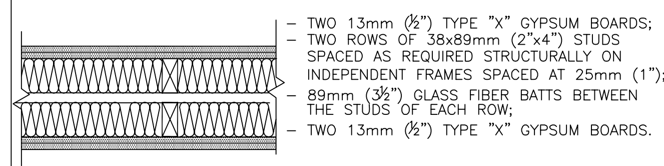
Classification curve (ASTM E 413-87)

Interval between the lowest and the highest sound transmission loss measured

AVERAGE STC = 58
MINIMUM STC MEASURED = 53
MAXIMUM STC MEASURED = 61

DESCRIPTION

DOUBLE GYPSUM BOARD, DOUBLE WOOD STUD PARTITION



PROJECT DESCRIPTION

QUALIFICATION OF THE DEGREE OF ACOUSTIC COMFORT – PHASE II

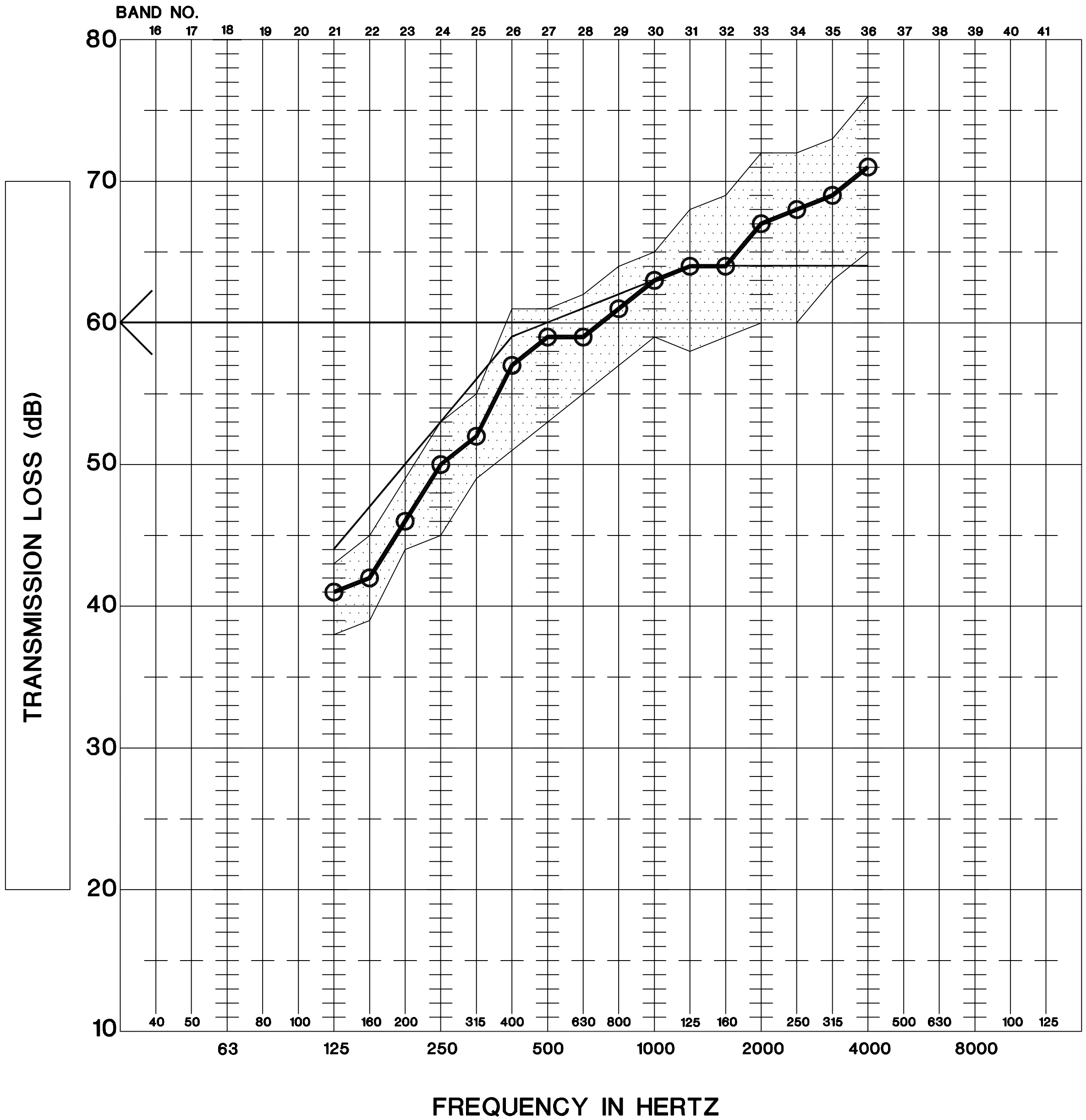
GRAPH TITLE

AIRBORNE NOISE TRANSMISSION LOSS
WOOD STUDS

GRAPH NUMBER 9	**FILE NAME:** 177GRA9
PROJECT NUMBER 177.021	**DATE** 2002 09

mjm

NOTE: THIS GRAPH ALONE DOES NOT REPRESENT A COMPLETE REPORT



LEGEND

Average transmission loss based on 5 field measurements

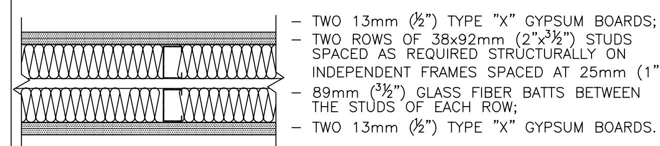
Classification curve (ASTM E 413-87)

Interval between the lowest and the highest sound transmission loss measured

AVERAGE STC = 60
MINIMUM STC MEASURED = 56
MAXIMUM STC MEASURED = 61

DESCRIPTION

DOUBLE GYPSUM BOARD, DOUBLE STEEL STUD PARTITION



PROJECT DESCRIPTION

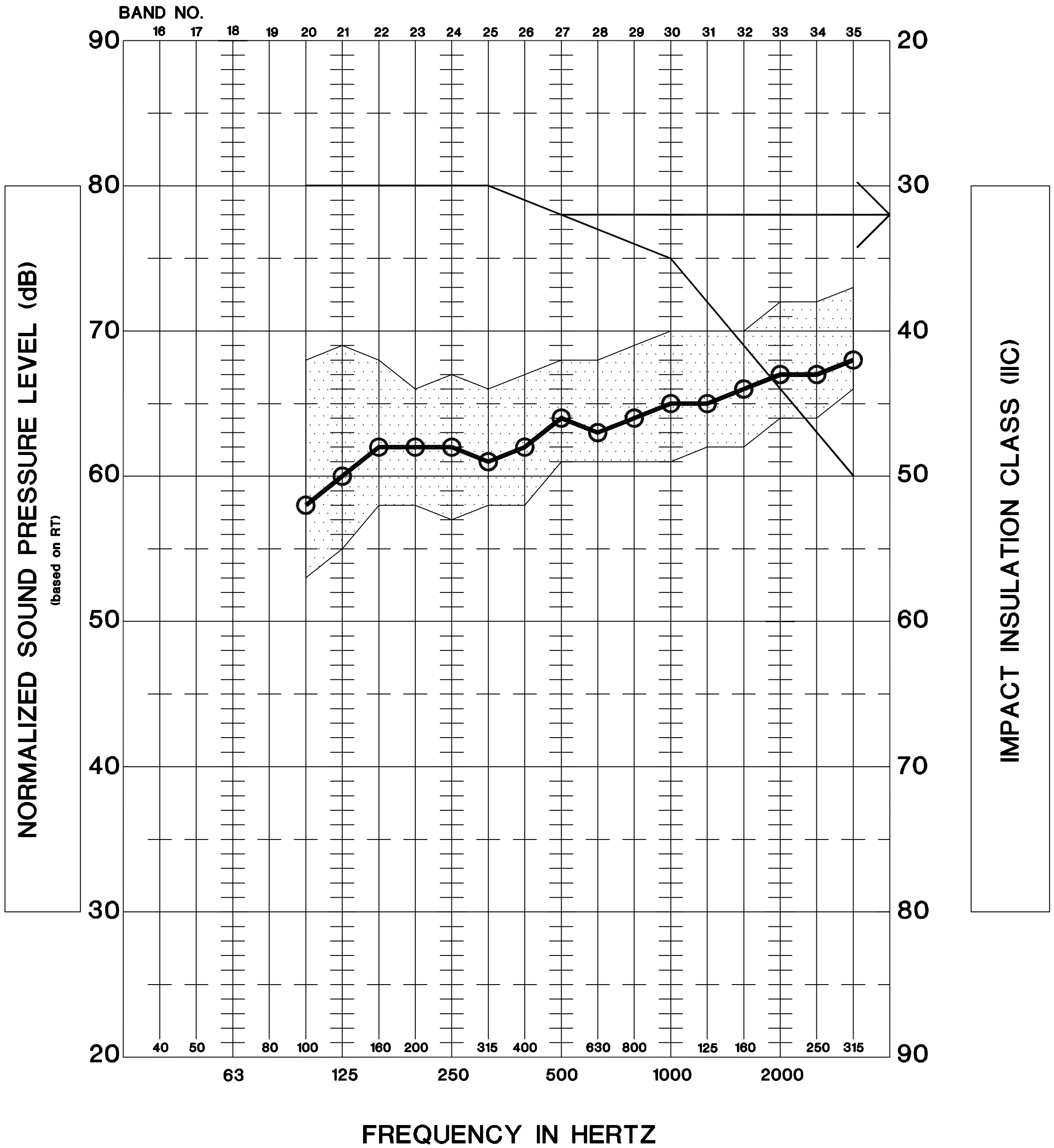
QUALIFICATION OF THE DEGREE OF ACOUSTIC COMFORT – PHASE II

GRAPH TITLE

AIRBORNE NOISE TRANSMISSION LOSS
STEEL STUDS

GRAPH NUMBER 10	**FILE NAME:** 177GRA10
PROJECT NUMBER 177.021	**DATE** 2002 09

NOTE: THIS GRAPH ALONE DOES NOT REPRESENT A COMPLETE REPORT



LEGEND

Normalized impact sound pressure level, average of 8 measurements

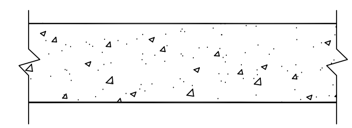
Interval between the lowest and the highest measured NISPL

Classification curve (ASTM E 989–89)

Field Impact Insulation Class FIIC = 32

DESCRIPTION

– 200 TO 250mm THICK CONCRETE SLAB



PROJECT DESCRIPTION

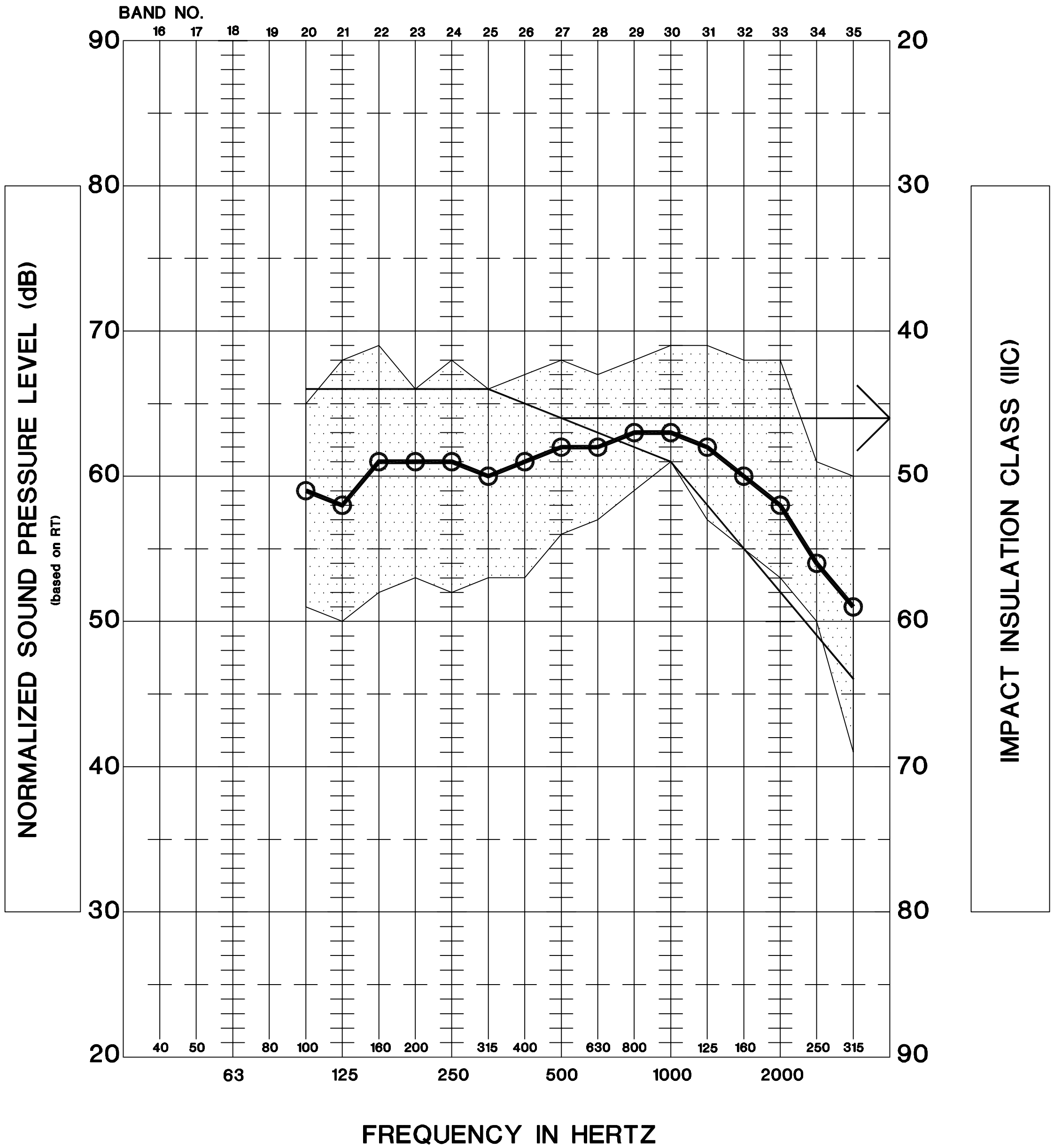
QUALIFICATION OF THE DEGREE OF ACOUSTIC COMFORT – PHASE II

GRAPH TITLE

AVERAGE NISPL MEASURED ON A 200 TO 250mm THICK CONCRETE SLAB

GRAPH NUMBER 11	**FILE NAME:** 177GRA11
PROJECT NUMBER 177.021	**DATE** 2002 11

NOTE: THIS GRAPH ALONE DOES NOT REPRESENT A COMPLETE REPORT



LEGEND

Normalized impact sound pressure level, average of 6 measurements

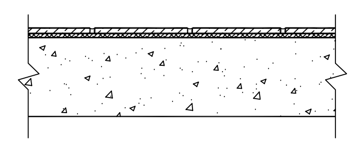
Interval between the lowest and the highest measured NISPL

Classification curve (ASTM E 989–89)

Field Impact Insulation Class
FIIC = 46

DESCRIPTION

- CERAMIC TOPPING
- 4 TO 6mm CORK
- 200 TO 250mm CONCRETE SLAB



PROJECT DESCRIPTION

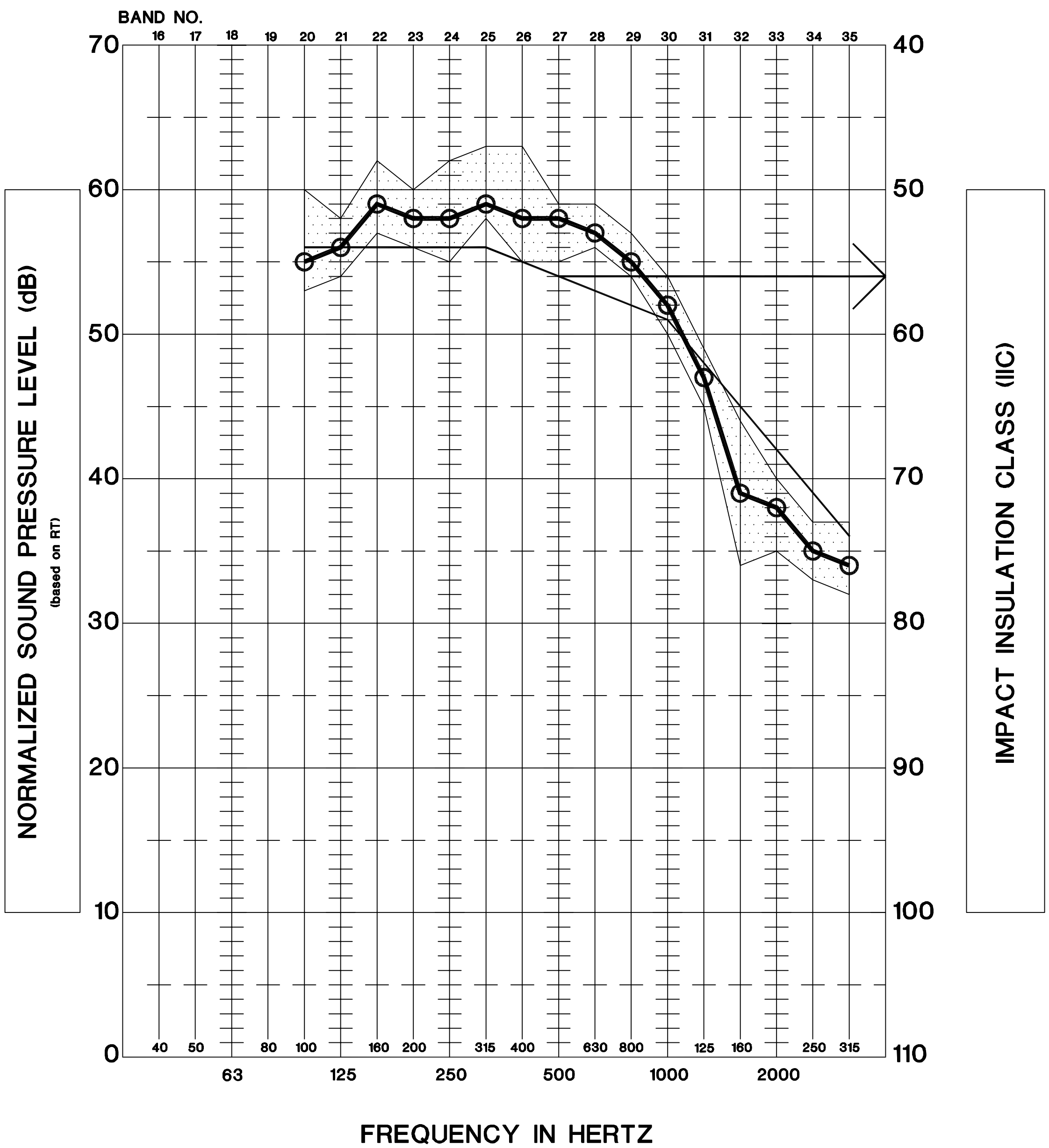
QUALIFICATION OF THE DEGREE OF ACOUSTIC COMFORT – PHASE II

GRAPH TITLE

AVERAGE NISPL MEASURED ON A 200 TO 250mm THICK CONCRETE SLAB COVERED WITH CERAMIC AND CORK

GRAPH NUMBER 12	**FILE NAME:** 177GRA12
PROJECT NUMBER 177.021	**DATE** 2002 11

NOTE: THIS GRAPH ALONE DOES NOT REPRESENT A COMPLETE REPORT



LEGEND

Normalized impact sound pressure level, average of 5 measurements

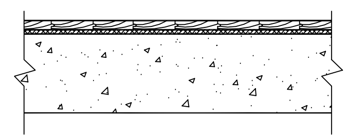
Interval between the lowest and the highest measured NISPL

Classification curve (ASTM E 989-89)

Field Impact Insulation Class
FIIC = 56

DESCRIPTION

- 9mm WOOD PARQUET FLOOR
- 3 TO 6mm CORK
- 200 TO 250mm CONCRETE SLAB



PROJECT DESCRIPTION

QUALIFICATION OF THE DEGREE OF ACOUSTIC COMFORT – PHASE II

GRAPH TITLE

AVERAGE NISPL MEASURED ON A 200 TO 250mm THICK CONCRETE SLAB COVERED WITH A PARQUET FLOOR AND CORK

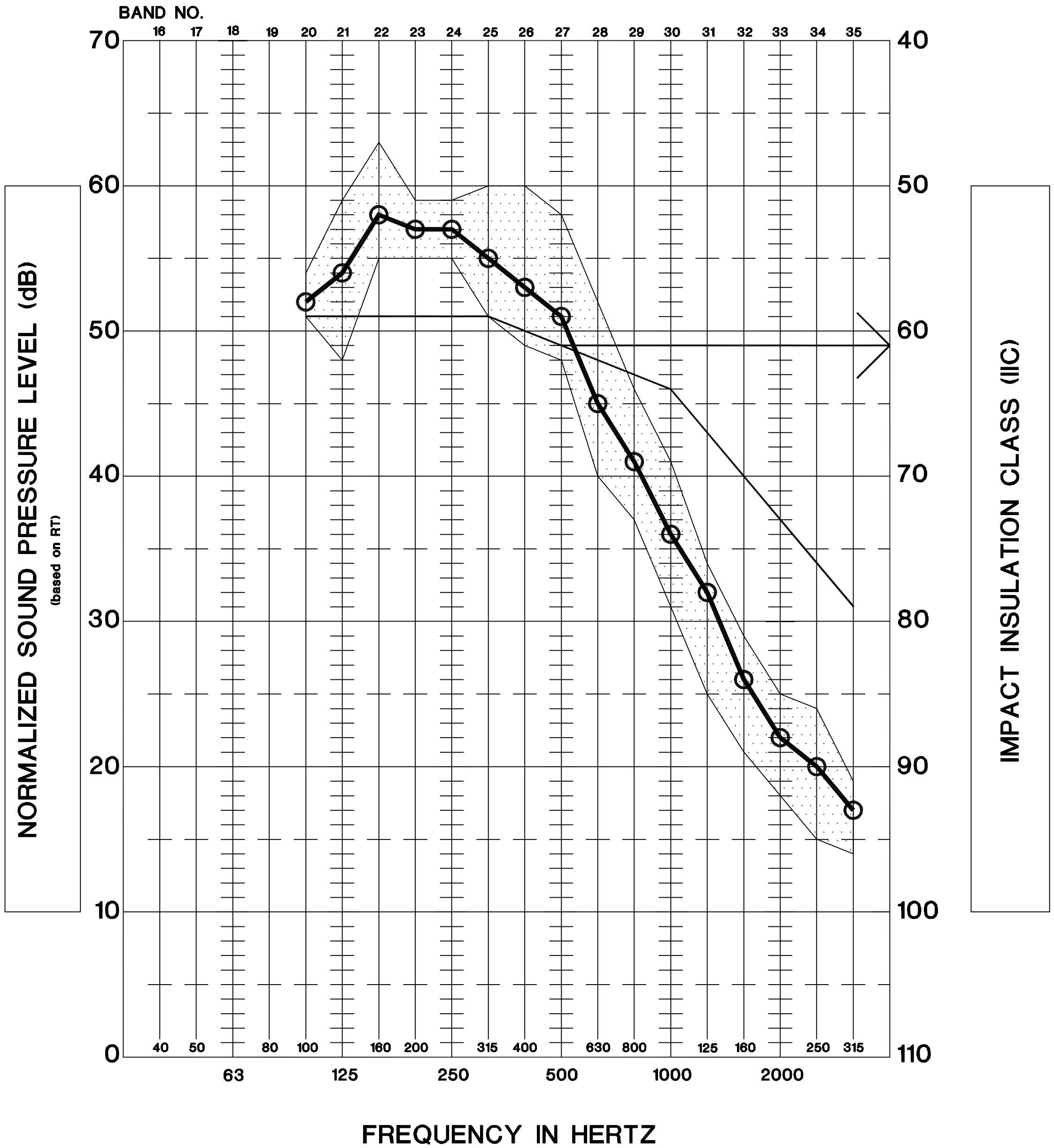
GRAPH NUMBER 13

FILE NAME: 177GRA13

PROJECT NUMBER 177.021

DATE 2002 11

NOTE: THIS GRAPH ALONE DOES NOT REPRESENT A COMPLETE REPORT



LEGEND

Normalized impact sound pressure level, average of 6 measurements

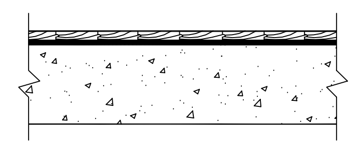
Interval between the lowest and the highest measured NISPL

Classification curve (ASTM E 989–89)

Field Impact Insulation Class
FIIC = 61

DESCRIPTION

- 9mm WOOD PARQUET FLOOR
- 5mm RECLYCLED RUBBER UNDERLAY
- 200 TO 250mm CONCRETE SLAB



PROJECT DESCRIPTION

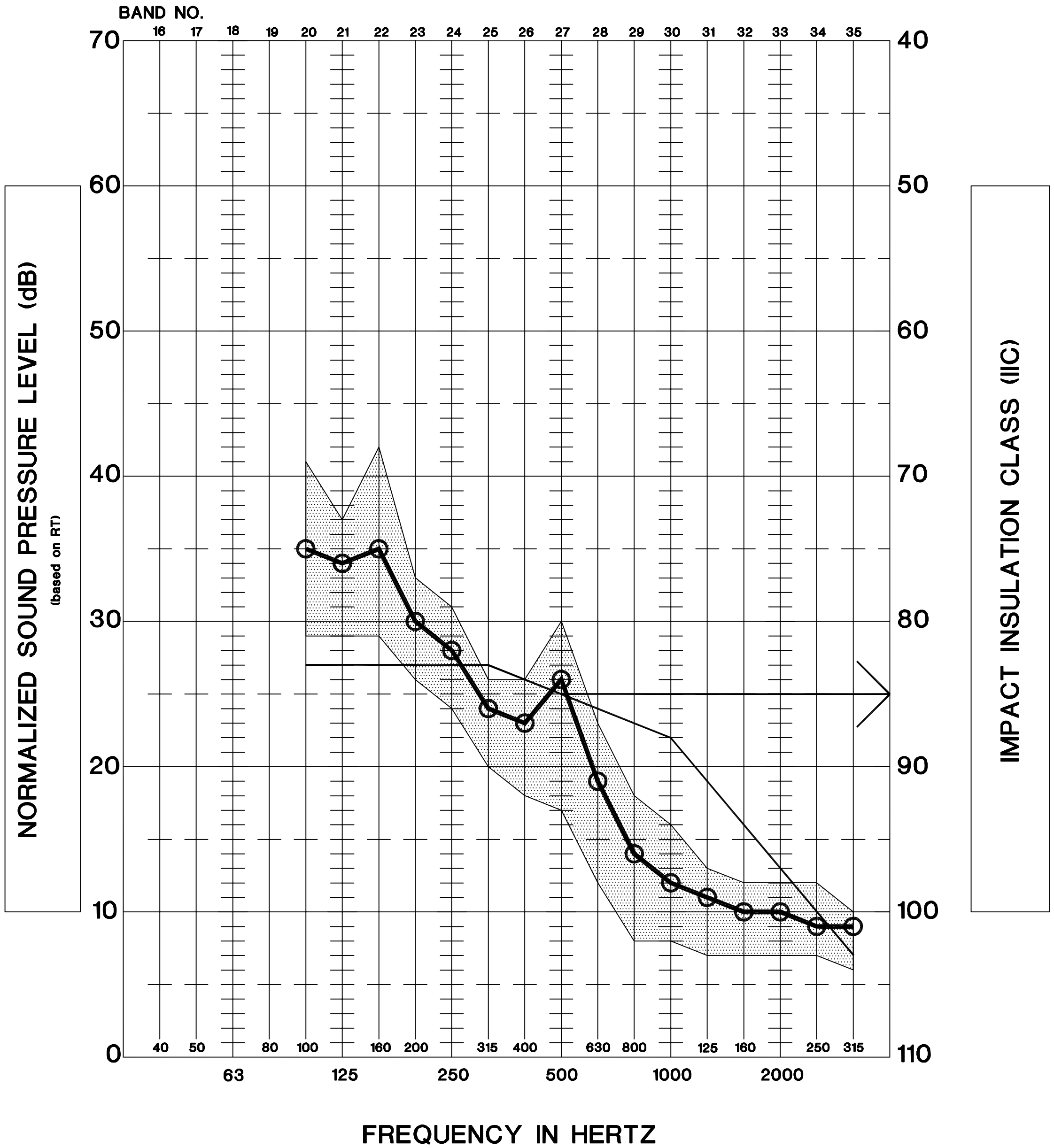
QUALIFICATION OF THE DEGREE OF ACOUSTIC COMFORT – PHASE II

GRAPH TITLE

AVERAGE NISPL MEASURED ON A 200 TO 250mm THICK CONCRETE SLAB COVERED WITH A PARQUET WOOD FLOOR AND A RECYCLED RUBBER UNDERLAY

GRAPH NUMBER 14	**FILE NAME:** 177GRA14
PROJECT NUMBER 177.021	**DATE** 2002 11

NOTE: THIS GRAPH ALONE DOES NOT REPRESENT A COMPLETE REPORT



LEGEND

Normalized impact sound pressure level, average of 5 measurements

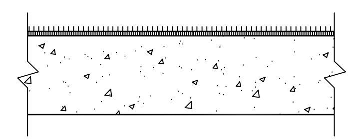
Interval between the lowest and the highest measured NISPL

Classification curve (ASTM E 989–89)

Field Impact Insulation Class
FIIC = 85

DESCRIPTION

– CARPET
– UNDER–CARPET
– 200 TO 250mm CONCRETE SLAB



PROJECT DESCRIPTION

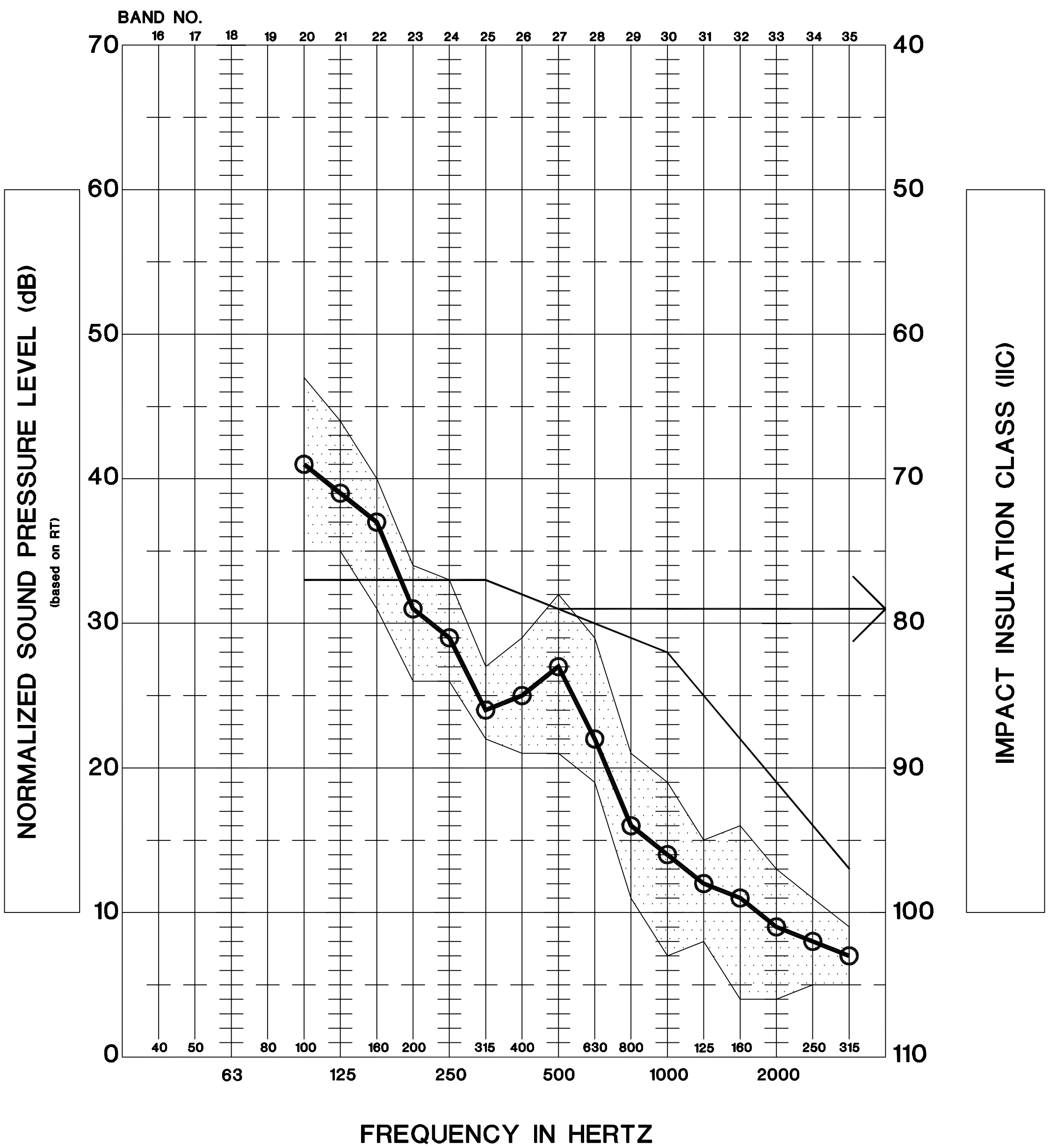
QUALIFICATION OF THE DEGREE OF ACOUSTIC COMFORT – PHASE II

GRAPH TITLE

AVERAGE NISPL MEASURED ON A 200 TO 250mm THICK CONRCRETE SLAB COVERED WITH CARPET AND AN UNDER–CARPET

GRAPH NUMBER 15	**FILE NAME:** 177GRA15
PROJECT NUMBER 177.021	**DATE** 2002 11

NOTE: THIS GRAPH ALONE DOES NOT REPRESENT A COMPLETE REPORT

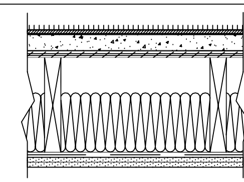


LEGEND

- Normalized impact sound pressure level, average of 4 measurements
- Interval between the lowest and the highest measured NISPL
- Classification curve (ASTM E 989-89)

Field Impact Insulation Class
FIIC = 79

DESCRIPTION



- CARPET AND UNDER-CARPET
- 38mm CONCRETE TOPPING
- 16mm PLYWOOD
- 235mm WOOD JOISTS
- 150mm GLASS FIBER BATTS BETWEEN THE JOISTS
- METAL FURRINGS SPACED AT 600mm c/c
- TWO 13mm GYPSUM BOARDS

PROJECT DESCRIPTION

QUALIFICATION OF THE DEGREE OF ACOUSTIC COMFORT - PHASE II

GRAPH TITLE

AVERAGE NISPL MEASURED ON A WOOD FLOOR COVERED WITH CARPET AND AN UNDER-CARPET

GRAPH NUMBER 16	**FILE NAME:** 177GRA16
PROJECT NUMBER 177.021	**DATE** 2002 11