RESEARCH PROJECT ON HOUSEHOLD APPLIANCE NOISE IN MULTI-UNIT BUILDINGS

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Canada Mortgage and Housing Corporation, the Federal Government's housing agency, is responsible for administering the National Housing Act.

This legislation is designed to aid in the improvement of housing and living in Canada. As a result, the Corporation has interests in all aspects of housing and urban growth and development.

Under Part V of this 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. CMHC therefore has a statutory responsability to make widely available, information which may be useful in the improvement of housing and living conditions.

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Cette publication est aussi disponible en français sous le titre «Projet de recherche sur le bruit d'appareils ménagers dans les immeubles multi-logements»

DISCLAIMER

This study was conducted by Décibel Consultants Inc. for Canada Mortgage and Housing Corporation wunder Part IX of the National Housing Act. The analysis, interpretations and recommendations are those of the consultant and do not necessarily reflect the views of Canada Mortgage and Housing Corporation or those divisions of the Corporation that assisted in the study and its publication.

RESEARCH PROJECT ON HOUSEHOLD APPLIANCE NOISE IN MULTI-UNIT BUILDINGS

EXECUTIVE SUMMARY

A study was commissioned by Canada Mortgage and Housing Corporation to evaluate the relevancy, for soundproofing purposes, of installing resilient materials at the junction between certain household and sanitary appliances, as well as counters, and structural elements in housing units.

This research project was realized jointly by the firm Décibel Consultants Inc. and the Centre for Building Studies of Concordia University.

The various tests were carried out in the University's laboratories on a test bench made up essentially of a raised floor covering an area of 2400 mm by 3000 mm. Wood was chosen as the main material for the floor, given its more frequent use by the construction industry in Canada. The floor composition was taken from the National Building Code with a sound transmission class rating of 50, i.e., the minimum imposed in the 1990 version.

On this platform, the following sanitary and household appliances were installed and submitted to specified conditions:

- washing machine : normal cycle
- dryer : normal cycle
- dishwasher : normal cycle
- bath with shower : shower operating
- toilet : water flowing from a height of 1 m from the ground
- counter : constant source of vibration on a wide band

The resilient materials that were submitted to tests are listed below; these were selected based on criteria of availability, cost and present use on the market.

- DURO 30 neoprene waffle pads, 14 mm thick
- Dodge Cork cork flooring, 5 mm thick
- Everlast recycled rubber flooring, 10 mm thick
- Acousti-mat floating floor [i]
- Enkasonic floating floor
- Sonopan floating floor

The main conclusions that were drawn from the tests are summarized below:

- The floor/ceiling assembly used in this study serves to reduce major structure-borne noises. All appliances produced noise levels equal to or lower than 45 dBA, which is the typical average ambient noise level for a unit (2).

- The resilient channel/ceiling system seems to have a 1/3-octave band (125 Hz) resonance which coincides with one harmonic of the vibration frequency of the motor-driven appliances tested. In spite of the relatively low noise levels that should be transmitted to a housing unit under the test bench floor/ceiling assembly, the presence of a tone could make the noise transmitted disturbing.

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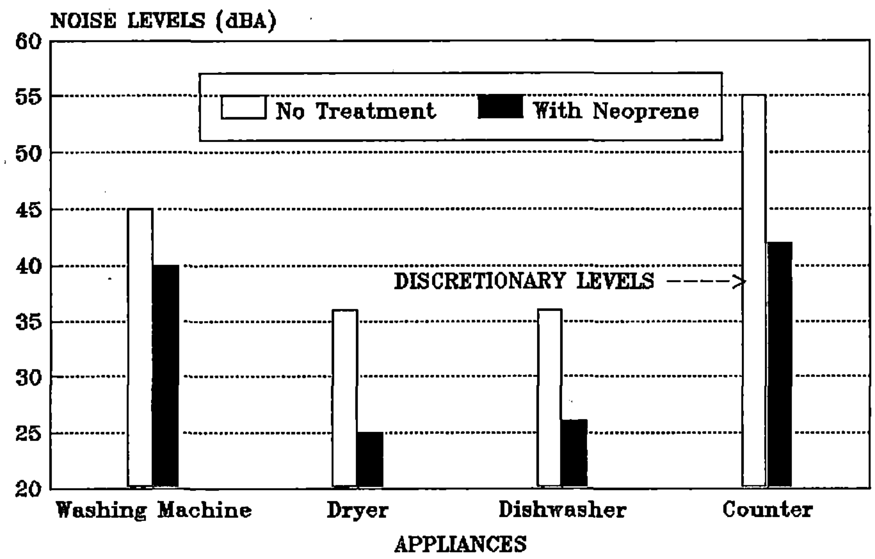
i *The floating floors had a 1000 mm by 1000 mm area and were made up of two 19 mm superimposed plywood sheets installed on the specified product, all this on the base floor.*

- The only soundproofing system to consistently reduce vibration transmission to the floor, and retransmission of the noise, is the 14 mm thick DURO 30 neoprene pads. The estimated noise levels for 4 tested appliances (See abbreviations on page viii) are indicated on the figure below. It is to be noted that this system also makes it possible, in most cases, to eliminate the tone mentioned in the preceding paragraph.



APPLIANCES ESTIMATED NOISE LEVELS
WITH AND WITHOUT NEOPRENE

It is recommended that the system using neoprene pads (C_1) be tested in various housing units with several types of floor/ceiling assemblies having structure-borne noise reduction capacities lower than that of the floor used in this study, including a concrete floor. The effectiveness of the system would then be measured in different real conditions and the recommendation of its general use could then be confirmed.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS

CMHC: Canada Mortgage and Housing Corporation

SOUNDPROOFING:

0 : Test without any soundproofing system

B : Test without any appliance in operation

C_1 : 50 mm X 50 mm neoprene waffle pad, DURO 30, 14 mm thick, installed under the appliance support points

C_2 : 1000 mm X 1000 mm cork flooring, Dodge Cork, 5 mm thick

C_3 : 1000 mm X 1000 mm recycled rubber flooring, Everlast, 10 mm thick

FF_1 : 1000 mm X 1000 mm floating floor, Acousti-mat

FF_2 : 1000 mm X 1000 mm floating floor, Enkasonic

FF_3 : 1000 mm X 1000 mm floating floor, Sonopan

APPLIANCES:

WM : Washing Machine
D : Dryer
DW : Dishwasher
C : Counter

LIST OF APPENDICES

INTRODUCTION

Persons residing in multi-unit buildings are becoming increasingly demanding with regard to the quality of soundproofing in their units, especially those owning their units.

The methods making it possible to attain an acceptable level of soundproofing as pertains to airborne noises are generally known and applied.

This aspect of residential soundproofing, however, does not cover the whole sound gamut as other sources of noise come into play which could disturb people in neighboring units, particularly plumbing noises, impact noises and noises from sanitary or household appliances.

Better acoustic soundproofing techniques would enhance the quality of high and average density housing and would represent a major incentive for potential purchasers of this type of unit.

Plumbing installation techniques designed to reduce noise transmission have been the subject of an earlier study by CMHC (1) and in the future should be applied on a wider scale. Moreover, a large number of builders make minimum use of hard flooring in order to reduce the transmission of impact noises. As for control of noise from sanitary and household appliances at the source, this is not the home builder's responsibility. There is no escaping the latter's responsibility, however, for the vibrations being transmitted directly to the floors from these appliances.

This study essentially aims at evaluating the effectiveness of soundproofing systems to deal with this aspect.

CHAPTER 1
DESCRIPTION OF THE STUDY

1.1 OBJECTIVE

This study essentially aims at quantifying, on a comparative basis, the degree of soundproofing provided by various resilient materials, in the form of pads or floating floors, installed under certain sanitary and household appliances, as well as counters.

1.2 METHODOLOGY

The general methodology developed to evaluate the efficiency of the selected anti-vibration materials is as follows. First, the noise generated by an appliance was measured from the space under the test floor. Then, the interface between the appliance and the base floor was modified; the noise transmitted to the space under the test floor was measured again and compared to the first measurements.

This study assessed the noise emitted by the appliances listed in Table 1, installed on the anti-vibration materials indicated in Table 2. It should be noted that the abbreviations given on page viii were used to identify these materials on the figures in this report.

TABLE 1
LIST OF APPLIANCES

Washer
Dryer
Dishwasher
Bath with shower
Toilet
Counter

TABLE 2
LIST OF ANTI-VIBRATION MATERIALS

50 mm X 50 mm neoprene waffle pa s, DURO 30, 14 mm thick
1000 mm x 1000 mm cork flooring, Dodge Cork, 5 mm thick
1000 mm X 1000 mm recycled rubber flooring, Everlast, 10 mm thick
Floating floor[1], Acousti-mat
Floating floor, Enkasonic
Floating floor, Sonopan

Technical brochures on some of the products indicated in Table 2 are presented in Appendix D.

A 2400 mm by 3000 mm test bench was built in Concordia University laboratory facilities, on which the tests were to be conducted. Its configuration is illustrated in Figure 1 on the following page.

The criterion used for deciding on the composition of the floor/ceiling assembly, indicated in Table 3, was a sound transmission class rating of airborne noises of 50 which is the minimum value imposed in the 1990 version of the National Building Code of Canada.

TABLE 3
COMPOSITION OF THE FLOOR/CEILING ASSEMBLY

11 mm plywood sheet
15.5 mm plywood sheet
38 mm X 235 mm joist, 400 mm o.c.
2 X 90 mm fiberglass wool
Resilients channels 200 mm o.c.
15.9 mm brand X gypsum board

1 *The 1000 mm by 1000 mm floating floors were made up of two superimposed 19 mm plywood sheets installed on the product specified in Table 2, all this on the base floor.*

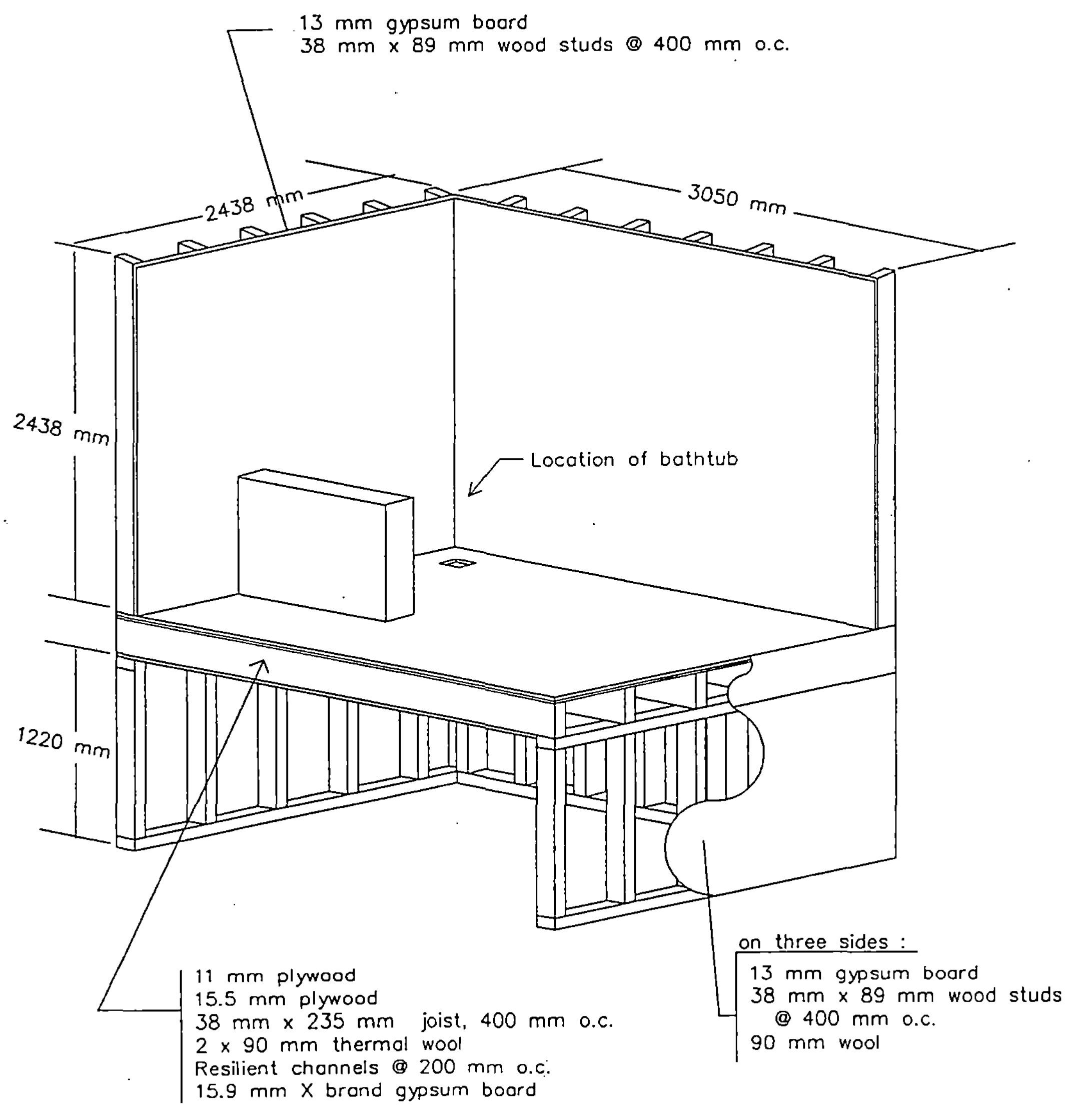


FIGURE 1 - CONFIGURATION OF TEST BENCH

For each of the tests carried out, the following readings were taken at the measurement points shown on Figures 2 and 3 on the following pages:

Appliances not operating:

- background noise measured at 1 m above the floor;
- sound intensity measured on opposite sides of a vertical axis at one point under the floor;
- acceleration on the floor (as well as on the wall, for the counter);

Appliances operating:

- ambient noise measured at 1 m above the floor at the beginning and the end of the test;
- sound intensity measured on opposite sides of a vertical axis at five points under the floor (see Figure 3);
- acceleration on the floor (as well as on the wall for the counter) at the beginning and at the end of the test.

The ambient noise and the acceleration measurement were calculated by establishing the average between the measurements taken at the beginning and at the end of the tests.

The intensity at each of the measurement points was determined as follows, depending on whether the sign of the two results obtained was identical or different.

Different sign: the amplitude was calculated by establishing the average of the absolute values of the two measurements; the sign was considered as exact;

Identical sign: the amplitude was calculated by dividing in one half the difference between the absolute values of the two measurements; the sign was the same as that of the highest amplitude measurement.

The final intensity is the average of all the values obtained at the 5 measurement positions.

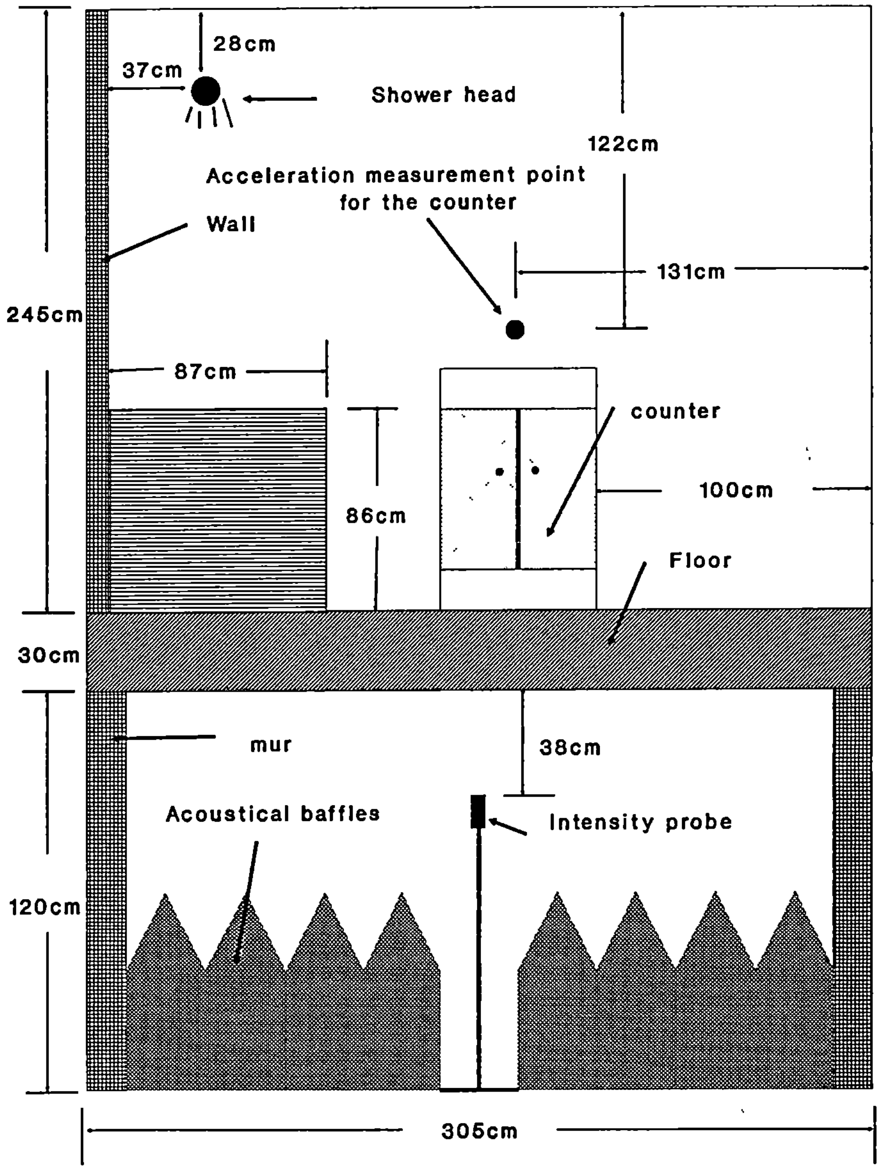


FIGURE 2 - LOCATION OF MEASUREMENT POINTS (side view)

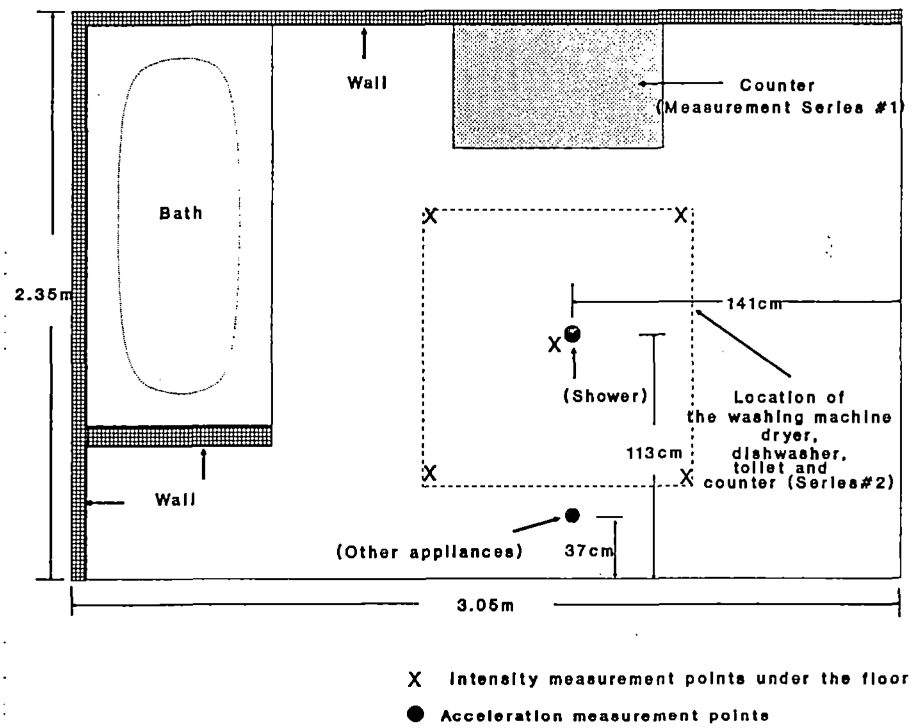


FIGURE 3 - LOCATION OF MEASUREMENT POINTS (top view)

It is to be noted that the intensity was measured on the two opposite sides of the axis to cancel the phase error that can take on major proportions when measurements are taken in an area containing standing waves (see Appendix A).

All the measurements were taken in dBA at 1/3-octave band from 63 Hz to 4000 Hz. The sampling period was 64 sec.

The list of tests carried out is presented in Table 4:

TABLE 4

LIST OF TESTS (Series 1)

Appliance	Materials to be Tested							
	B	0	C_1	C_2	C_3	PF_1	PF_2	PF_3
Washing Machine	X	X	X	X	X	X	X	X
Dryer	X	X	X	X	X	X	X	X
Dishwasher	X	X	X	X	X	X	X	X
Bath with Shower	X	X	X					
Toilet	X	X				X	X	X
Counter	X	X	X					

Sound intensity was the main parameter on which the efficiency of the products tested was to be based.

After completion of the initial tests, the sound energy produced in the space under the floor/ceiling assembly, as measured by its acoustic intensity, proved to be too complex to draw valid conclusions with regard to the efficiency of the different systems studied.

The measurement results for vibration and ambient noise close to appliances in operation were retained for the purposes of the test.

Changes indicated on Figure 4 of the following page were therefore made on the test bench in order to reduce the transmission of noise by flanking paths.

This did not entail significant changes on the sound field; the hypotheses which could explain this situation are indicated in Appendices A1, B1 and C1, as proposed by Dr. Guy of Concordia University.

An additional problem was identified subsequent to preliminary tests, i.e. the weak signal/noise ratio. In fact, in spite of the presence of flanking paths, the noise level under the floor was not significantly higher than the background noise in the laboratory. This situation can be explained, on the one hand, by the small amount of noise radiated by the appliances tested and, on the other hand, by the "excessive" reduction of structure-borne and airborne noise produced by the floor/ceiling assembly.

The general measurement methodology was therefore modified and adapted to the constraints inherent in the test bench configuration.

The major change involved the parameter used to evaluate the efficiency of the various materials tested. It was agreed that the parameter which best illustrated the extent to which the materials tested had the property to reduce the transmission of noise through the floor was the level of vibration in the gypsum board ceiling

Since the noise level in the space under the floor/ceiling is directly proportional to the level of ceiling vibration, the latter may be used to evaluate/compare the noise reduction produced by the various systems.

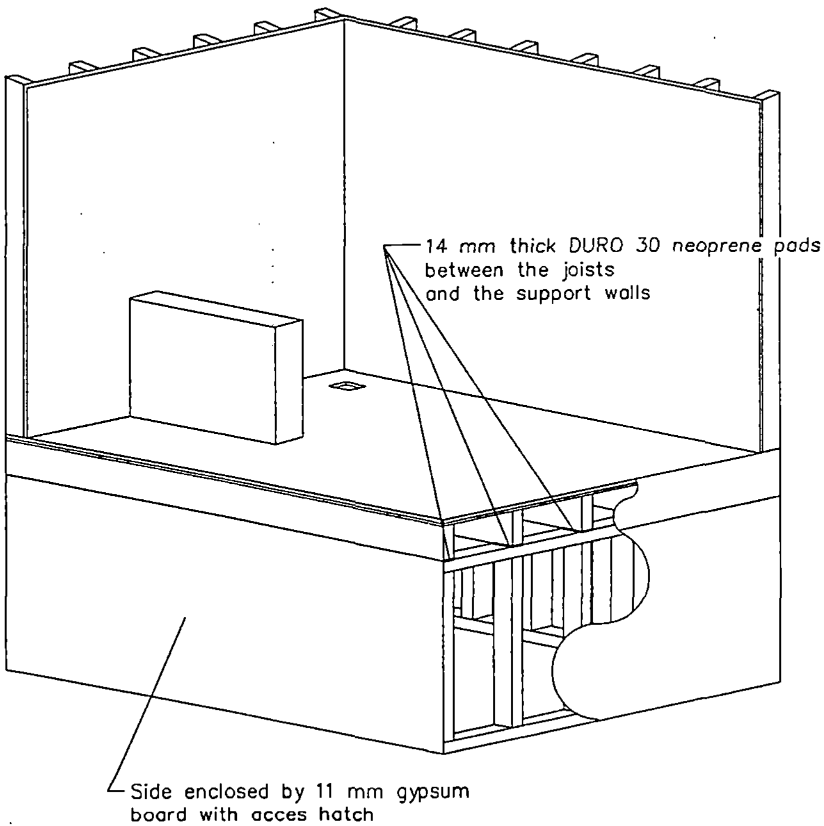


FIGURE 4 - CONFIGURATION OF MODIFIED TEST BENCH

In order to evaluate, in absolute terms, the noise level that should be perceived in a space located under one of the appliances tested and operating on the test bench floor/ceiling assembly, a specific test was developed to establish the correlation between the levels of ceiling vibration and the level of noise radiated.

This specific test consisted in locating, at the center of the floor, a source of broad-band intense noise and vibration installed under a gypsum board enclosure lined with a fiberglass wool pad. The ceiling vibration was then measured as well as the sound pressure level in the space under the floor/ceiling assembly.

Given that the flanking noise was eliminated by adding an enclosure around the noise source, the sound pressure reading measured solely the noise coming through the floor. Through calculations, the sound pressure level for each situation was therefore determined with the vibration/noise relation established by this test.

The list of tests conducted in the second series is presented in Table 5. This series was limited to appliances having generated the highest vibration levels as measured in the first series of measurements.

TABLE 5

LIST OF TESTS (Series 2)

Appliance	Materials to be Tested							
	B	0	C_1	C_2	C_3	PF_1	PF_2	PF_3
Washing Machine	X	X	X	X	X	X	X	X
Dryer	X	X	X	X	X	X	X	X
Dishwasher	X	X	X	X	X	X	X	X
Counter	X	X	X	X	X	X	X	X

1.3 INSTRUMENTATION

The test instruments are outlined in Figure 5 for series 1. In summary, a Brüel & Kjaer 3360 analyzer was used to collect and process the data. The latter was controlled by two programs based on an IBM micro-computer with a GPIB interface.

A B&K 2209 sonometer was connected to channel A for ambient noise measurement. The acceleration was measured by a B&K 2511 sensor connected to channel B. An intensity probe with 12 mm microphones was located 375 mm under the floor and was hooked up to channels A and B.

Each instrument was calibrated before the tests and the necessary corrections were made as needed.

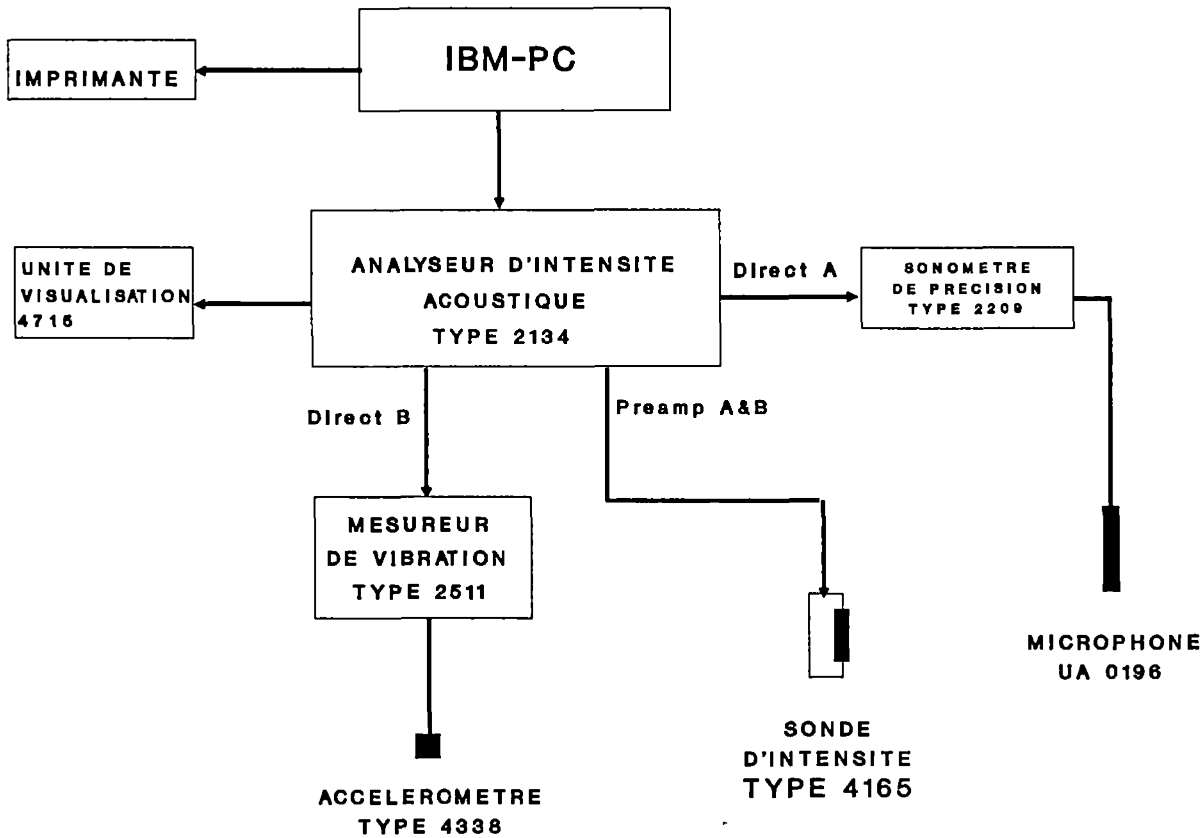


FIGURE 5 - INSTRUMENTS FOR MEASUREMENT SERIES 1

CHAPTER 2
MEASUREMENT RESULTS AND ANALYSES

2.1 MEASUREMENT SERIES #1

As previously mentioned (see Chapter 1) the measurement series 1 data that were retained for the purposes of this study were the vibration levels as measured on the floor as well as the noise level measured close to the operating appliances. The results are presented in Appendix E.

It is to be noted that the vibration levels were presented for third octave bands from 63 Hz to 1000 Hz, the accelerometer mounting assembly presenting a 1250 Hz resonance.

The main conclusions that can be drawn from these figures are presented in the following paragraphs. It is to be noted that the comments formulated on the different systems are to be considered as reference only since the readings taken during the second series of tests are more likely to provide information on noise transmission to the space under the floor/ceiling assembly.

The figures in section 2.1 (Figures 6 to 8) present the differences in the global vibration levels measured on the floor, with and without soundproofing systems. Consequently, the higher the value indicated, the more effective the system.

2.1.1 **Washing Machine** (see Figures E1 and E6)

The washing machine generated the highest vibration levels in the group of appliances tested for low frequencies, in particular in the 1/3- third octave band (125 Hz.).

Use of the various systems produced global vibration reduction levels (dBA) as indicated in Figure 6.

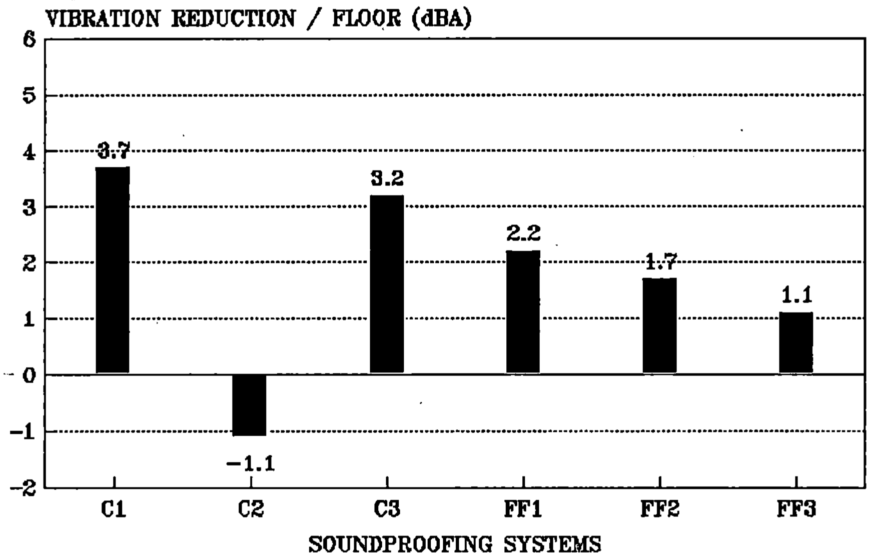


FIG. 6 – WASHING MACHINE VIBRATION REDUCTION

The reductions obtained are marginal, with the best results for neoprene pads (C_1) and recycled rubber flooring (C_3) being reductions of close to 3 dBA.

2.1.2 **Dryer** (see Figures E2 and E7)

The dryer generated the highest vibration levels at average and high frequencies, which could be due to the presence of a jacket with metal buttons inside this machine. It is to be noted that the noise levels indicated in Figure E2 are to be considered as reference only since the air exhaust was not connected to a flexible duct.

Using recycled rubber flooring (C_3) produced a global vibration reduction on the floor of over 7 dBA.

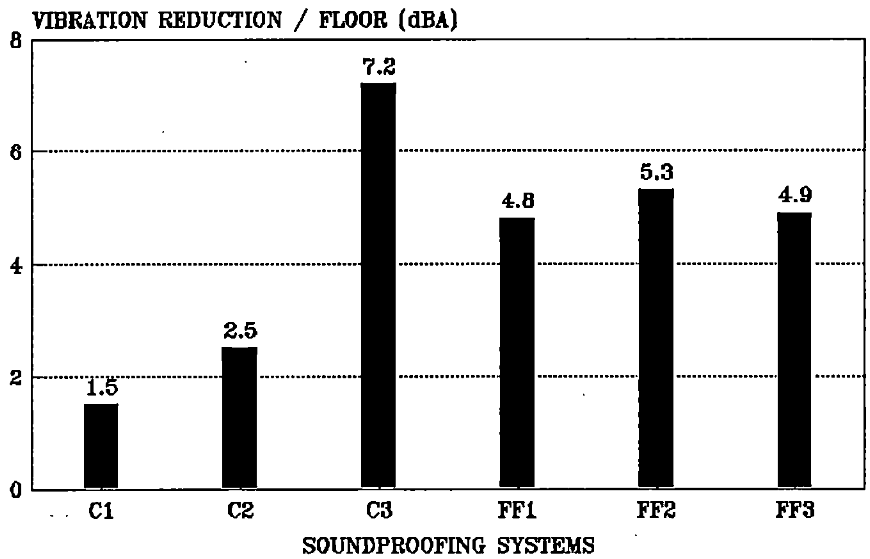


FIG. 7 - DRYER
VIBRATION REDUCTION

As for floating floors, they produced reductions of around 5 dBA.

2.1.3 **Dishwasher** (see Figures E3 and E8)

The dishwasher generated average and high frequencies, for the most part, without any particular tone.

The best performing systems were neoprene pads (C_1) and recycled rubber flooring (C_3).

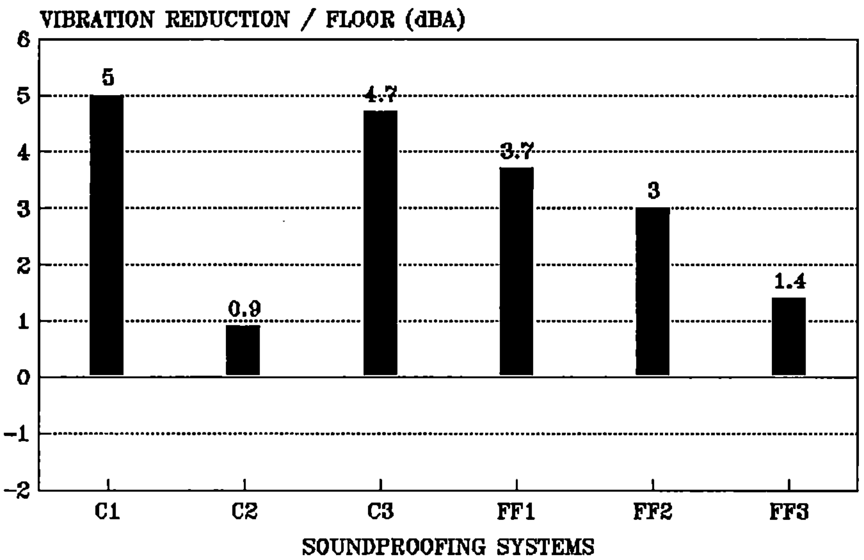


FIG. 8 – DISHWASHER VIBRATION REDUCTION

2.1.4 Bathtub (see Figures E4 and E9)

Water flowing in the bathtub generated average and high frequency vibrations. The peak in noise levels measured was due to a whistling noise produced by the shower head.

Installing neoprene between the wall and the bathtub and under bathtub floor supports only produced a reduction of 2 dBA in the global level of vibration on the floor.

2.1.5 **Toilet** (see Figures E5 and E10)

Water flowing from a height of 1 m generated high noise and vibration levels at 400 Hz.

Installing the toilet on floating floors made it possible to obtain reductions in vibration levels of up to 13 dBA as measured on the floor.

2.1.6 Counter

The level of vibration generated cannot be commented on since the source of vibration was discretionary.

Installing neoprene between the counter and the wall caused a 4 dBA drop in the global vibration level on the wall and a 1 dBA drop on the floor; this shows how being attached to the wall facilitates the transmission of vibrations to spaces beneath through the floor. Installing additional neoprene between the counter and the floor produced a reduction of nearly 12 dBA in vibrations measured on the floor.

2.2 MEASUREMENT SERIES #2

All the results of the measurement series #2 are presented in Appendix F. This data is analyzed in the following paragraphs.

The figures in section 2.2 (Figures 9 to 12) present global estimated noise levels under the floor/ceiling assembly with and without soundproofing systems. Consequently, the higher the levels indicated, the more effective the system. The reduction obtained corresponds to the difference between the estimated levels with soundproofing systems (C_1 to FF_3) and the levels without systems (0).

2.2.1 **Washing Machine** (see Figures F1 and F5)

An operating washing machine causes vibrations characterized by a peak in the one-third octave band (125 Hz.) in the ceiling (gypsum board on resilient channels).

The estimated noise levels in the space under the test bench floor/ceiling assembly are indicated in Figure 9. The use of neoprene pads (C_1) produced a noise level reduction of 5 dBA, in addition to eliminating the peak (125 Hz.).

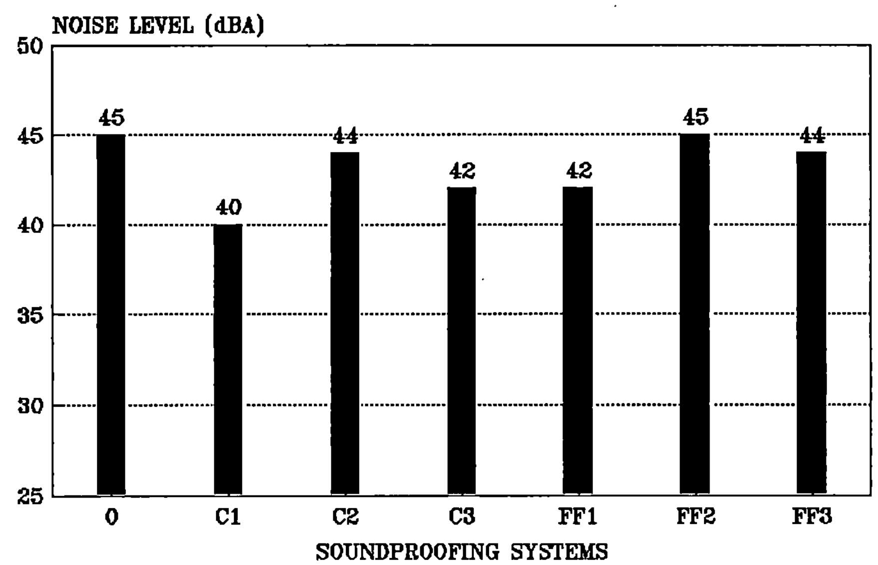


FIG. 9 – WASHING MACHINE
ESTIMATED SOUND LEVELS

2.2.2 Dryer (see Figures F2 and F6)

Contrary to what had been measured on the floor in measurement series 1, the vibrations generated by the operation of the dryer presented a peak at 125 Hz, which could be due to a resonance in the resilient channel - ceiling system set in motion by the motor of the dryer.

The estimated noise levels for the various soundproofing systems are indicated at Figure 10.

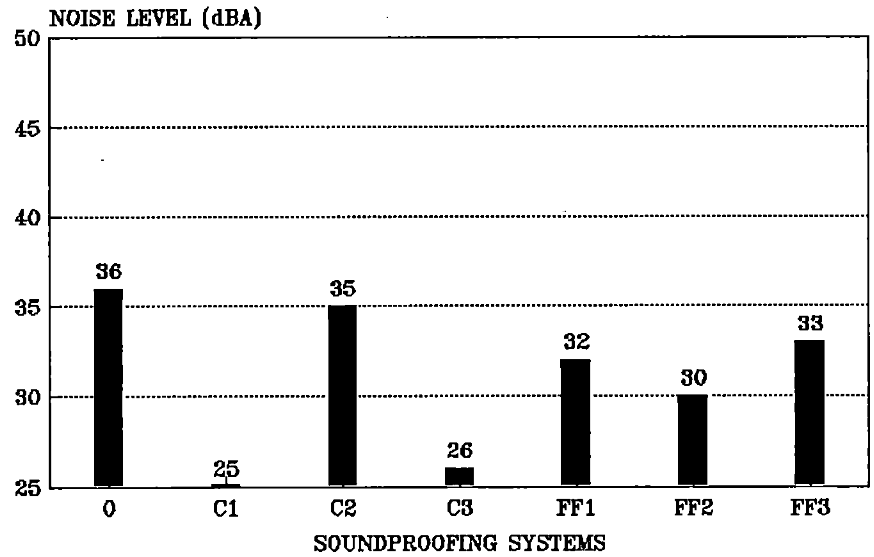


FIG. 10 - DRYER
ESTIMATED NOISE LEVELS

The installation of neoprene pads (C_1) as well as the recycled rubber flooring (C_3) produced a reduction in the estimated noise in the range of 10 dBA. Neoprene padding was the only system, however, to eliminate the 125 Hz peak.

2.2.3 **Dishwasher** (see Figures F3 and F7)

The vibrations generated by the operating of the dishwasher also presented a peak at 125 Hz.

Installing neoprene pads (C_1) as well as the recycled rubber flooring (C_3) once again produced the greatest reductions, up to 10 dBA for the pads. The peak was not reduced as much, however, compared to the data for the washing machine and the dryer.

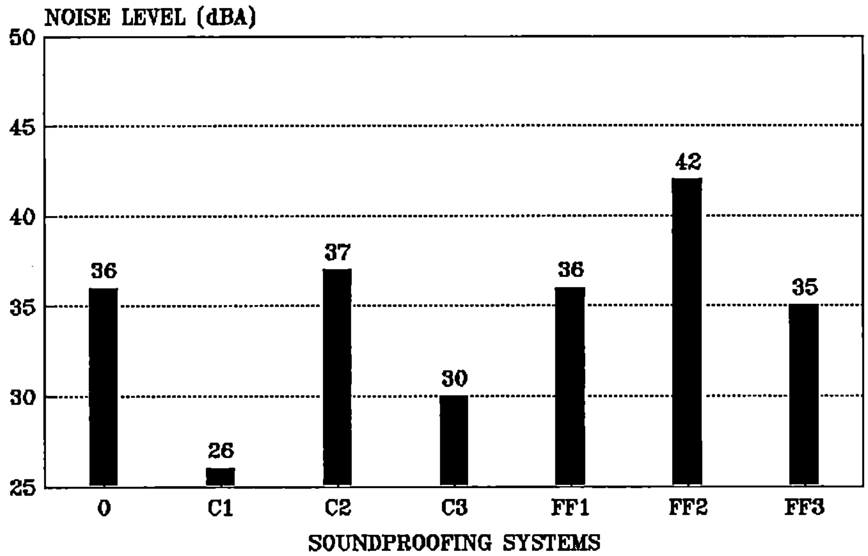


FIG. 11 – DISHWASHER
ESTIMATED NOISE LEVELS

2.2.4 **Counter** (see Figures F4 and F8)

The estimated noise levels for the counter tests are presented in Figure 12. It is to be noted that the levels are not representative of a real situation since the source of vibration installed on the counter was discretionary.

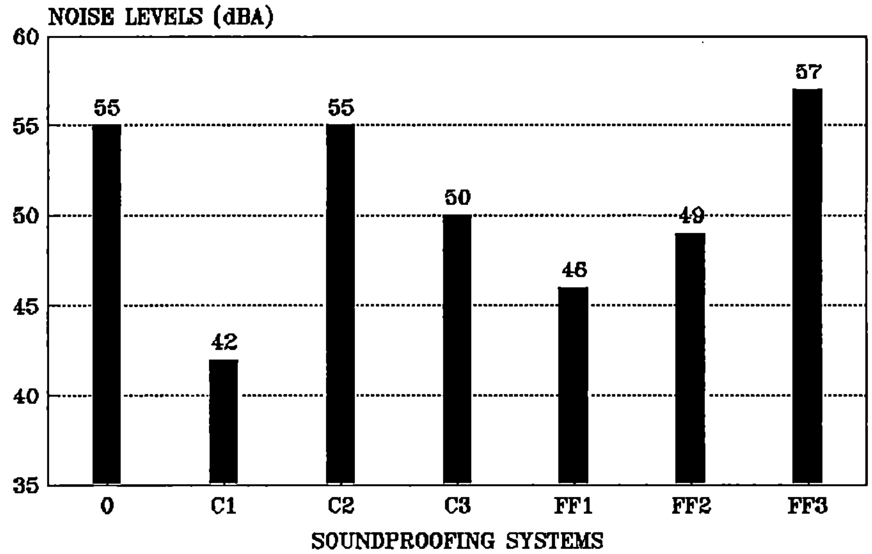


FIG. 12 – COUNTER
ESTIMATED NOISE LEVELS

The systems producing the largest reductions are the neoprene cushions and the Acousti-mat floating floor. The latter is not particularly effective, however, at low frequencies.

CONCLUSIONS

1 The floor/ceiling assembly used in this study serves to reduce major structure-borne noises. All appliances produced noise levels equal to, or lower than 45 dBA, which is the typical average ambient noise level for a housing unit (2).

2 The resilient channel/ceiling system seems to have a 1/3 octave 125 Hz band resonance, which coincides with one harmonic of the vibration frequency of the motor-driven appliances tested. In spite of the relatively low noise levels that should be transmitted to a housing unit under the test bench floor/ceiling assembly, the presence of a tone could make the noise transmitted disturbing.

3 The only system to consistently show the capacity to reduce vibration transmission to a floor, and retransmission of the noise is that involving the installation of 14 mm thick DURO 30 neoprene pads under the appliances' support points. This system makes it possible to eliminate tones in most cases.

RECOMMENDATIONS

It is recommended that the system using neoprene pads (C_1) be tested in various housing units with several types of floor/ceiling assemblies having structure-borne noise reduction capacities lower than that of the floor used in this study, including a concrete floor. The effectiveness of the system would then be measured in different real conditions and the recommendation of its general use could then be confirmed.

Martin Meunier, Engineer
Pointe-Claire

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1. Morin Michel, "Research project on plumbing noise in multi-dwelling buildings", submitted to Housing Innovation Division, C.M.H.C. Canada, September 1990.

2. Bradley, J.S., "Acoustical Measurements in Some Canadian Homes", National Research Council

ANNEXE A

Domestic Appliance Vibration Isolation Project:
Sound Intensity Measurements
What went wrong!

Appendix A

Domestic Appliance Vibration Isolation Project:

Sound Intensity Measurements

—— What Went Wrong!!

1. Introduction

The Domestic Appliance Vibration Isolation Project in collaboration with Decibel Consultants was initially designed to make full use of the relatively new Sound intensity measurement procedure.

The objectives were of a direct nature, namely, to construct a typical kitchen floor assembly, operate typical domestic appliances upon it with and without a series of vibration isolation mounts, and determine the acoustic energy transmitted to a lower level via the floor thus ranking the various isolation procedures. The floor construction, domestic appliances and vibration isolation procedures are discussed in the main report.

The test floor assembly is shown in Figure A1, and it can be seen that conventional sound pressure measurement procedures would not be sufficient to determine transmitted acoustic energies because of obvious flanking paths. The sound intensity technique was employed to resolve this problem because of its ability to sense vector energy flow - hence the required energies from the ceiling(beneath the test floor) could be distinguished from side wall flanking energies.

In this project, the sound intensity measurement technique did not yield the required data at and over a critical low frequency range(63Hz to 250Hz). This appendix is written to examine the reasons why and contribute to our knowledge stock in the matter of sound intensity usage.

2. Sound Intensity Measurement Procedure

The present test series requires measurements in third octave bands from 63Hz upwards for all measurands, pressure, intensity, velocity and acceleration. Intensity measurements at lower frequencies require careful attention to avoid inherent error problems(finite difference approximation error) which it is now known(see Appendix B) are exacerbated in the presence of standing waves; in the present test circumstance it was anticipated that standing waves would arise at low frequencies in the lower floor cavity despite the presence of absorption materials.

Two measurement procedures were employed to resolve these problems:

a) Probe reversal;
b) Probe scanning with increased microphone spacing.

a) Probe Reversal

Probe reversal is a technique designed to remove channel phase difference errors by measuring with the probe in one direction, then with the probe reversed through 180°, and processing the two sets of data.

Examining the available literature(see Appendix B), it was clear that an adequate processing formulation for measurements within standing waves had not yet been developed and an auxiliary test series was initiated to remedy this fact.

The auxiliary test series is presented in Appendix B of this report and a new correction formulation and reversal procedure is determined to be accurate even in most adverse standing wave circumstances.

The probe reversal procedure was implemented in the present test series by construction of a special probe stand. The probe holder was building floor mounted and positioned the probe approximately 15cm underneath the lower ceiling of the test rig. A single axis, probe arm allowed reversal in the vertical direction upon rotation through 180°. In these measurements a 12mm spacer was used.

In the appliance test series, a typical intensity result determined as an average of five point measurements evenly distributed about the centre section of the ceiling, over a four foot square area, is shown in Figure A2. In the low frequency range negative intensities are evident, and indicate a power flow into the ceiling as opposed to determining a power flow out, which was expected from the appliance caused vibration.

Whilst different appliances and/or vibration isolation treatments caused differing results, negative energy flow was still evident at one or more frequencies in the low frequency range of intensity; in consequence the results did not allow assessment of vibration isolation efficacy.

Two test details could explain the unexpected result:

i) Very high side wall flanking;
ii) Inadequate point sampling over the whole ceiling surface.

As a partial remedy to high side wall flanking, the test rig was modified by cutting all direct structural connections between the test floor and its supporting side wall structure, and then placing vibration isolation pads between them.

The question of inadequate point sampling was addressed by employing a total ceiling surface scan technique.

b) The Scan Technique

Intensity scanning is a popular method of surveying energy from a test surface in that an automatic integration of total surface result is obtained. At the time of writing no standard test procedure is available in North America, however, a procedure has been introduced in the Scandinavian Countries and is referred to as 'The Nord Test Method', a copy of relevant portions are appended as Appendix C of this report.

The Nord test procedure as described in Appendix C, and employing a 50mm probe spacer, was used to monitor the transmitted intensity over the full ceiling surface at a distance of 10cm.

A typical result was similar to Figure A2 particularly with respect to negative power flow at about 125Hz. In consequence this test procedure also could not be used to assess vibration efficacy.

3. Why?

In the initial(probe reversal) test series it was not considered necessary to monitor the vibration of the resiliently mounted ceiling of the test floor assembly as intensity measurement was to indicate transmitted energies. A floor mounted accelerometer was monitored and a typical spectrum similar to that shown in Figure A3 was found; of particular note is that no significant reading or response compared to other frequencies may be ascribed to the frequency regions about 125Hz.

In the second(probe scanning) test series, an accelerometer was mounted at the ceiling centre and monitored as part of the data acquisition sequence. A typical result is shown in Figure A3. Clearly a significant resonance exists at or about 125Hz; since this response is not evident at the floor it is apparent that a ceiling resonance exists.

Both intensity measurement techniques support the fact of an energy flow into the ceiling at or about 125Hz, it therefore is evident that the resilient furring in combination with the ceiling mass is acting as a resonant panel absorber. Under these circumstance energy from flanking paths is being absorbed by the ceiling and positive energy flows can not be sensed. In brief, the floor is too good in relation to the source strength and flanking paths, and also acts as a very efficient absorber from the underside direction.

Compounding these observations are resonance predictions for the isolation pads, see Table A1, which indicate appliance/pad combination resonance frequencies throughout the low frequency range of interest encompassing also the ceiling resonance frequency.

4. Conclusion

In conclusion, the intensity measurements were correctly indicating the power flows but by unforeseeable accident of ceiling design, compounded by the characteristics of some vibration isolation systems, the power flow measurements do not allow one to conclude domestic appliance vibration isolation efficacy. Fortunately, the ceiling/floor vibration measurements do allow useful conclusions to be drawn.

Isolator		C1	C2	C3	C4	PF1	PF2	PF3
Stiffness Constant, K Kg/m per m^2		1.77E7	1.10E8	8.80E7	1.20E8	1.18E6	1.42 E6	8.91 E6
Support Area, A m^2		.0224	.00776	.00776	.00776	.6561	.6561	.6561
Weight W,Kg	Appliance	Isolator Resonant Frequency, Fn, Hz						
97.0	Washer	31.9	46.8	41.8	48.8	42.3	46.4	116.1
48.6	Dryer	45.0	66.1	59.1	69.0	57.0	62.5	156.5
74.7	Dish Washer	36.3	53.3	47.7	55.7	47.5	52.1	130.4
42.8	Toilet	48.0	70.4	63.0	73.5	60.0	65.8	164.8
57.1	Counter	41.5	60.9	54.5	63.7	53.3	58.4	146.4
-	Bath							
10.7	Platform for PF1, PF2, PF3							

Tale A1 : Predicted Resonance Frequencies for isolators and appliance combinations.

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Acoustique, bruit et vibration
Acoustics, noise and vibration

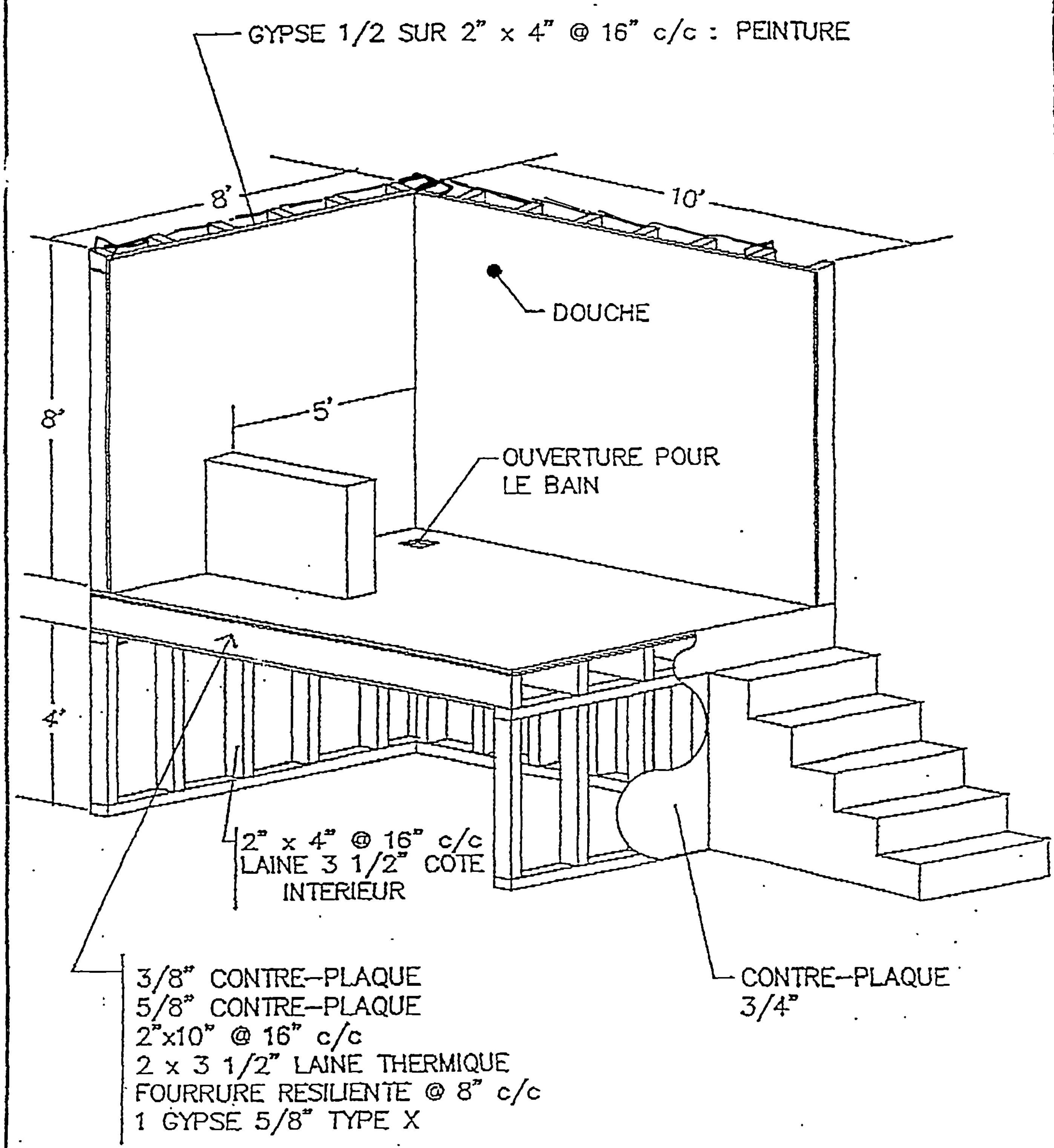

Figure A1 : BANC D'ESSAIS – PROJET SCHL

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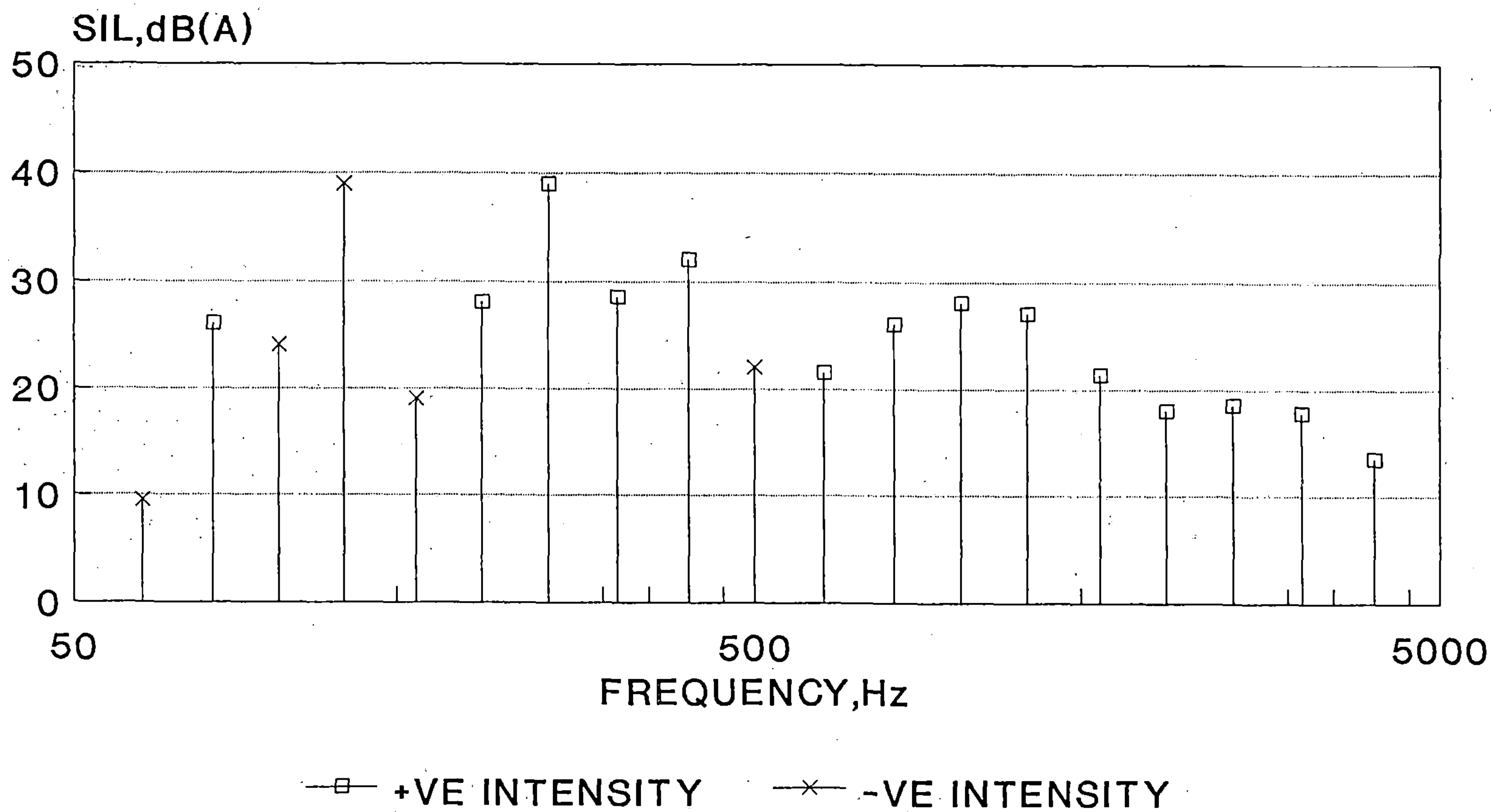

Figure A2: SOUND INTENSITY LEVEL WITH DAMPING PF3 FOR WASHER TEST, LV2/PF3. (PROBE REVERSAL)

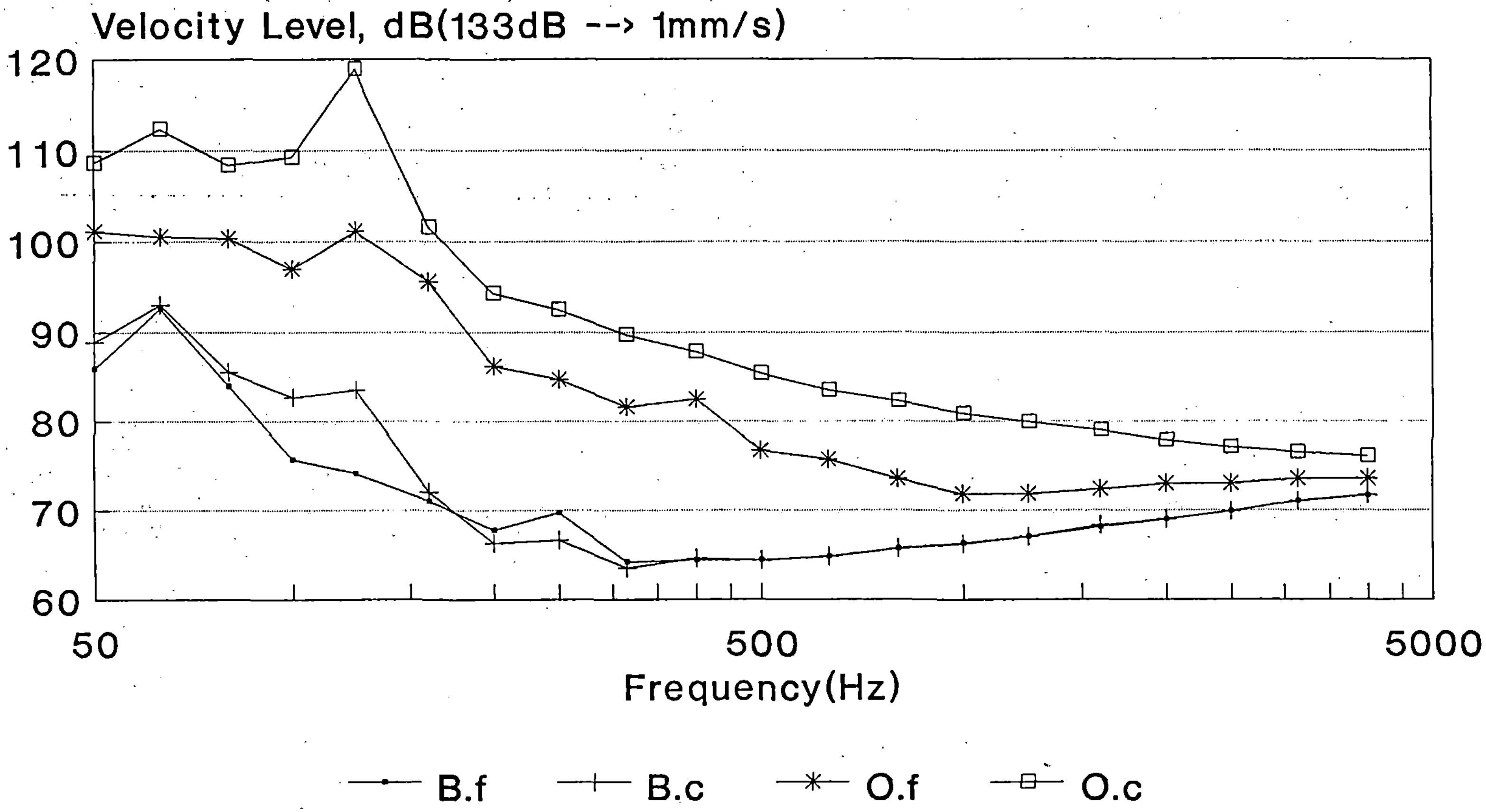

Figure A3:Background(B) and Operation(O) Velocity Levels of the Washer with Treatment PF3. Floor(f) and Ceiling(c)

ANNEXE B

True Intensity Assessment Employing Probe Reversal

APPENDIX B

TRUE INTENSITY ASSESSMENT EMPLOYING PROBE REVERSAL

1. INTRODUCTION

When a pressure-pressure probe system is employed to measure intensity an assessment is made of the acoustic particle velocity via a finite difference approximation to the local spatial gradient of sound pressure; this in turn requires that the instrumentation (probe plus processor) be capable of detecting the phase difference between the two microphones of the probe.

Problems of accurate intensity measurement will arise when the phase difference between microphones resulting from the acoustic field are similar to or less than the system channel phase errors. This circumstance can arise even for a well phase matched system is highly reactive fields as might be encountered during a sound power assessment within a reverberation chamber, or, a surface intensity measurement within an unfurnished reception room undertaken to establish a walls' transmission loss.

Channel phase mismatch errors may be compensated for by analytical or computational procedures when a Fast Fourier transfer based system is employed [1,2]; in the case of real time analysis or FFT based systems - "The effect of phase mismatch may effectively be eliminated by taking half the difference (in linear units) between the signed intensities measured (a) with the probe in any position and orientation, and (b) after rotation by 180° about the phase of symmetry (probe reversal)" [3].

It will later be shown that the 'half difference' referred to above requires additional modification, however the probe reversal principal having been stated, there is a dearth of data supporting employment of the technique. By way of testing the procedures efficacy in association with a simple formulation which also accommodates the finite difference approximation error [6] this work presents the results of some probe reversal measurements for different frequencies and probe spacing. In addition a range of ratios between field phase and channel phase error are also investigated including extreme circumstances when the measured intensity does not change sign upon probe reversal.

2. CORRECTION FORMULATION

for sinusoidal signals, the time average value of sound intensity when measured by a pressure-pressure probe may be written as [5]:

$$I = \frac{P_1 P_2 \sin(\phi)}{\omega \rho \, \Delta r_o} \tag{1}$$

where P_1 and P_2 are the rms values of the sinusoidal pressure signal at microphones 1 and 2 respectively

ϕ is the phase angle between the pressure signals

ϖ the angular frequency

ρ is the density

and Δr_o the microphone spacing

For on axis free field measurements, equation (1) can be processed to yield [6]:

where I_m is the measured intensity

$$I_m = I_T . \frac{\sin(k\Delta r_o)}{k\Delta r_o} \quad (2)$$

I_T is the true intensity

k is the wave number

and $\frac{\sin(k\Delta r_o)}{k\Delta r_o}$ is a finite difference error term

If a channel phase mismatch error ($\pm\theta$) is now introduced then:-

$$I_m = I_T . \varepsilon \quad (3)$$

where ε is a modifying multiple to the true intensity involving both finite difference and channel phase error elements and has the general form:

$$\varepsilon = \frac{\sin(k\Delta r_o)}{k\Delta r_o} . \cos(\theta) + \sin(\theta) . C \quad (4)$$

For on axis measurements within planar standing waves, ε may be written as [4]:where

$$C = \frac{1}{2Rk\Delta r_o} [(R^2+1)\cos(k\Delta r_o) + (R^2-1)\cos(2kx)] \quad (5)$$

R is the standing wave ratio (linear)

and x is the measurement position such that cos (2kx) = -1 for measurements at a pressure minimum and cos (2kx) = 1 for measurements at a pressure maximum.

In a free field measurement, R = 1, $C = \frac{\cos(k\Delta r_o)}{k\Delta r_o}$

and equation (4) reduces to the well known form [6]

where θ may be + ve or - ve.

$$\varepsilon = \frac{\sin\,(k\Delta r_o + \theta)}{(k\Delta r_o)} \tag{6}$$

By making on axis probe reversal measurements the true intensity direction and the channel phase difference error is reversed and their respective formulations may be written from equations (3), (4), and (5) as:

$$Im_1 = I_T \left\{ \frac{\sin\,(k\Delta r_o)}{k\Delta r_o} \,.\, \cos(\theta) + \sin(\theta) \,.\, C \right\} \tag{7}$$

$$Im_2 = -I_T \left\{ \frac{\sin(k\Delta r_o)}{k\Delta r_o} \,.\, \cos(\theta) - \sin(\theta) \,.\, C \right\} \tag{8}$$

where Im_1 and Im_2 are respectively the signed measured intensities before and after probe reversal.

Taking the difference between equations (7) and (8), it now follows that:

$$I_T = \frac{Im_1 - Im_2}{2\,\dfrac{\sin(k\Delta r_o)}{k\Delta r_o} \,.\, \cos\theta} \tag{9}$$

It may be seen from the denominator of equation (9) that the probe reversal principal as stated in reference [3] (referred to in the introduction) requires qualification in that a correction other than a half difference between signed intensities may be required; this correction does however reduce to one half for small angles $k\Delta r_o \rightarrow 0$ and $\theta \rightarrow 0$.

With the exceptions of residual intensity measurement (that is measurements within a pressure coupler at nominal zero intensity) or zero channel phase difference, the unsigned measured intensities cannot have equal magnitude. Equation (9) may now be expressed in terms of measured logarithmic values as:

$$IL_T = sgn\,(IL_{max})10\log_{10}\left|\frac{sgn(IL_{max}).10^{|IL_{max}|/10} - sgn\,(IL_{min})\,.\,10^{|IL_{min}|/10}}{2.\dfrac{\sin(k\Delta r_o)}{k\Delta r_o}\,.\,\cos\theta}\right| \qquad (10)$$

where |ILmax| is the unsigned maximum of the measured intensity level

|ILmin| is the unsigned minimum of the measured intensity level

sgn ( ) refers to the sensed sign (+ or -) of the bracketed intensity level, and the argument of the logarithmic evaluation is taken to be an absolute value.

It should be noted that IL_{max} and IL_{min} will have the same sign when the magnitude of the second term C.sinθ within the brackets of equation (7) and (8) is greatest. This circumstance typically arises when C > 1, which may be seen from equation (5) may occur with high standing wave ratios together with locations where the field phase is minimal (at or about a pressure maximum); when this occurs the direction of the true intensity is the direction indicated when measuring the highest intensity level, IL_{max}.

3. MEASUREMENT PROCEDURE

Measurements were undertaken within a five meter long standing wave tube of square cross section, twenty four by twenty four centimetres, shown diagrammatically in Figure 1.

The operable frequency range is nominally 50 Hz to 630 Hz with the lower frequency limit chosen to avoid pressure maxima sensing at the termination; in the present test series all intensity measurements are taken at or about the pressure maximum approximately $\lambda/2$ from the termination with the exception of 31.5Hz which are taken close to the termination; these locations ensure the greatest phase difference induced error.

Two ¼" B&K microphones, type 4135 are employed in a face to face configuration as shown in Figure 3, in this way physical probe differences upon reversal were minimized. The microphone assembly was mounted on a carriage of small cross section and could be traversed to any position along the longitudinal axis of the tube whilst maintaining the probe at the centre of the tube cross section, see Figure 1.

Precise probe reversal was achieved by manually reversing the probe assembly about a vertical axis extending from the center of the microphone spacer; care was also taken to ensure that microphone cartridge vent ports presented the same aspect to the axis of propagation upon probe reversal.

Pressure measurements to establish the standing wave ratio were taken from one microphone of the pair; when a pressure maximum was established, the probe carriage was maneuvered so that both microphones of the pair displayed similar pressure readings with each microphone located on either side of the maximum. One exception to this procedure was with respect to measurements at the 31.5Hz pressure maximum; these were assumed given by the nearest microphone to the termination when the carriage was at extreme travel; the nearest microphone was then approximately twenty centimetres from the termination.

Measurements were undertaken at discrete frequencies although a third octave band analyzer and intensity processor B & K type 2134 was employed; for each measurement an averaging time not less than T = 400/B seconds was employed, where B is the third octave band width.

Five frequencies, 500 Hz, 250 Hz, 125 Hz, 63 Hz and 31.5 Hz were tested, each in association with a 6 mm and a 12 mm spacer. In addition a nominally hard reflecting surface and a ten centimetre thick acoustic absorbent foam lined termination was employed; in this way both lower and high standing wave ratios were established over most of the frequency's range.

The residual pressure-intensity index for the instrument was measured for each discrete test frequency by employing a pressure cavity fitted to the end of a one inch diameter standing wave tube of the B & K apparatus type; as described in reference [7], these results are displayed in Table 1 and are referenced to a probe spacing of 12 millimetres.

4. THE RESULTS

The net propagating sound intensity of the standing wave was established from a measurement of the pressure maximum and minimum via the relationship:

$$I = \frac{p\,\mathrm{max}\ .\ p\,\mathrm{min}}{\rho c} \tag{11}$$

where p max is the maximum pressure (rms)

p min is the minimum pressure (rms)

ρ the density of air

c the velocity of sound

In all cases, the intensity established via equation (11) before and after probe reversal did not differ by more than 0.5 dB, more typically 0.2 to 0.3 dB. The average of equation (11) applied before and after probe reversal is referred to as IL_p avge in Table 2.

Intensity level measurements at or about the pressure maximum are shown as $IL_{max\,1}$ and IL_{max2} within Table 2 where $ILmax_1$ is recorded before and $ILmax_2$ after probe reversal. Processing of these values in accordance with equation (10) are shown as IL_{max} avge in Table 2.

The pressure intensity index (PII) is often employed [9] as an indicator of measurement circumstance, the higher its value in relation to the Residual Pressure Intensity Index the greater is the measurement error. For all measurements at or about a pressure maximum PII was positive but differed dependent upon the intensity level indicated for a given probe orientation, typically it was close to R(dB)/2.

5. DISCUSSION

Equation (4) details an error term expressed as a multiple to the true intensity with respect to measurements within a planar standing wave.

In the absence of probe or instrument sensitivity limitations, measurements at or about a pressure maximum will lead to greatest channel phase error induced errors of measurement, with higher errors occurring at high standing wave ratios.

The measured results $ILmax_1$ and $ILmax_2$ clearly exhibit this trend when compared to the true intensity ILp_{avge} and it can also be seen that high standing wave ratio circumstances (> 45dB in the present measurements) generally cause an absence of sign reversal for the measured intensity upon probe reversal.

The corrected probe reversal measurements in accordance with equation (10) are shown as $ILmax_{avge}$ in Table 2.

Compared to the presumed correct intensity ILp_{avge}, they can be seen to display good agreement.

The instrument (probe + processor) employed in the present measurements qualifies as a general use class II measurement system when tested in accordance with IEC draft standard 1043 [8]. The draft standard stipulates a standing wave performance test whereby a precision class I instruments should not exhibit a difference greater than ± 1.5 dB for intensity measurements along the axis of a wave of standing wave ratio 24 dB at a frequency in the range 125 Hz to 400 Hz (lowest frequency chosen as specified for use); with the exception of 250 Hz in the case of the 12 mm spacer (R=53.6) and 125 Hz in the case of the 6 mm spacer (R=50.4), this tolerance is met despite the significant increase in standing wave ratio and the fact that the standard test circumstance suggest employment of a probe spacing greater than 25 mm (typically 50 mm).

At lower frequencies (63 Hz & 31.5 Hz) an assessment of equation (10) efficacy may be made by comparing results against the free field predictions of equation (4) for a class I probe having a maximum instrument channel error phase difference of 0.09° (the draft standard [8] has a lower frequency limit of 50 Hz but the channel error phase difference implied from pressure-residual intensity requirements is presumed here to extend down to 31.5 Hz).

Figure (3) displays the free field predictions of equation (4) at low frequencies ($\theta = \pm 0.09°$) and the high standing wave low frequency corrected results (63 & 31.5 Hz) of Table 2, compare favourably with them despite the dramatic difference in field circumstances, (R = 0 dB compared to R > 45 dB).

The lower frequency limit for free field measurements employing 12 mm or 6 mm probe spacing is advised by a manufactures (Bruel & Kjaer) to be 125 Hz. The probe reversal corrected result at 63 Hz and standing wave ratio R < 30 dB (in the present measurements) yields an error difference of 0.6 dB and 0.3 dB respectively which is well within the earlier described standing wave test (requirement ±1.5 dB for class I probe at 125 Hz with R = 24 dB). Whilst modestly higher errors are evident at 31.5 Hz, +2.9 dB and 2.4 dB for the 12 and 6 mm probe spacers respectively with R > 45 dB, there are grounds to suppose that these errors will be decreased if a lower standing wave ratio (say < 30 dB) had existed. One may conclude that the frequency range of probe/spacer application may usefully be decreased by employing the probe reversal correction procedure.

CONCLUSIONS

Probe reversal measurements can be used to achieve relatively high accuracy in field circumstances which would normally dictate greater error both in magnitude and directional indications.

A class II probe can yield results equal or better than class I probe requirements when employing the probe reversal technique although great care must be exercised in maintenance of the probes acoustic centre.

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9. International Organisation for Standardization (ISO) 9614 "Determination of the Sound Power Levels of Noise Sources Using Sound Intensity Measurements at Discrete Points", ISO/DIS 9614-1, 1989.

FREQUENCY	31.5	63	125	250	500
PRII (dB)	0.7	9.7	10.5	14.1	11.9

Table 1: Pressure Residual Intensity Index (dB) at Discrete Test Frequencies for the Intensity Probe with 12 millimetre spaces.

Frequency Hz	Δr mm	R dB	$ILmax_1$ dB	$ILmax_2$ dB	ILp_{avge} dB	$ILmax_{avge}$ dB
500	12	53.4	-74.0	-76.0	67.8	68.7
	6	48.8	57.9	-61.4	58.6	60.0
	12	10.7	84.9	-84.7	84.6	84.8
	6	11.9	84.2	-84.8	84.0	84.5
250	12	56.6	-82.4	-83.7	72.7	74.8
	6	51.9	-76.0	-76.5	63.2	63.9
	12	6.0	82.8	-82.1	82.3	82.5
	6	6.1	86.6	-86.1	85.9	86.4
125	12	52.2	-85.3	-85.9	74.1	74.0
	6	50.4	-73.5	-78.6	69.2	74.0
	12	20.0	80.6	-80.0	80.3	80.3
	6	19.2	85.7	-86.7	85.6	86.2
63	12	49.0	81.5	80.7	69.5	70.7
	6	47.6	85.0	84.2	69.6	74.2
	12	26.7	84.4	73.3	80.4	81.0
	6	27.0	88.3	79.8	84.3	84.6
31.5	12	45.7	82.4	81.5	69.2	72.1
	6	45.4	82.8	82.0	69.6	72.0

TABLE 2: Test Results for Probe Reversal Measurements and Corrected Values in Accordance with Equation (10).

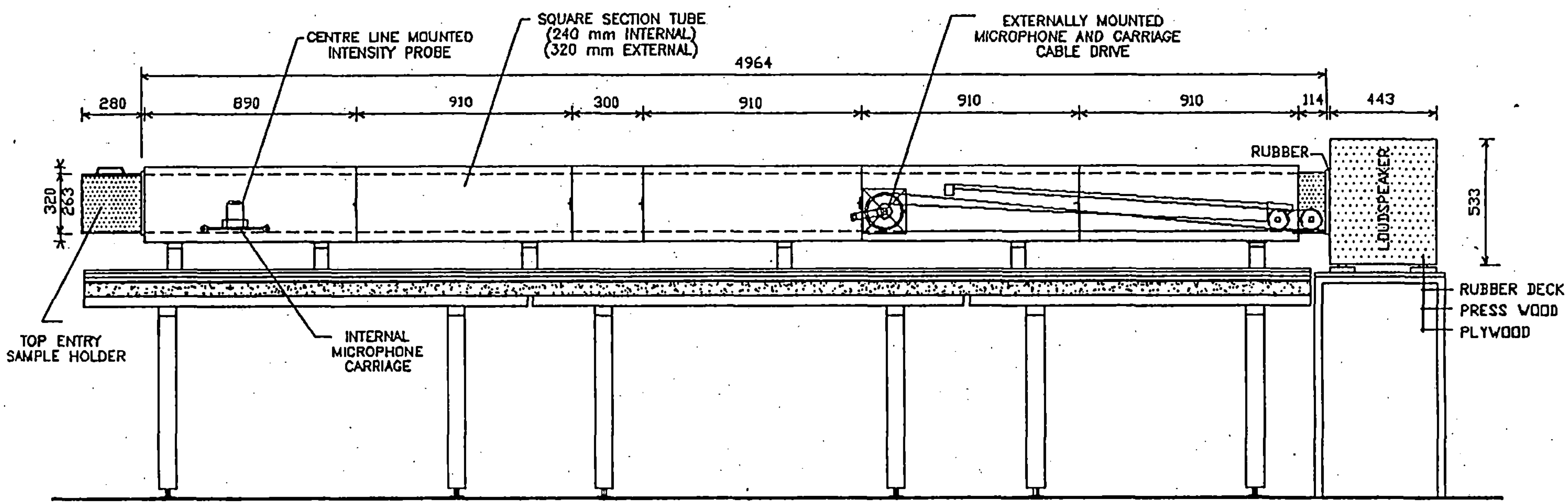


FIG.(B1) CBS LOW FREQUENCY STANDING WAVE TUBE

(ALL DIMENSIONS IN MILLIMETRES)

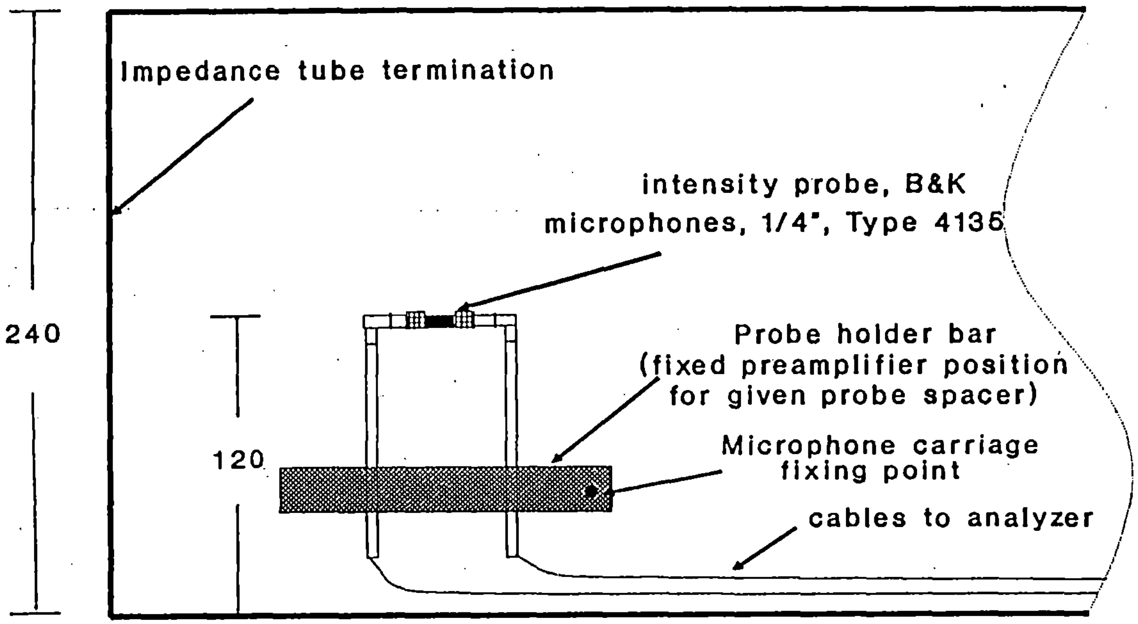


Figure B2: Mounting Configuration of the Intensity Probe inside the Impedance Tube (all dimensions in millimeters)

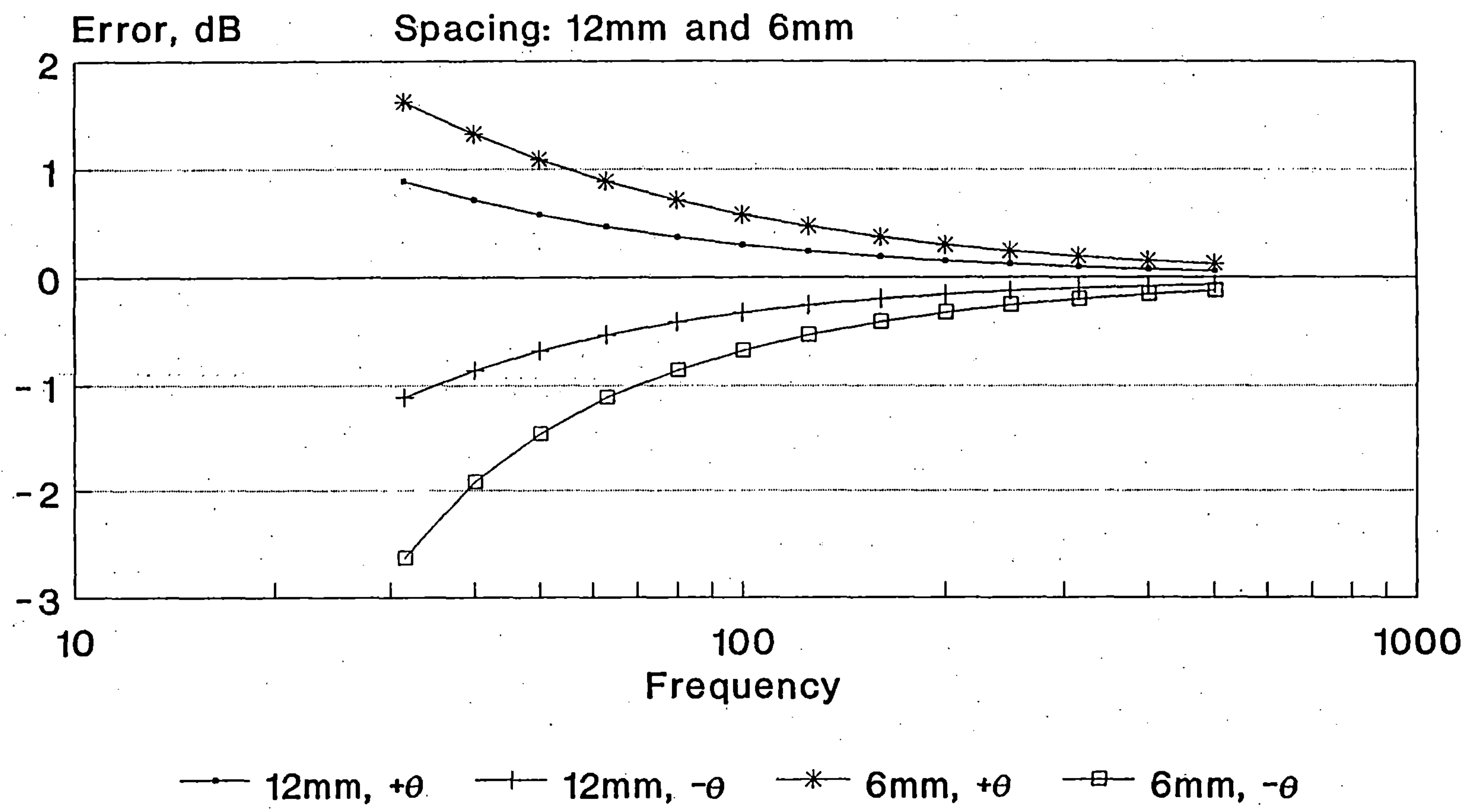


Figure B3: Predicted Intensity Error(dB) versus Frequency with Phase Error θ=0.09° in a Free-field Measurement(Equation 6).

ANNEXE C

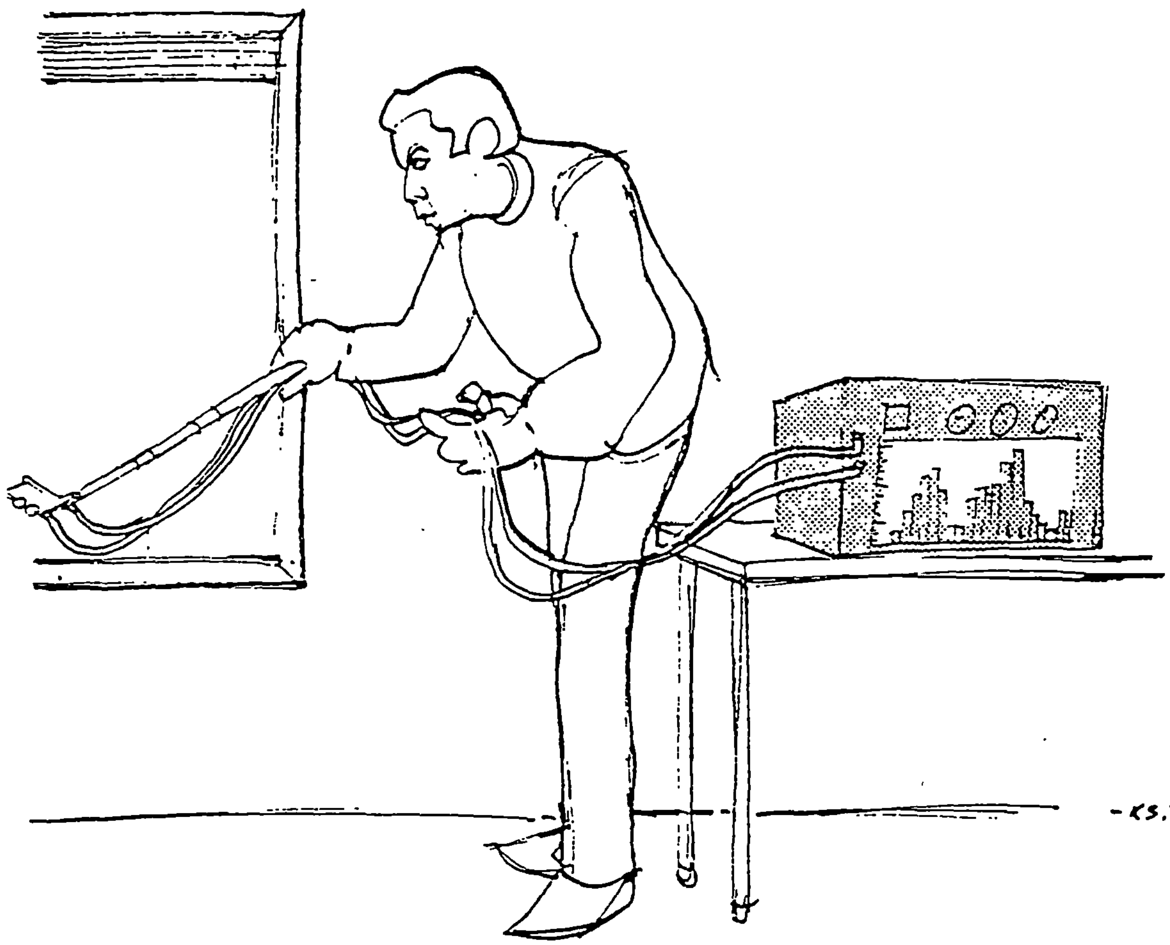
Measurements of Sound Reduction Index with Intensity Technique

Hans G. Jonasson

Appendix C

Measurements of sound reduction index with intensity technique

Nordtest Project 746-88



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7 Proposal for Nordtest method

Building elements:
Sound insulation measurements with an intensity scanning method under laboratory conditions

0 Introduction

The ISO 140 series specifies methods to measure the sound reduction index of building elements in the laboratory. This NORDTEST method is primarily aiming at being a supplement to ISO 140 to be used whenever the flanking transmission prevents accurate measurements according to that standard.

1 Scope

This NORDTEST method specifies a sound intensity scanning method to determine the sound reduction index, as defined by ISO 140/3, of a building element.

2 Field of application

2.1 General

This NORDTEST method is primarily intended to be used in the laboratory when the traditional ISO 140/3 method fails because of high flanking transmission. This may, for instance, be the case when measuring on windows, doors or heavy constructions with high sound insulation.

Relevant parts of the method can of course also be used for measurements on facade elements, suspended ceilings and small building elements according to ISO 140 Parts 5,9 and 10 respectively.

2.2 Precision

The absolute precision of this Nordtest method is not known. As the method will primarily be used in parallel with the traditional ISO 140/3 method and not as a self standing method the estimated precision in relation to this traditional method is given in Table 1.

Frequency, Hz	Average overestimate	Standard deviation
50 Hz	5 dB	6 dB
63 - 80	1,5 dB	3 dB
100 Hz	1 dB	2 dB
125 - 400 Hz	1 dB	1,5 dB
500 - 1600 Hz	0,5 dB	1,5 dB
2000 - 3150 Hz	1 dB	2 dB
4000 Hz	1,5 dB	2 dB
5000 Hz	1,5 dB	3 dB
100 - 3150 Hz, R_W	0,5 dB	1 dB

Table 1 Estimation of the precision with which this Nordtest method will reproduce the traditional ISO 140/3 method.

Note - The estimates in Table 1 are based on about 30 comparison measurements carried out in three different Scandinavian laboratories.

3 References

ISO 140/3, Acoustics - Measurement of sound insulation in buildings and of building elements - Part 3: Laboratory measurements of airborne sound insulation of building elements.

ISO 140/5, Acoustics - Measurement of sound insulation in buildings and of building elements - Part 5: Field measurements of airborne sound insulation of facade elements and facades.

ISO 140/9, Acoustics - Measurement of sound insulation in buildings and of building elements - Part 9: Laboratory measurement of room-to-room airborne sound insulation of suspended ceiling with a plenum above it.

ISO 140/10, Acoustics - Measurement of sound insulation in buildings and of building elements - Part 10: Measurement of sound insulation of small building elements.

ISO 717, Rating of sound insulation in buildings and of building elements.

ISO 3741, Acoustics - Determination of sound power levels - Precision method in a reverberation room

IEC 942, Sound calibrators

IEC 1043, Instruments for the measurement of sound intensity(at present at the stage of draft).

4 Definitions

4.1 average sound pressure level in a room, L_p:

10 times the common logarithm of the ratio of the space and time average of the sound pressure squared to the square of the reference sound pressure, the space average being taken over the entire room with the exception of those parts where the direct radiation of a sound source or the near field of the boundaries (wall, etc.) is of significant influence.

4.2 sound intensity, I:

Time averaged rate of flow of sound energy per unit area oriented normal to the local particle velocity. This is a vectorial quantity which is equal to

$$\vec{I} = 1/T \int_0^T p(t)\, \vec{u}(t)\, dt \quad W/m^2 \qquad (1)$$

where

p(t) is the instantaneous sound pressure at a point, in pascals;
$\vec{u}(t)$ is the instantaneous particle velocity at the same point, m/s;
T is the averaging time, in seconds;

4.3 normal sound intensity, $\vec{I}_n$:

Sound intensity component in the direction normal to the measurement surface. The signed magnitude of $\vec{I}_n$ is denoted by I_n and the unsigned magnitude by $|I_n|$.

4.4 normal sound intensity level, L_{In}:

Ten times the common logarithm of the ratio of the unsigned value of the normal sound intensity to the reference intensity I_0 as given by:

$$L_{In} = 10\,\lg(\,|\,\vec{I}_n\,|\,/\,I_0) \quad \text{dB} \tag{2}$$

where

$I_0 = 10^{-12}$ W/m^2

4.5 pressure-intensity indicator or field indicator, F:

The difference between time and surface averaged sound pressure level and sound intensity level on the measurement surface given by:

$$F = L_p - L_{In} \text{ dB} \tag{3}$$

4.6 residual pressure-intensity indicator, F_0:

The difference between indicated sound pressure level and sound intensity level when the probe is placed in a sound field in such an orientation that the particle velocity in the direction of the probe measurement axis is zero(e.g. in an acoustic coupler or transverse to the direction of propagation of a plane sound wave).

4.7 sound reduction index, R:

Ten times the commmon logarithm of the ratio of the sound power W_1 incident on a test specimen to the sound power W_2 transmitted through the specimen. This quantity is denoted by R:

$$R = 10\,\lg(W_1 / W_2) \text{ dB} \tag{4}$$

For the purpose of ISO 140/3 the sound reduction index is evaluated from

$$R = L_{p1} - L_{p2} + 10\,\lg(S / A) \quad \text{dB} \tag{5}$$

where
L_{p1} is the average sound pressure level in the source room;
L_{p2} is the average sound pressure level in the receiver room;
S is the area of the test specimen, which is normally equal to the free test opening;
A is the equivalent absorption area in the receiving room.

Note - The deduction from eq. (4) to eq. (5) assumes that the sound fields are perfectly diffuse including a diffuse sound incident and that the sound is transmitted only through the test specimen.

4.8 intensity sound reduction index, R_I:

This index is evaluated from eq.(5) assuming that the sound fields are not perfectly diffuse and that the average sound pressure level in a room must include corrections for a higher energy density close to the boundaries as given in ISO 3741. In that case

$$R_I = L_{p1} - 6 - L_{In} + 10\,\lg(1 + \frac{S_{b2}\,\lambda}{8\,V_2}) - 10\,\lg(S_m / S) \qquad (6)$$

where
L_{p1} is the average sound pressure level in the source room;
L_{In} is the average sound intensity level over the measurement surface in the receiver room;
S_{b2} is the area of all the boundary surfaces in the receiving room;
λ is the wavelength of the midband frequency;
V_2 is the volume of the receiving room;
S_m is the area of the measurement surface;
S is the area of the test specimen.

If the receiving room is not defined the room correction $10\,\lg(1 + \frac{S_b\,\lambda}{8\,V})$ shall be applied to the source room in stead.

Note - The room correction $10\,\lg(1 + \frac{S_{b2}\,\lambda}{8\,V_2})$ must be used in order to simulate the same result as the traditional method.

4.9 weighted intensity sound reduction index, $R_{I,w}$:

Intensity sound reduction index R_I weighted according to ISO 717/1.

5 Instrumentation

5.1 General

The intensity measuring instrumentation shall comply with IEC 1043 and be able to measure intensity levels re 10^{-12} W/m^2 in decibels in one-third octave bands. The intensity shall be measured in real time.

The residual pressure-intensity indicator F_0 of microphone probe and analyzer shall be higher than F+10 dB.

The equipment for sound pressure level measurements shall meet the requirements of ISO 140/3. In addition the microphone in the source room must give a flat frequency response in a diffuse sound field.

Note - A 13 mm pressure microphone will normally yield satisfactory frequency response.

5.2 Calibration

In a p-p-probe both microphones shall be sound pressure level calibrated before and after each measurement series using a class 2 or better acoustical calibrator in accordance with IEC Publication 942. It is also recommended to make a corresponding intensity calibration providing such a calibrator is available and the probe build up allows it.

p-u-probes should be calibrated according to the manufacturer's instructions.

6 Arrangement

6.1 Rooms

The source room shall meet the requirements of the respective standard in the ISO 140 series. The receiving room can be any room meeting the requirements of the field indicator and the background noise, see 7.4.3 and 7.4.5.

6.2 The test specimen

The test specimen shall meet the requirements of the respective ISO-standard.

6.3 Mounting conditions

Mount the test specimen according to the requirements of the respective ISO standard.

7 Test procedure

7.1 General

The average sound pressure level in the source room and the average sound intensity level on a measurement surface in the receiver room are measured. Providing the field indicator is satisfactory the intensity sound reduction index can then be calculated.

7.2 Generation of sound field in the source room

Loudspeaker, noise and loudspeaker position(s) shall meet the requirements of the respective standard in the ISO 140 series.

7.3 Measurement of average sound pressure level in the source room

This procedure shall meet the requirements of the respective standard in the ISO 140 series.

7.4 Measurements on the measurement surface in the receiving room

7.4.1 Measurement surface

The acoustical measurements in the receiving room shall take place on a measurement surface totally enclosing the test opening.

If the test specimen is mounted in a niche the measurement surface is normally the flat surface of the niche opening flush with the wall in the receiving room. If the test specimen is not mounted in a niche or if the depth of the niche is less than 0,1 m a boxshaped measurement surface has to be used.

Measurement distances shorter than 0,1 m shall be avoided because of the complicated near field of the vibrating element. In the near field the intensity tends to change sign very often. The sound field is also normally more uniform in the niche opening than inside the niche. When using box-shaped measurement surfaces measurement distances longer than 0,3 m shall be avoided.

7.4.2 Scanning procedure

The probe shall always be held normal to the measurement surface while scanning and it shall be directed to measure the positive intensity outwards from the building element under test.

The measurement surface shall be divided into one or more subareas. The scanning time of each subarea shall be proportional to the size of the area. The scanning shall be made with a steady speed between 0,1 and 0,3 m/s. The measurements may be interrupted when going from one subarea to another. Other stops shall be avoided.

Each subarea shall be scanned using parallel lines turning at each edge as shown in Fig. 1. The scanning line density depends on how irregular the sound radiation is. A large amount of irregularities such as leakages requires a higher line density. Normally the line density is chosen to be equal to the measurement distance.

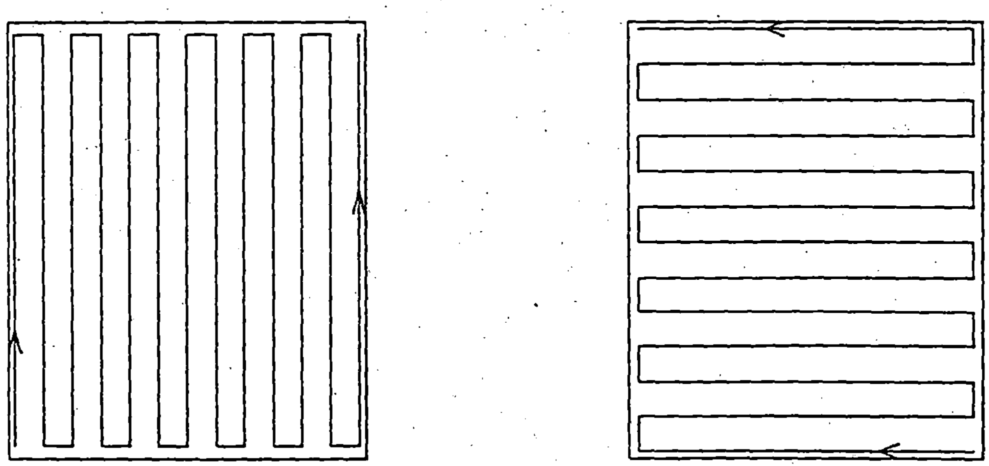


Figure 1 Scanning patterns for the two scans.

If the measurement surface is box shaped as shown in Figure 2 particular care should be given to the areas close to the intersection between the box surface and the partition wall in which the test specimen is mounted. The measurement surface must be "closed" properly, that is it is essential to scan as close as possible to the partition wall.

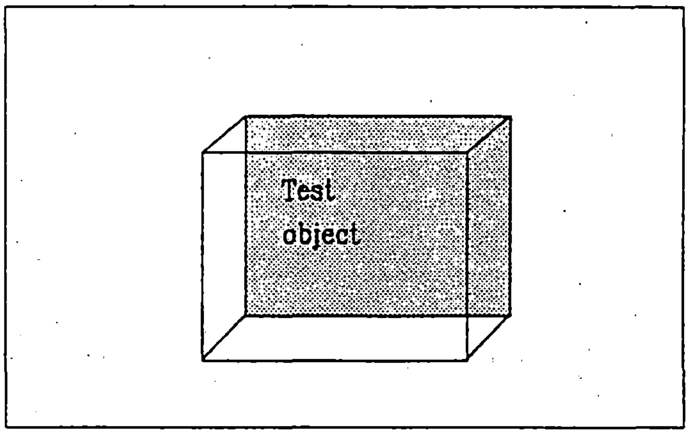


Figure 2 Box shaped scan surface.

7.4.3 Sound intensity, one scan area

During the scan the time and space integrated sound intensity level L_{In} is measured. If possible the time and space integrated sound pressure level L_p is measured simultaneously. Then the field indicator is calculated from

$$F = L_p - L_{In} \qquad (7)$$

If the measured intensity is negative or if F is not satisfactory, that is if $F>10$ dB for a sound reflecting test specimen or if $F>6$ dB for a test specimen with a sound absorbing surface in the receiver room, the measurement environment must be improved. First try to increase the measurement distance 5-10 cm. If this fails add sound absorbing material to the receiver room. The field indicator requirement is valid for each scan and each loudspeaker position. However, it is only valid for the total measurement surface and not for individual sub surfaces, see 7.4.4.

Note - As a rule of thumb $F<10$ db requires $S / A < 1{,}25$ where S is the area of the measurement surface, A is the sound absorption area of the receiving room.The more flanking transmission the more A must be increased.

Once the measurement environment is satisfactory two complete scans are carried out and the results are compared. The scanning path shall be turned 90 degrees between the two scans. If the difference between the two measurements is less than 1,0 dB for any one frequency band the measurement result is given by the arithmetic average of the two measurements. If the difference is larger than 1,0 dB the measurements are not valid and new scans must be carried out until the requirement is fulfilled. If the requirement cannot be fulfilled, scanning pattern, measurement surface or measurement environment must be changed and the measurements repeated until the requirement is fulfilled. If, despite these efforts, it turns out to be impossible to comply with these requirements, the results may still be given in the test report providing that all deviations from the requirements of this method are clearly stated

If two or more loudspeaker positions are used a pair of scans shall be carried out in each position. Each pair of scans shall comply with the requirements above. All results, including sound reduction index and field indicator, are given by the arithmetic mean of all scans carried out.

7.4.4 Sound intensity, several sub scan areas

If the measurement surface is divided into several sub areas, each with the area S_i and each being scanned individually, the total sound intensity L_{In} must be evaluated from

$$L_{In} = 10 \lg(\Sigma S_i \, 10^{LIi/10}) - 10 \lg(S) \quad (8)$$

where $S = \Sigma S_i$. If the sound intensity for a subarea has a negative direction, that is the flow of energy is in the direction towards the test object a minus-sign shall be inserted before the respective LIi in eq. (8).

To calculate the field indicator L_p and L_I are given by the following equations:

$$L_I = 10 \lg(\Sigma S_i I_i) - 10 \lg(\Sigma S_i) \quad (9)$$

$$L_p = 10 \lg(\Sigma S_i \, 10^{Lpi/10}) - 10 \lg(\Sigma S_i) \quad (10)$$

where

$I_i = 10^{LIi/10}$, energy flow out from the test surface (11)

or

$I_i = - 10^{LIi/10}$, energy flow towards the test surface (12)

For different loudspeaker positions or scans the procedures of 7.4.3 are then applicable.

7.4.5 Background noise

Both sound pressure level and sound intensity level shall be at least 10 dB higher than the background noise.

Note - These requirements may be tested by applying the following procedure:
If the field indicator F< 10 dB then lower the source level 10 dB. If F is changed less than 1 dB then the requirements are fulfilled.

7.5 Frequency range of measurements

The sound pressure level and the sound intensity level shall be measured using one-third octave band filters having at least the following centre frequencies in hertz:

100 125 160 200 250 315 400 500 630 800 1000 1250 1600 2000 2500 3150 4000 5000

If additional information in the low frequency range is required then third octave band filters with the following centre frequencies should be used:

50 63 80

8 Expression of results

For the statement of the airborne sound insulation of the test specimen, the intensity sound reduction indices shall be given at all frequencies of measurement to one decimal place in tabular form and in the form of a curve. In addition a curve of the pressure-intensity indicator shall always also be given in the graph. Any deviations from the basic requirement that the difference between two scans must not exceed 1 dB shall be clearly indicated. For graphs with the level in decibels plotted against frequency on a logarithmic scale, the following dimensions shall be used:

5 mm for a one-third octave,
20 mm for 10 dB.

9 Test report

With reference to this NORDTEST method the test report shall state:

a) name of organization that has performed the measurements;
b) date of test;
c) manufacturer's name and product specification;
d) description of test specimen;
e) description of details of the test opening;
f) volumes of both measurement rooms
g) air temperature in the measuring rooms (if relevant);
h) intensity sound reduction index and pressure-intensity indicator of test specimen as a function of frequency including a clear indication of any deviations from this method.;
i) brief description of details of procedure and equipment;
j) limit of measurement in case of background noise;
k) single number rating according to ISO 717
l) measurement distance and shape of measurement surface.

APPENDIX D

Technical Brochures: Certain
Resilient Soundproofing Systems

LIST OF SUPPLIERS OF RESILIENT MATERIALS

C_1 : 50 mm X 50 mm neoprene waffle pads, DURO 30, 14 mm thick, installed under the appliance support points

RACAN INDUSTRIES Inc.
3737 Lite Blvd.
Laval, Quebec
H7E 4X8
Telephone: (514) 324-5050

C_2 : 1000 mm X 1000 mm cork flooring, Dodge Cork, 5 mm thick
C_3 : 1000 mm X 1000 mm recycled rubber flooring, Everlast, 10 mm thick

PHOENIX, Produits pour plancher et mur
(Floor and Wall Products)
6660 Côte-de-Liesse
St-Laurent, Quebec
H4T 1E3
Telephone: (514) 942-3000

FF_1 : 1000 mm X 1000 mm floating floor, Acousti-mat
FF_2 : 1000 mm X 1000 mm floating floor, Enkasonic

NOMAT
3175 Industrial Blvd.
Laval, Quebec
Telephone: (514) 662-2604

FF_3 : 1000 mm X 1000 mm floating floor, Sonopan

Quincaillerie Val-Royal (Val-Royal Hardware)

DODGE-REGUPOL
INCORPORATED

SPECIFICATION SHEET

1. PRODUCT NAME

Everlast Tile

2. MANUFACTURER

Dodge-Regupol, Inc.
P.O. Box 989
Laurel & Manor Streets
Lancaster, Pa. 17603
Tel.: (717) 295-3400
Fax: (717) 295-3414

3. PRODUCT DESCRIPTION

Basic Use: The all rubber Everlast Tile, available in a wide range of colors, is specially designed and manufactured for weight rooms, aerobic areas, health clubs/fitness centers, ice rink walkways, locker rooms and pro shop areas. Everlast is the ideal tile floor covering for areas which require resilient shock absorbing, spike resistant and anti-skid surfacing. Everlast Tile also acts as an effective buffer against acoustic vibration.

Composition of Materials: Everlast is a non-laminated, one piece floor tile consisting of polymerically bound recycled rubber mixed with colored EPDM granules or pigmented SBR rubber. The colored rubber particles are homogeneously mixed throughout the entire tile and have no chance of wearing away.

Standard Sizes: Everlast Tile is offered in 18" x 18" (2.25 sq ft.) x 1/4" or 36" x 36" (3 sq ft.) x 3/8" thickness.

Life Expectancy: Everlast Tile, if properly installed and maintained, should endure for at least 10 years.

4. TECHNICAL DATA

Weight: Approx. 1.8 lbs/sq ft. at 1/4" thickness
Approx. 2.5 lbs/sq ft. at 3/8" thickness
Density: 67 lbs/cu ft.
Shore A Hardness ASTM Test: 60 +/-5
Compression at 100 psi: 5 to 15
Recovery: 85 min.
Electric Conductivity: 1.1 x 10.2
Chemical Resistance: Unaffected by most acids and chlorine.
Abrasion Resistance: (2100 cycl.): .5150
Coefficient of Friction: .057 dry; .072 wet
Compression Endurance: 10,000 cycles with 4-9 ton load.
Acoustic Rating: Superior
Colors: Gray, Green, Red, Brown, White, Blue and Custom Blended
New York State Fire Gas Toxicity Test:
09300-900216-4006

5. PREPARATION OF SUBFLOORS

All subfloors should be thoroughly cleaned, filled, and primed. Remove paint, varnish, oil, grease, and wax. On wood floors, use a chemical paint or varnish remover. On concrete, use solution of trisodium phosphate (or xylol for rubber based paint). For oil, grease, or wax, scrub with trisodium phosphate or machine sand. In all cases, complete with thorough washing and rinsing.

Concrete floors must be made even with latex floor fill. Fill cracks with latex crack filler. If floor is new, be sure it is completely dry (several months curing is preferred). Sweep clean.

In wood floors, fill cracks with plastic wood, sand uneven boards, renail loose boards, or replace where necessary, and prime with floor size. If needed, floor may be covered with 5-ply 5/8" plywood or hardboard, or covered with latex floor fill. Single wood floors of tongue and groove construction should be completely covered with latex floor fill or hardboard or plywood, and primed with floor size.

6. INSTALLATION

After the subfloor has been properly prepared, laying the tile floor may begin.

Mark the floor into quarters with chalk and lay tile a quarter at a time. Start from center and work to borders. Follow lines of permanent fixtures. For protective edges use bevelled edging.

Spread adhesive, being Synthetic Surfaces #78H Epoxy or equal in accordance with the instructions provided with the adhesive. Please note, Synthetic Surfaces #78H Epoxy is a non-solvent adhesive and a material safety data sheet is available from the manufacturer upon request. Press the tile firmly to adhesive and butt to adjacent tile. Roll with 100 lb. roller. Remove excess adhesive. When floor is completed, roll again.

7. MAINTENANCE

Do not wash the floor for at least 5 days after installation. Otherwise, we recommend general cleaning with a damp mop and mild detergent (with or without a germicide) on a regular basis. You may choose to apply a liquid acrylic wax but test to make sure no fading or dulling of colors occurs.

Ideally we recommend Taski Sutter's program for sealing, protecting, cleaning and resurfacing of Everlast. Their range of products includes: Taski Undercover, Brilliant and Ombra as acrylic sealers, if desired, Taski Solsan, R50 or Profi for regular cleaning, and finally Taski Wiwax for alternate cleaning days. For additional information regarding this program please call: Taski, (803) 767-0540.

CAUTION

1. Avoid abrasive alkaline or cheap cleaners.
2. Keep surface free of grit, sand and cinders.
3. Protect against indentation from furniture, by using furniture rests.
4. Finished floors should not be exposed to direct sunlight or high intensity lamps as fading may occur.

ACOUSTI-MAT™
Product Specification Sheet

1 Product

Acousti-Mat™

2 Manufacturer

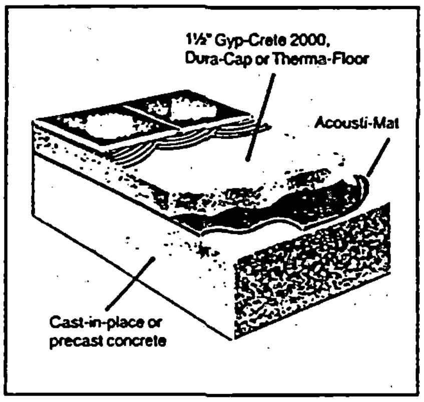
Gyp-Crete Corporation
920 Hamel Road
P.O. Box 253
Hamel, Minnesota 55340
Phone: (612) 478-6072
FAX: (612) 478-2431

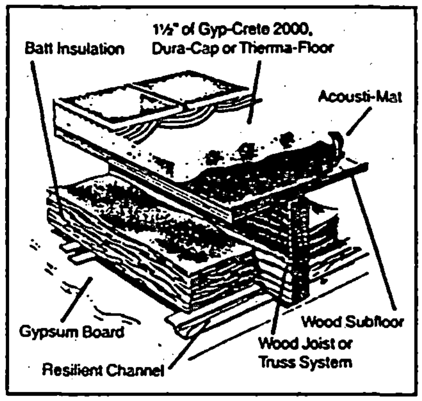
3 Description

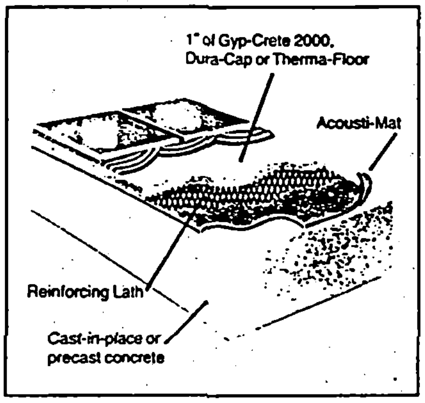
Basic Use: Acousti-Mat is a dense rubber pad that inhibits the transfer of impact noise through floor/ceiling assemblies. Acousti-Mat is installed over wood or concrete subfloors in structures that require an Impact Insulation Class (IIC) rating of not less than 50 and a Sound Transmission Class (STC) rating of not less than 50. The Acousti-Mat is covered with a high-strength Gyp-Crete Floor Underlayment which serves as the base for new floor coverings. Acousti-Mat can be used in conjunction with radiant floor heat.
Color: Blue
Packaging: 120-lb. rolls
Composition: Acousti-Mat is a complex blend of Styrene Butadiene rubber that resists deterioration and crumbling.
Limitations: (1) The structural floor should be adequate to withstand design loads with a deflection limitation of L-360. (2) Acousti-Mat should be installed after the drywall. (3) Acousti-Mat should not be installed over delaminated wood subfloors.

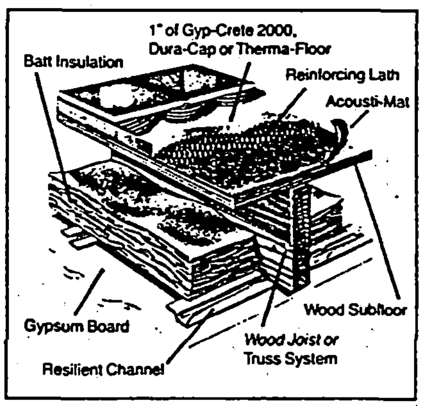
4 Physical Properties

Thickness: ¼"
Width: 54"
Length: 60'
Density: 20 lbs.per cubic foot (min.)
R-Value: 0.31









Flammability Tests: ASTM E-662 Pass (smoke chamber) ASTM E-84 Class B
Acoustical Performance: See Table 1. The sound tests F-STC (Field Sound Transmission Class) were performed in accordance with ASTM E 336 and E 413. The F-IIC (Field Impact Insulation Class) were performed in accordance with ASTM E 1007, E 989, and C 423.

5 Installation

Building interior should be enclosed and maintained at a temperature above 50°F until structure and subfloor temperatures are stabilized. Preferred wood frame construction is agency approved, ¾ inch tongue and groove veneer or nonveneer subfloors. The subfloor must be broom clean and contaminant free.

Before rolling out Acousti-Mat, the subfloor is coated with a company-approved primer.

Acousti-Mat is rolled up the walls approximately 2" to isolate sound transfer. The Acousti-Mat is taped at butt joints.

The Acousti-Mat surface is coated with a company-approved primer before the underlayment is poured.

Continuous ventilation and adequate heat should be provided to rapidly remove moisture from the area until the underlayment is dry. The general contractor must supply mechanical ventilation and heat, if necessary. Under the above conditions, 10 to 14 days are usually adequate drying time.
Testing: Compressive strength testing must be performed in accordance with modified ASTM C 472. Before independent sampling, contact the Gyp-Crete Corporation quality control department to ensure that proper procedures are followed.

ACOUSTI-MAT™
Product Specification Sheet

6 Product Support

Additional product literature and information are available upon request. Material and installation costs can be obtained from the nearest Gyp-Crete dealer. Acousti-Mat is available throughout the United States, Canada, Scandinavia, New Zealand and Australia.

7 Warranty

The Gyp-Crete Corporation guarantees that Acousti-Mat will not crumble as a result of oxidation or aging under a Gyp-Crete gypsum floor underlayment. This warranty applies only to the original installation, and only when properly installed over smooth, flat, structurally sound subfloors.

This warranty does not include any cost or expense for removal or installation of Acousti-Mat or the Gyp-Crete underlayment. Gyp-Crete Corporation assumes no liability for any incidental or consequential loss, damage or expense.

Gyp-Crete underlayments are warranted to be free from manufacturing defects. Manufacturing defects are considered to be those defects that occur due to the quality of the ingredients or from the manufacturing process itself. For complete warranty information, see your Gyp-Crete products dealer.

8 Technical Services

Technical performance verification and acoustical consulting services are available through official testing laboratories. Write for further information.

Underlayment Compressive Strengths

Gyp-Crete 2000	Dura-Cap	Therma-Floor
Typical range of 1,600 to 2,000 psi for the 1.8 mix design.	Typical range of 1,900 to 2,500 psi for the 1.8 mix design.	Typical range of 1,600 to 2,000 psi for the 1.8 mix design.
Typical range of 2,000 to 2,500 psi for the 1.4 mix design.	Typical range of 2,500 to 3,000 psi for the 1.4 mix design.	Typical range of 2,000 to 2,500 psi for the 1.4 mix design.

Sound Tests. (Table 1)

Type of Subfloor	¼" Acousti-Mat	Underlayment	Batt Insulation	Ceiling Suspended on Channel	Floor Covering	Ceiling Drywall	Rating	Test Number
Wood Joist with ¾" OSB Subfloor, 2" x 10" Joists	Yes	1½" Gyp-Crete 2000®	3½"	Yes	Vinyl	⅝"	56-FIIC	4143-90-0156.6
Wood Joist with ¾" OSB Subfloor, 2" x 10" Joists	Yes	1½" Gyp-Crete 2000	3½"	Yes	None	⅝"	56-FSTC	4143-90-0156.8
6" Cast-in-Place Concrete	No	None	None	None	None	None	36 F-IIC	4143-90-0420.4
6" Cast-in-Place Concrete	Yes	1½" Gyp-Crete 2000	None	None	Ceramic Tile	None	54 F-IIC	4143-90-0420.1
6" Cast-in-Place Concrete	Yes	1" Gyp-Crete 2000 reinforced with metal lath	None	None	Ceramic Tile	None	55 F-IIC	4143-90-0420.3
6" Cast-in-Place Concrete	Yes	1½" Gyp-Crete 2000	None	None	Vinyl	None	59 F-IIC	4143-90-0420.2

F-IIC (Field Impact Insulation Class) sound tests were performed in accordance with ASTM E-1007 and E-989. F-STC (Field Sound Transmission Class) sound tests were performed in accordance with ASTM E-336 and E-413. Actual tests are available upon request. Gyp-Crete Underlayments and Acousti-Mat are but two components of an effective sound control system. No sound control system is better than its weakest component. Care must be taken in the installation of components of construction to assure the ultimate designed acoustical performance.

ACOUSTI-MAT™

Gyp-Crete Corporation
920 Hamel Road
P.O. Box 253
Hamel, Minnesota 55340
Phone: (612) 478-6072
Fax: (612) 478-2431

For more information contact:

9/90 2211

ENKASONIC®

Sound Control Matting

SPECIFICATIONS

Description

ENKASONIC sound control matting is a composite of extruded nylon filaments forming a three-dimensional geomatrix that has a nonwoven fabric heat bonded to its upper surface. The durable yet pliable construction of ENKASONIC obstructs sound transmission by its ability to convert and store vibrational energy.

Recommended Use

For sound-rated floors requiring an Impact Insulation Class (IIC) rating of not less than 50 and a Sound Transmission Class (STC) rating of not less than 50 when used with recommended floor systems. The STC ratings are determined by ASTM Standards E90 or E336 and E413. The IIC ratings are determined by ASTM Standard E492.

Nominal Dimensions and Weights

Nominal Dimensions and Weights	Type 9110
Material	Nylon 6
Width	39 (plus 3 in. overlap)
Length	111 ft.
Area	360 ft²
Thickness	0.4 in.
Roll Diameter	27 in.
Gross Roll Weight	58 lbs.
Total Weight	22.9 oz/yd²
Matrix Weight	19.4 oz/yd²
Fabric Weight	3.5 oz/yd²

Deflection

Deflection characteristics of the most pliable of the CTI approved ENKASONIC Sound-Rated Floor Systems; Case #5—ENKASONIC overlain by Wonder-Board®.

Pressure (psf)	Deflection (In.)
100	0.028
200	0.046
300	0.061
400	0.075
500	0.087
1000	0.131
2000	0.189
4000	0.256

Flammability

Fuel Contribution	0	ASTM E-84
Smoke Density	NFPA Class A	ASTM E-84
Flame Spread	NFPA Class A	ASTM E-84

Standards

Tile Council of America Inc. RF900-89
New York City Dept. of Buildings MEA 144-89-M
Ceramic Tile Institute CTI-R 4-113-79
ICBO Report 4778

AKZO

Akzo Industrial Systems Company
P.O. Box 7249
Asheville, NC 28802
Telephone (704) 665-5050
Telefax (704) 665-5009

FICHE 1

PLANCHER ACOUSTIQUE
(brevet en instance)

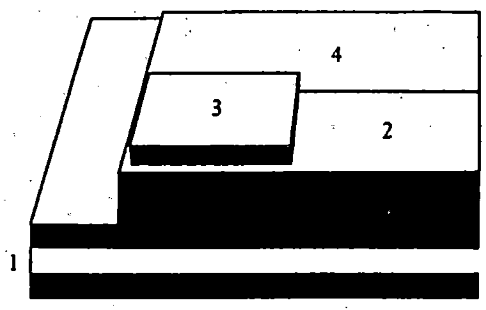
Un des problèmes majeurs dans l'insonorisation du bâtiment est, sans doute, l'isolation sonore des bruits de chocs : bruits de pas, de chaises, chocs de panneaux d'armoire, claquement des portes, etc. Aussi, est-il difficile de respecter la norme FIIC 65 en utilisant des matériaux de finition de plancher comme le bois dur, la marqueterie, le marbre, la céramique, le linoléum.

Insonorisation GLH inc. a développé, après plusieurs années de recherches en laboratoire et d'essais sur le chantier, un nouveau plancher acoustique qui permet de dépasser cette norme FIIC 65. Composé et assemblé en usine, ce nouveau plancher acoustique comprend :

- un panneau composite bois-gypse;
- des lattes de bois;
- des pastilles résilientes spéciales qui assurent l'isolation vibratoire;
- un matelas absorbant.

Plusieurs principes d'isolation sonore sont en action dans cette composition originale. Le dépassement de la norme FIIC 65 est garanti lorsque le montage est conforme aux instructions. **Insonorisation GLH inc.** peut s'occuper de son installation ou former votre équipe d'installateurs.

Ce nouveau plancher acoustique a été choisi et installé par les promoteurs des copropriétés de la Cité Bellevue (Québec), lauréats du prix Nobilis 1989, notamment pour la meilleure insonorisation (cuisine et salle d'eau surélevées sur plancher acoustique).

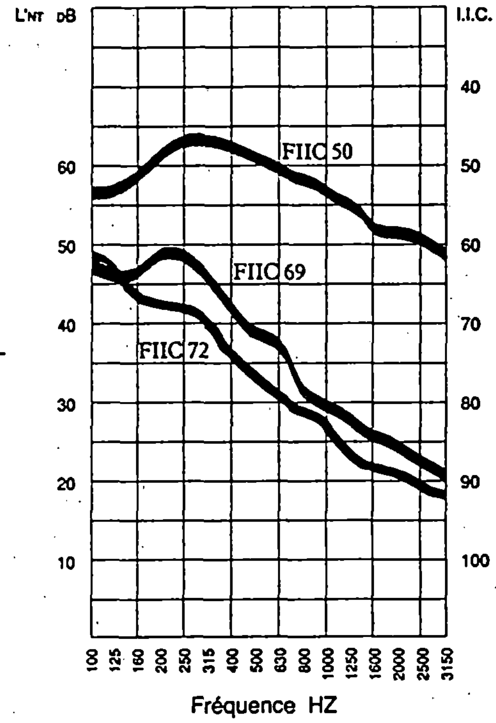


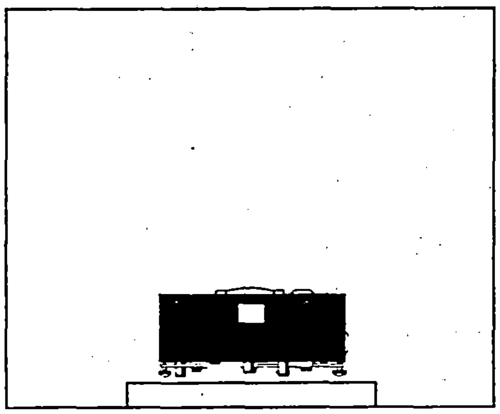
1 un panneau composite bois-gypse
2 lattes de bois
3 pastilles résilientes spéciales qui assurent l'isolation vibratoire
4 un matelas absorbant

Insonorisation GLH inc.
911, Saint-Antoine
Saint-Ferréol-les-Neiges
Québec
G0A 3R0
(418) 826-2589

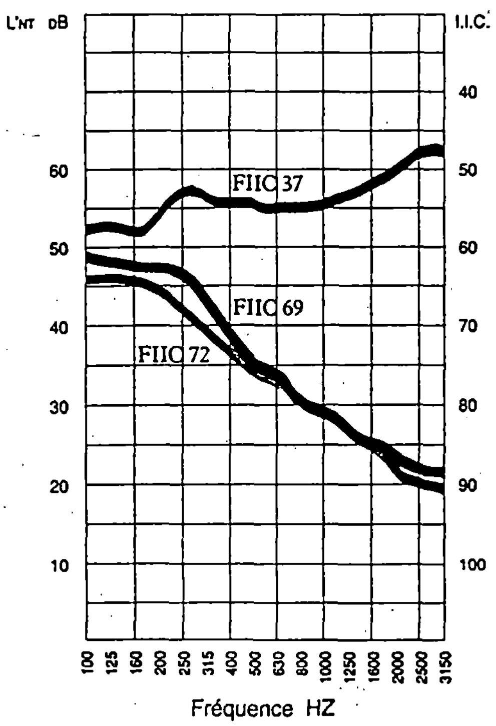
ISOLATION ACOUSTIQUE STANDARDISÉE AUX BRUITS DE CHOCS

↔	100	125	160	200	250	315	400	500	630	800	1000	1250	1600	2000	2500	3150	HZ
FIIC 50	56	56	58	61	63	63	62	61	59	58	56	55	52	52	51	49	dB
FIIC 69	48	47	47	50	50	47	43	40	39	33	31	29	27	26	24	22	dB
FIIC 72	48	48	44	43	43	42	37	35	33	30	29	26	23	23	21	20	dB





dalle de béton



↕	100	125	160	200	250	315	400	500	630	800	1000	1250	1600	2000	2500	3150	HZ
FIIC 37	54	54	53	56	59	57	57	56	56	56	57	58	59	61	64	63	dB
FIIC 69	50	49	48	48	47	43	39	36	35	31	30	27	26	24	23	22	dB
FIIC 72	47	47	46	45	43	41	38	36	34	31	30	27	26	23	22	21	dB

FIIC 37
FIIC 50 : dalle de béton (seule)
FIIC 69 : marqueterie
FIIC 72 : céramique

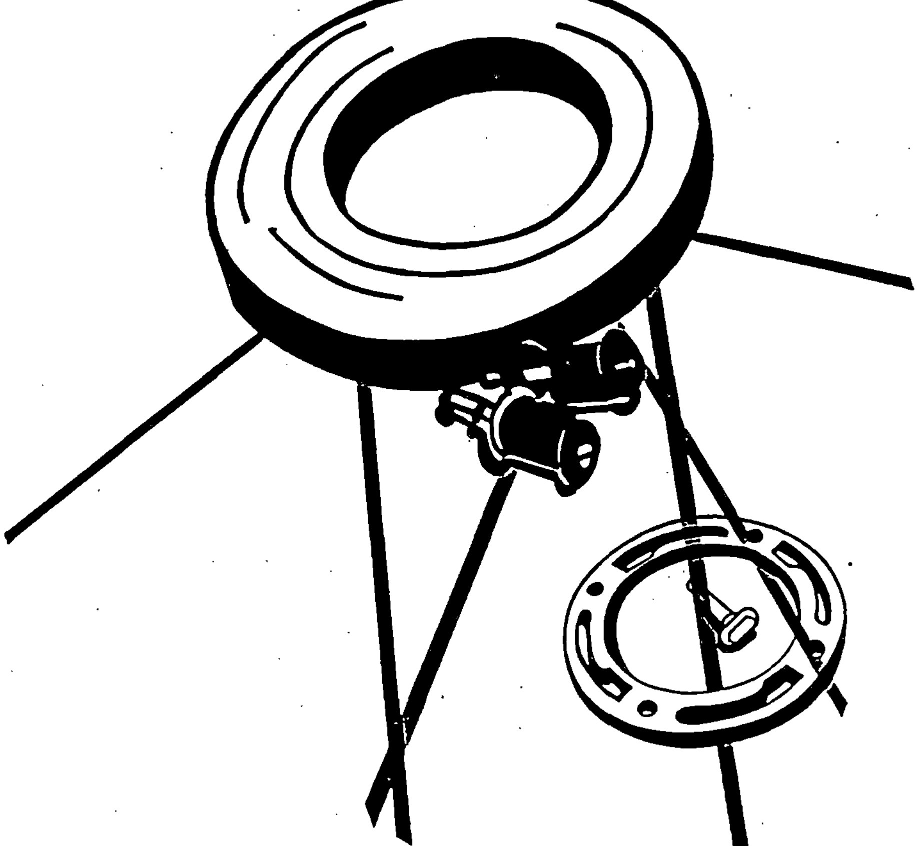
FICHE 4

PRÊT-À-MONTER POUR L'INSONORISATION DE LA CUVETTE DES CABINETS (brevet en instance)

Un des problèmes acoustiques les plus fréquents dans l'habitation est, sans contredit, le bruit transmis lors de l'utilisation des cabinets ou toilettes, plus particulièrement celui émanant de la cuvette. Le bruit est transmis par la dalle de béton aux surfaces voisines qui, en vibrant, regénèrent et amplifient ce bruit quelque peu ennuyeux, sinon agaçant.

Après plusieurs recherches et essais en laboratoire, **Insonorisation GLH inc.** a trouvé une solution pour isoler ce bruit. Offert sous forme de prêt-à-monter, l'ensemble comprend une bande résiliente autocollante et deux attaches flexibles s'adaptant à la forme et aux caractéristiques de la cuvette.

D'installation facile, l'ensemble assure la discrétion souhaitée en éliminant le bruit à la source...



Insonorisation GLH inc.
911, Saint-Antoine
Saint-Ferréol-les-Neiges
Québec
G0A 3R0
(418) 826-2589

PANNEAU ACOUSTIQUE

SONOPAN

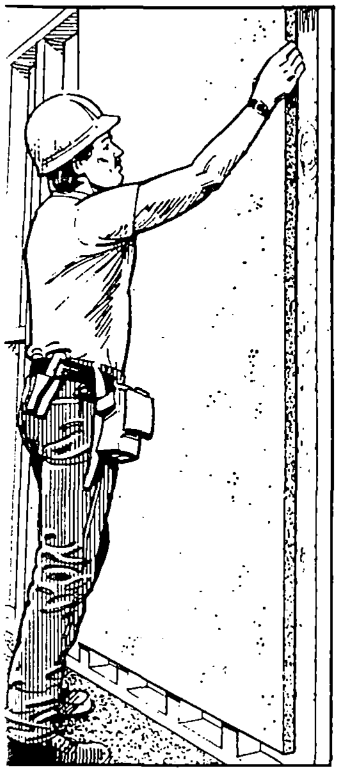
ACOUSTIC PANEL

les matériaux
Cascades
inc.

PANNEAU ACOUSTIQUE

SONOPAN

ACOUSTIC PANEL



DÉCOUVREZ SONOPAN

Parmi une foule de critères déterminants, on reconnaît d'emblée aujourd'hui que la qualité d'une habitation se traduit également par le confort et la quiétude de son environnement sonore.

Soucieux de répondre aux exigences croissantes en ce domaine, Matériaux Cascades inc., en collaboration avec le Laboratoire Acoustique Architectural 3D inc., spécialistes en acoustique du bâtiment, ont développé le nouveau panneau acoustique «SONOPAN» dont l'une des grandes propriétés est d'agir comme une véritable barrière du son dans tout type de murs ou de planchers.

UN PRODUIT INNOVATEUR

Fabriqué à base de fibres de bois et de papier recyclé, le panneau acoustique SONOPAN est un produit naturel qui ne contient aucun agent toxique. Il ne nécessite donc pas le port de gants, de masque ou de vêtements ajustés lors de la pose.

Léger et facile à manoeuvrer, le panneau SONOPAN est offert en format de 4' X 4' (plafonds), 4' X 8' et 4' X 9' (murs et planchers). D'une épaisseur de 3/4", il a une densité moyenne de 15 lbs/pi.cu.

UNE EFFICACITÉ MAXIMALE

Fruit de longues recherches en usine et en laboratoire, le panneau acoustique SONOPAN réunit plusieurs caractéristiques qui lui assurent une efficacité maximale.

- **Un procédé unique de gonflage de la fibre de bois permet d'augmenter de façon notable le coefficient d'absorption sonore.**
- **Une perforation calculée de chacun des panneaux optimise la surface d'absorption du son.**
- **Doté d'une structure fibreuse rigide, le panneau acoustique SONOPAN ne s'affaisse pas et augmente donc l'étanchéité sonore pour tout type de cloisonnement.**
- **D'installation facile et rapide, il est d'une grande maniabilité. Il se coupe et se scie facilement, se cloue ou se visse aisément. Ce qui se traduit par une économie de temps et d'énergie sur le chantier.**
- **S'adapte à tous les types de systèmes de murs et de planchers en structure de bois, de métal ou de béton.**

DISCOVER SONOPAN

Today the comfort of a home is determined by many factors and one of the most important is the quality of its acoustic environment.

Attentive to the growing needs in this area, Matériaux Cascades Inc., in collaboration with the Laboratoire Acoustique Architectural 3D Inc., specialists in building acoustics, have developed the new acoustic panel "SONOPAN". The panel's most important property is its ability to act as a sound barrier in all types of walls and flooring.

AN INNOVATIVE PRODUCT

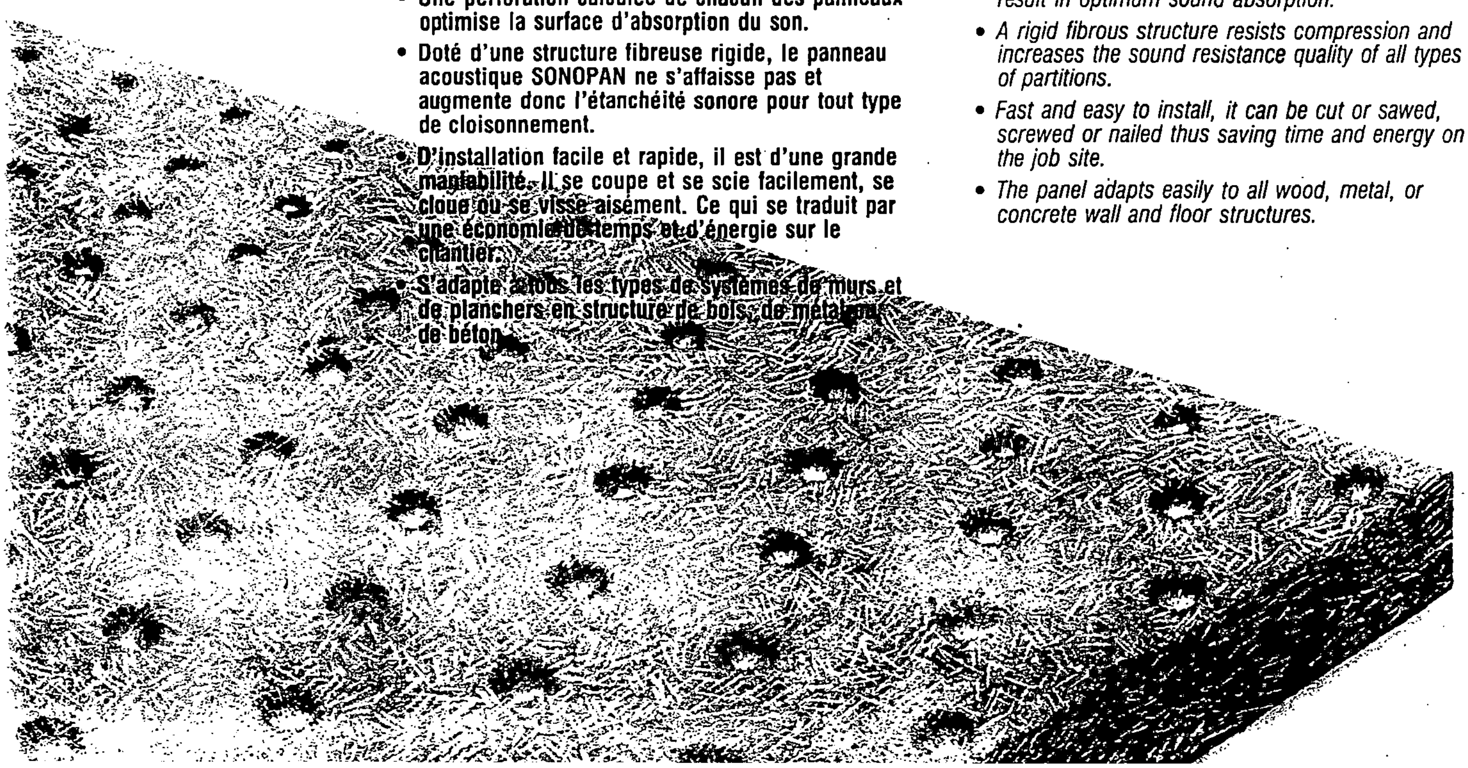
The SONOPAN acoustic panel is a natural product manufactured from wood fibres and recycled paper. Gloves, masks, or other protective clothing are not necessary for installation as the panel contains no toxic agents.

Light and easy to handle, the SONOPAN panel is available in 4' X 4' (ceilings), 4' X 8' and 4' X 9' (walls and floors) formats. Each panel has a thickness of 3/4" with an average density of 15 lbs./cu.ft.

MAXIMUM EFFICIENCY

The result of extensive laboratory and factory research, the SONOPAN acoustic panel combines many important characteristics to ensure maximum efficiency.

- *A unique procedure used to expand the wood fibres significantly increases sound absorption.*
- *Specifically calculated perforations in each panel result in optimum sound absorption.*
- *A rigid fibrous structure resists compression and increases the sound resistance quality of all types of partitions.*
- *Fast and easy to install, it can be cut or sawed, screwed or nailed thus saving time and energy on the job site.*
- *The panel adapts easily to all wood, metal, or concrete wall and floor structures.*



DEVIS D'INSTALLATION

[illegible] le panneau acoustique SONOPAN absorbera avec une efficacité maximale l'énergie sonore environnante. Dans une composition de mur, le panneau doit être installé de manière à exposer sa surface perforée au volume d'air de l'assemblage. Il est fixé de façon similaire à une planche de gypse, soit une vis aux 18" au périmètre et de 6 à 8 vis au centre.

Il en va ainsi dans une composition de plancher où le panneau SONOPAN peut être installé au-dessus des solives, les perforations étant ainsi dirigées vers le bas. Placé en-dessous des solives, les perforations seront alors dirigées vers le haut, en contact avec l'air de la cloison. (Voir le schéma 1 ci-dessous)

Le schéma 2 permet de mieux visualiser les compositions de murs simples et de murs plus complexes.

Un côté identifié aux 16" c/c et 24" c/c permet une localisation facile et rapide des solives et colombages lors de son installation. Poser un pare-feu temporaire lors de la soudure de la tuyauterie.

N. B.: Le panneau SONOPAN est sujet à l'approbation d'un ingénieur en structure pour l'installation du produit sous les murs porteurs.

INSTALLATION SPECIFICATIONS

The perforated surface of the SONOPAN acoustic panel provides maximum absorption of airborne sounds. When constructing a wall, the panel must be installed with the perforated surface facing the air space in the assembly. Like gypsum board, it is installed with screws every 18" around the perimeter and 6 to 8 screws along the centre of the panel.

This principle should be used in the construction of floors, where the SONOPAN panel is installed above the joists, the perforated surface will face downward. When installed below the joists, the perforations should be facing upward. (See diagram 1 below)

Diagram 2 better illustrates the construction of standard and more complex walls using the SONOPAN acoustic panel.

One side of the panel is marked every 16" and 24" on centre, which allows easy location of joists and studs during installation. Install temporary fire guard when soldering pipes.

N. B.: The use of the SONOPAN panel under load-bearing walls must be approved by a structural engineer.

[illegible]

[illegible]

Note:
Les indices présentés dans ce document proviennent de résultats de tests effectués par le CNRC et le LABORATOIRE ACOUSTIQUE ARCHITECTURAL 3D INC.

STC AND IIC RATINGS

Sound transmission class (STC) and impact insulation class (IIC) are used to classify the average noise reduction in decibels for sounds like the human voice passing through a wall or floor. The higher the rating, the more the noise is reduced.

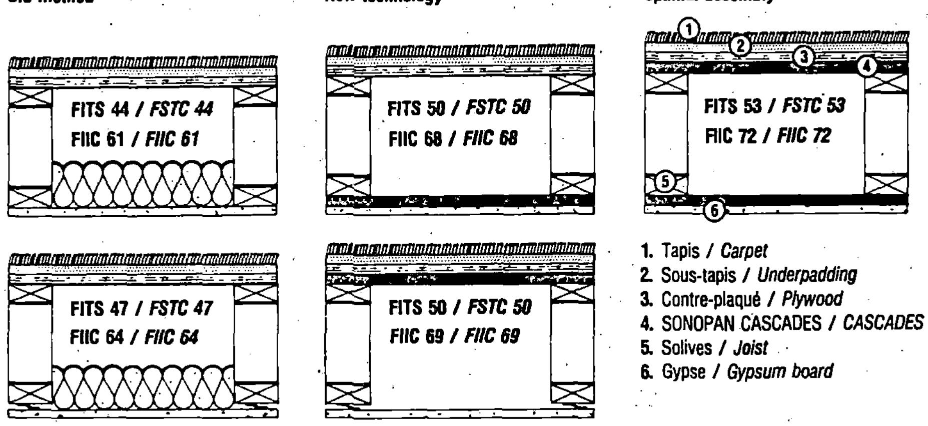
A rating preceded by the letter "F" indicates that the measurement was made in the field, i.e. in a building, and not in a laboratory.

Examples:
*Imagine a **loud conversation** on one side of a dividing wall. The following ratings indicate the sound perceived on the other side.*

FSTC 45 Conversation intelligible
FSTC 50 Conversation unintelligible
FSTC 55 Conversation inaudible

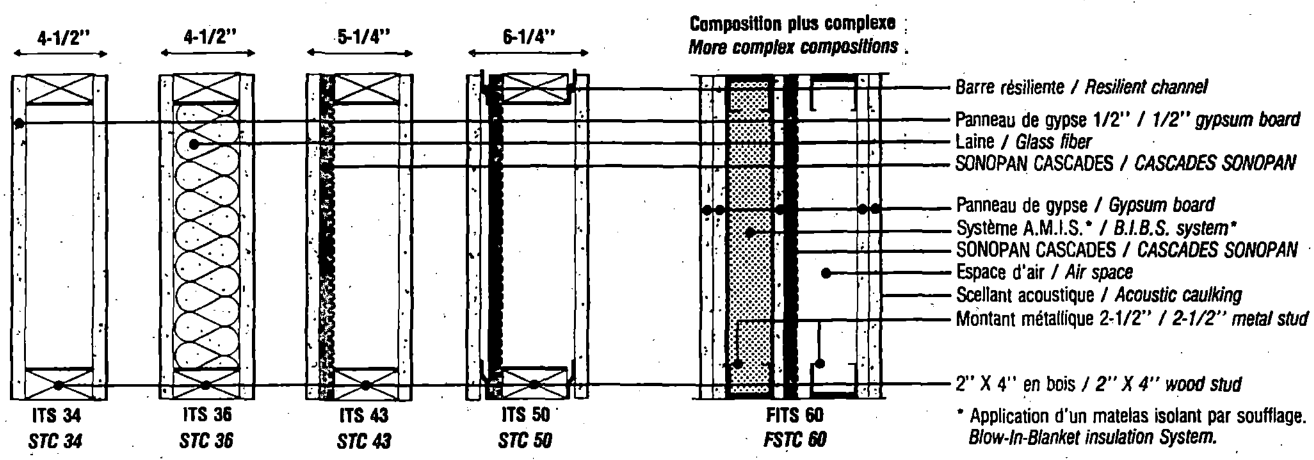
Note:
The ratings in this document are taken from the results of tests conducted by the CNRC and the LABORATOIRE ACOUSTIQUE ARCHITECTURAL 3D INC.

SCHÉMA 1 - COMPOSITIONS DE PLANCHERS / *DIAGRAM 1 - COMPOSITION OF FLOOR STRUCTURES*



1. Tapis / *Carpet*
2. Sous-tapis / *Underpadding*
3. Contre-plaqué / *Plywood*
4. SONOPAN CASCADES / *CASCADES SONOPAN*
5. Solives / *Joist*
6. Gypse / *Gypsum board*

SCHÉMA 2 - COMPOSITIONS DE MURS / *DIAGRAM 2 - COMPOSITION OF WALL STRUCTURES*

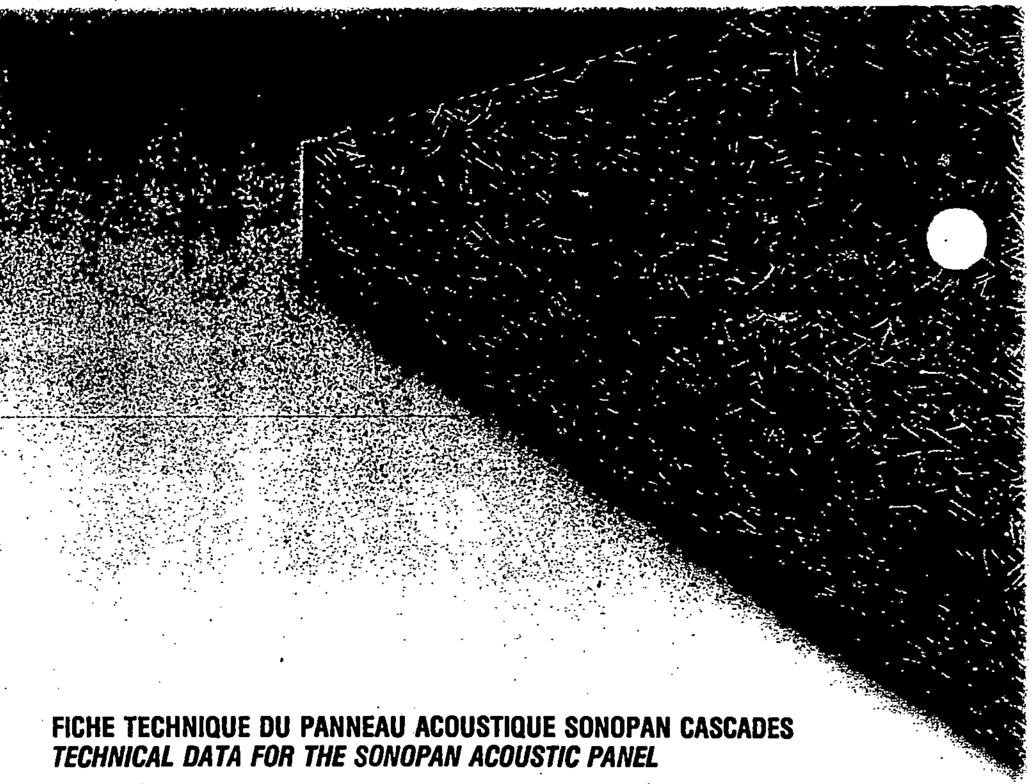


* Application d'un matelas isolant par soufflage.
Blow-In-Blanket insulation System.

PANNEAU ACOUSTIQUE

SONOPAN

ACOUSTIC PANEL



Normes utilisées pour réaliser les tests acoustiques:
FITS
ASTM E-336-84, E-413-87
FIIC
ASTM E-989-89, E-1007-89

Prenez note:
Les indices de transmission du son et d'isolement au bruit de chocs normalisés ont été établis dans des environnements contrôlés. La présence de certaines fuites acoustiques (aux jonctions des murs, planchers et plafonds) peut faire varier de façon notable les indices établis. Pour s'assurer des rendements souhaités, nous mettons à votre disposition le support technique de nos spécialistes en acoustique.

Specifications used in acoustic testing:
FSTC
ASTM E-336-84, E-413-87
FIIC
ASTM E-989-89, E-1007-89

Important:
The sound transmission class (STC) and impact insulation class (IIC) ratings are established in controlled environments. Sound leakage (at junction of walls, floors, and ceilings) may significantly alter these ratings. Our acoustic specialists are available to provide technical assistance to ensure best results.

TESTS DE COMPRESSION**
*COMPRESSION TESTS***

Pourcentage de compression *Percentage of compression* **(%)**	**Force exercée** *Pressure applied* **(lb/po²) / (lb./sq.in.)**
5	7.7
10	20.2
15	39.0
20	63.6
25	95.8
30	135.6
35	184.3
40	246.7

Recouvrement après deux heures: 91%.
Recovery after two hours: 91%.

** En concordance avec la norme ASTM D-3501.
In accordance with ASTM D-3501 specifications.

FICHE TECHNIQUE DU PANNEAU ACOUSTIQUE SONOPAN CASCADES
TECHNICAL DATA FOR THE SONOPAN ACOUSTIC PANEL

Épaisseur / *Thickness*	[illegible]
Absorption d'eau / *Water absorption*	7% à 10% (max.) / *7% to 10% (max.)*
Conductivité thermique / *Thermal conductivity*	.055 (W/M°K)
Facteur R* (3/4") / *R Factor* (3/4")*	2.1
Densité / *Density**	15 lbs/pi.cu. / *15 lbs./cu.ft.*
Couleur / *Colour*	Vert / *Green*

* En concordance avec la norme ASTM C-209.
In accordance with ASTM C-209 specifications.

PANNEAUX SONOPAN / CHARGEMENT DE CAMION
SONOPAN PANELS / TRUCKLOAD

Format *Format*	**Feuilles/palette** *Sheets/pallet*	**Palettes/camion** *Pallet/truck*	**Surface totale** *Total surface*
4' X 4'	65	44	45 760 pi²/camion / *45,760 sq.ft./truck*
4' X 8'	65	22	45 760 pi²/camion / *45,760 sq.ft./truck*
4' X 9'	65	20	46 800 pi²/camion / *46,800 sq.ft./truck*

En instance de brevet.
Patent pending.

RENSEIGNEMENTS

Au delà des excellents produits qu'elle fabrique, Matériaux Cascades inc. met à votre disposition son équipe de spécialistes afin de vous aider à sélectionner les produits les mieux adaptés à votre budget.

Pour plus d'information, n'hésitez pas à communiquer avec le service des ventes de Matériaux Cascades inc.

INFORMATION

In addition to its excellent products, Matériaux Cascades Inc. has a team of specialists available to help you choose the products best adapted to your needs.

For more information, please contact the Matériaux Cascades Inc. sales office.

les matériaux Cascades inc.

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Communigraph Litho Canada

APPENDIX E

Test Results
Measurement Series #1

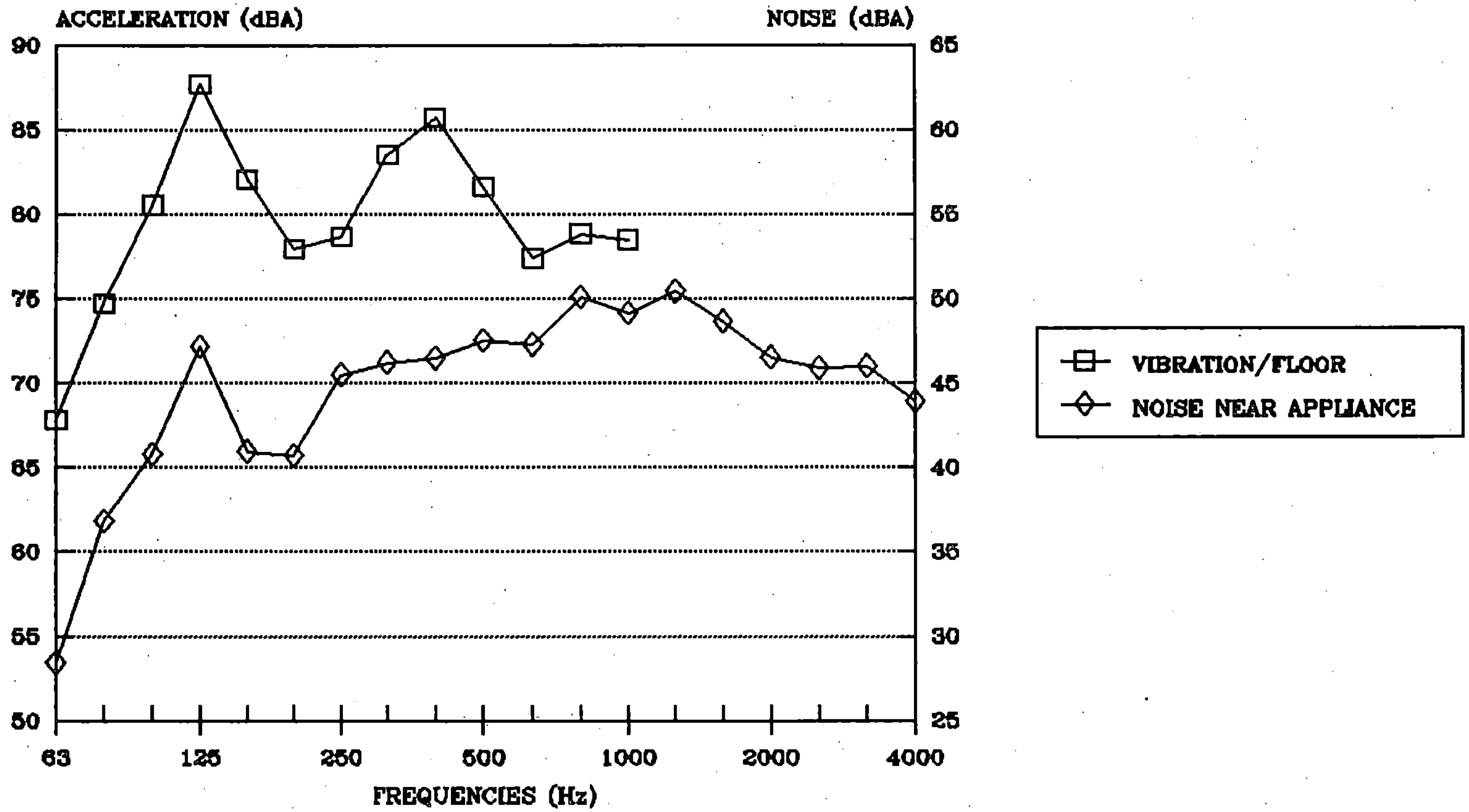

FIG. E1 – WASHING MACHINE TEST WITHOUT ANY SOUNDPROOFING SYSTEM (SERIES 1)

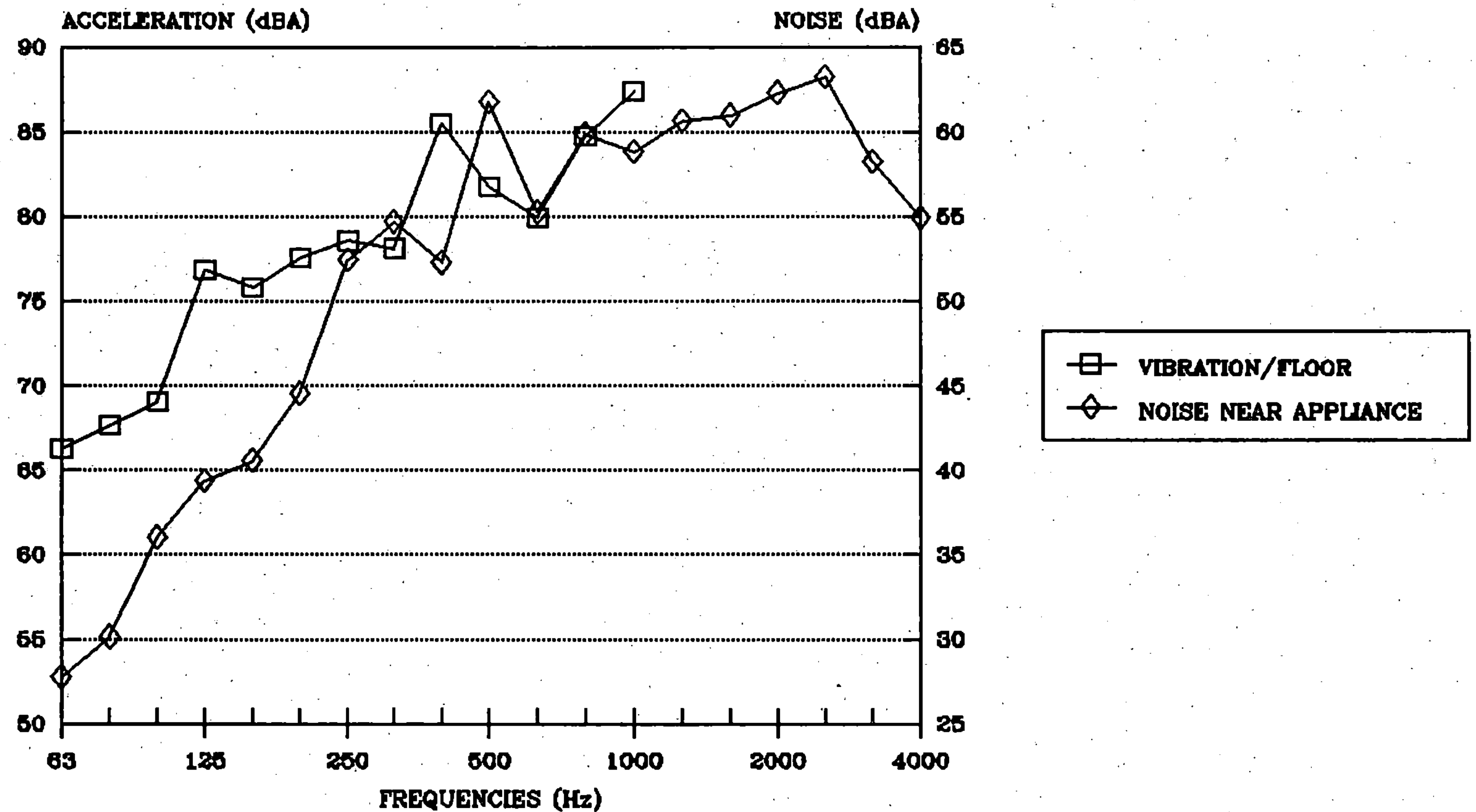

FIG. E2 – DRYER TEST WITHOUT ANY SOUNDPROOFING SYSTEM (SERIES 1)

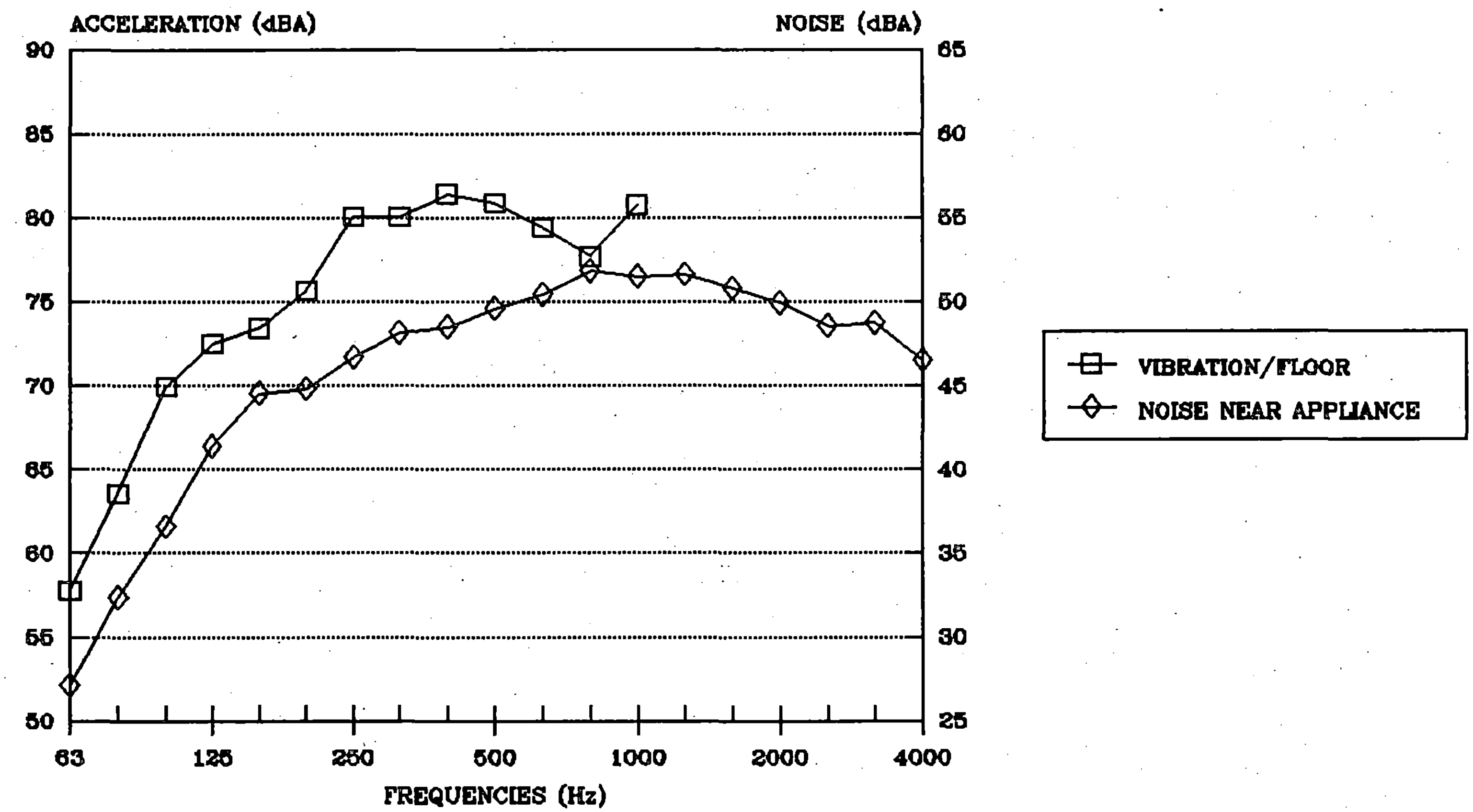

FIG. E3 – DISHWASHER TEST WITHOUT ANY SOUNDPROOFING SYSTEM (SERIES 1)

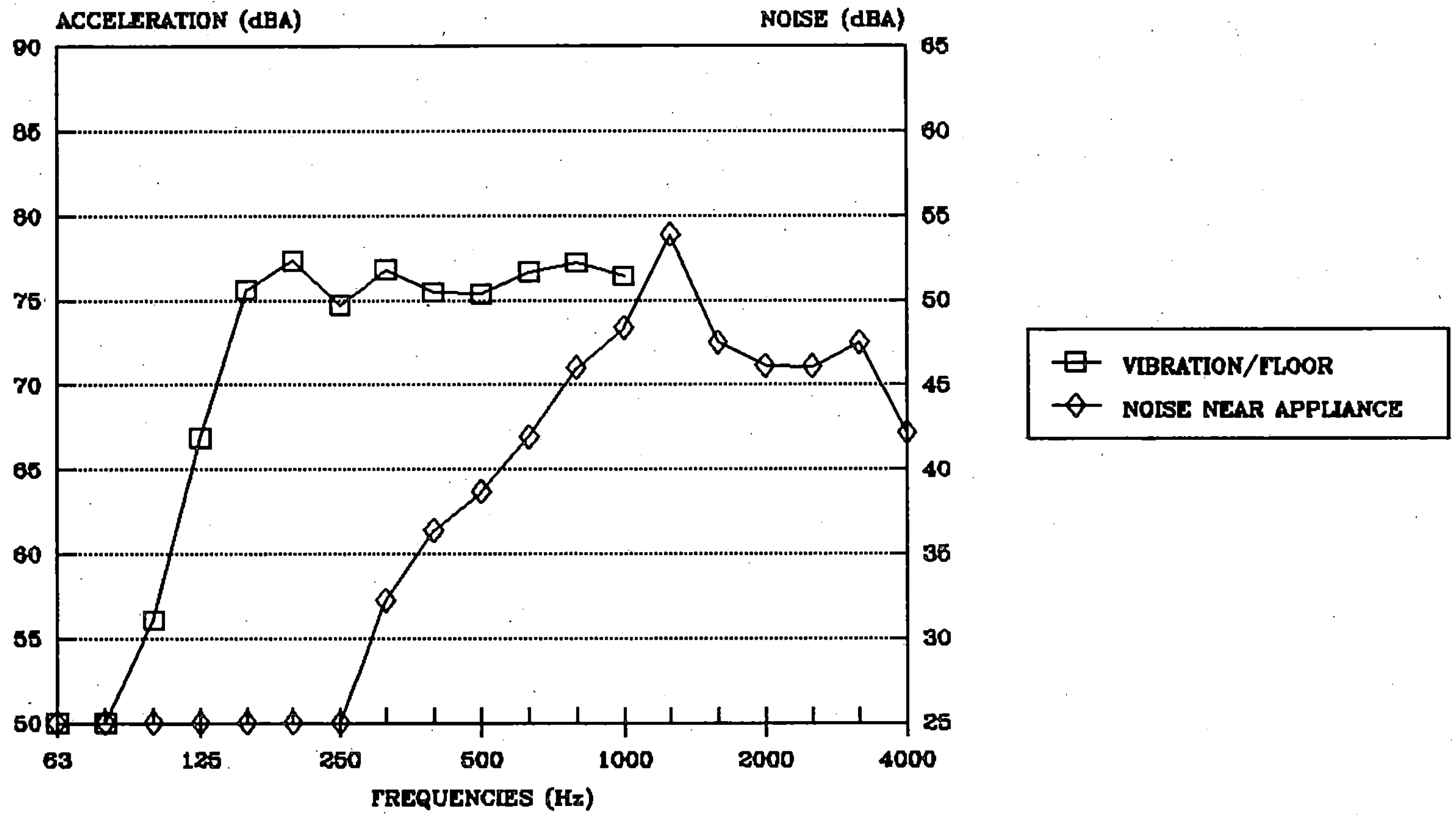

FIG. E4 – BATHTUB TEST
WITHOUT ANY SOUNDPROOFING SYSTEM
(SERIES 1)

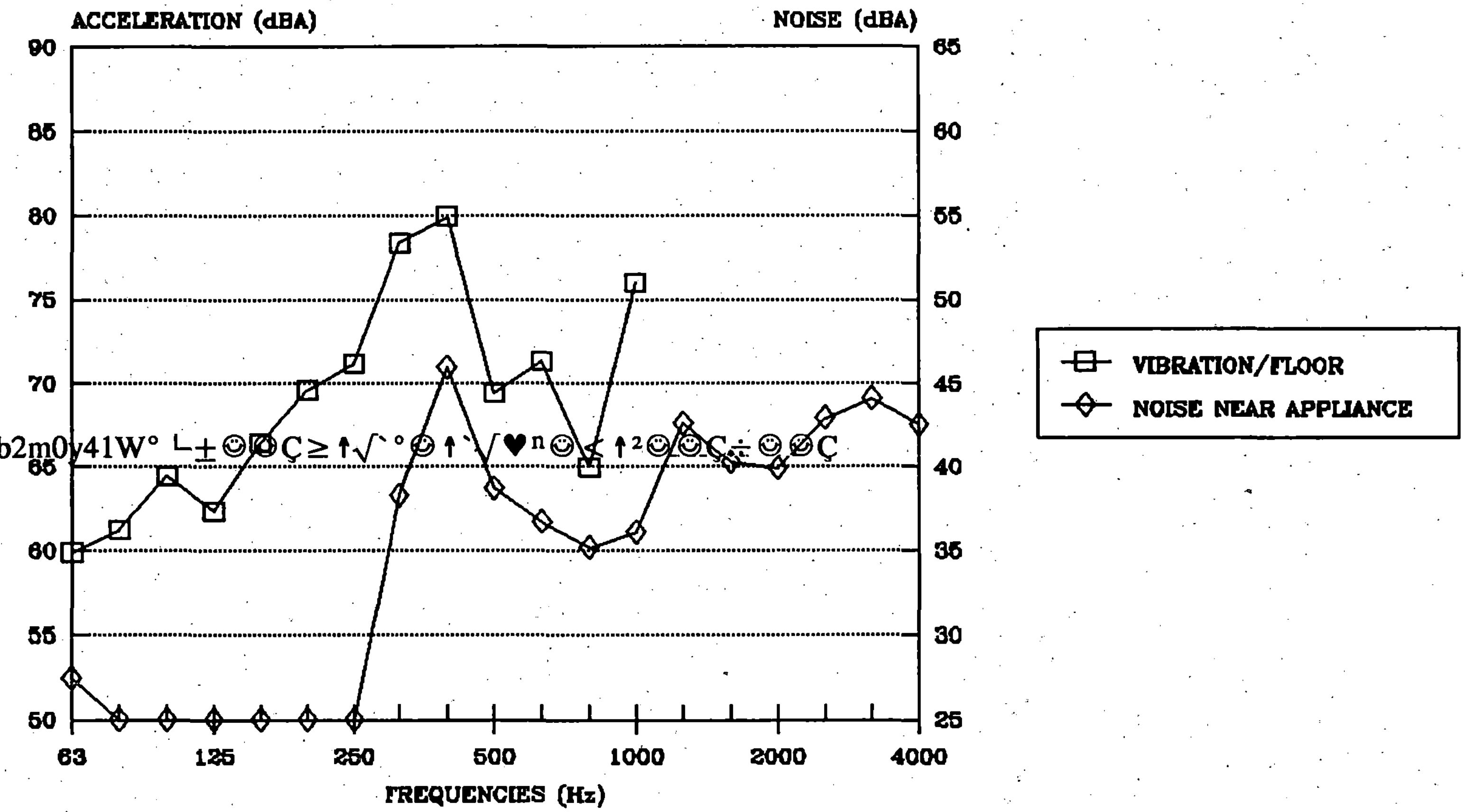

FIG. E5 – TOILET TEST
WITHOUT ANY SOUNDPROOFING SYSTEM
(SERIES 1)

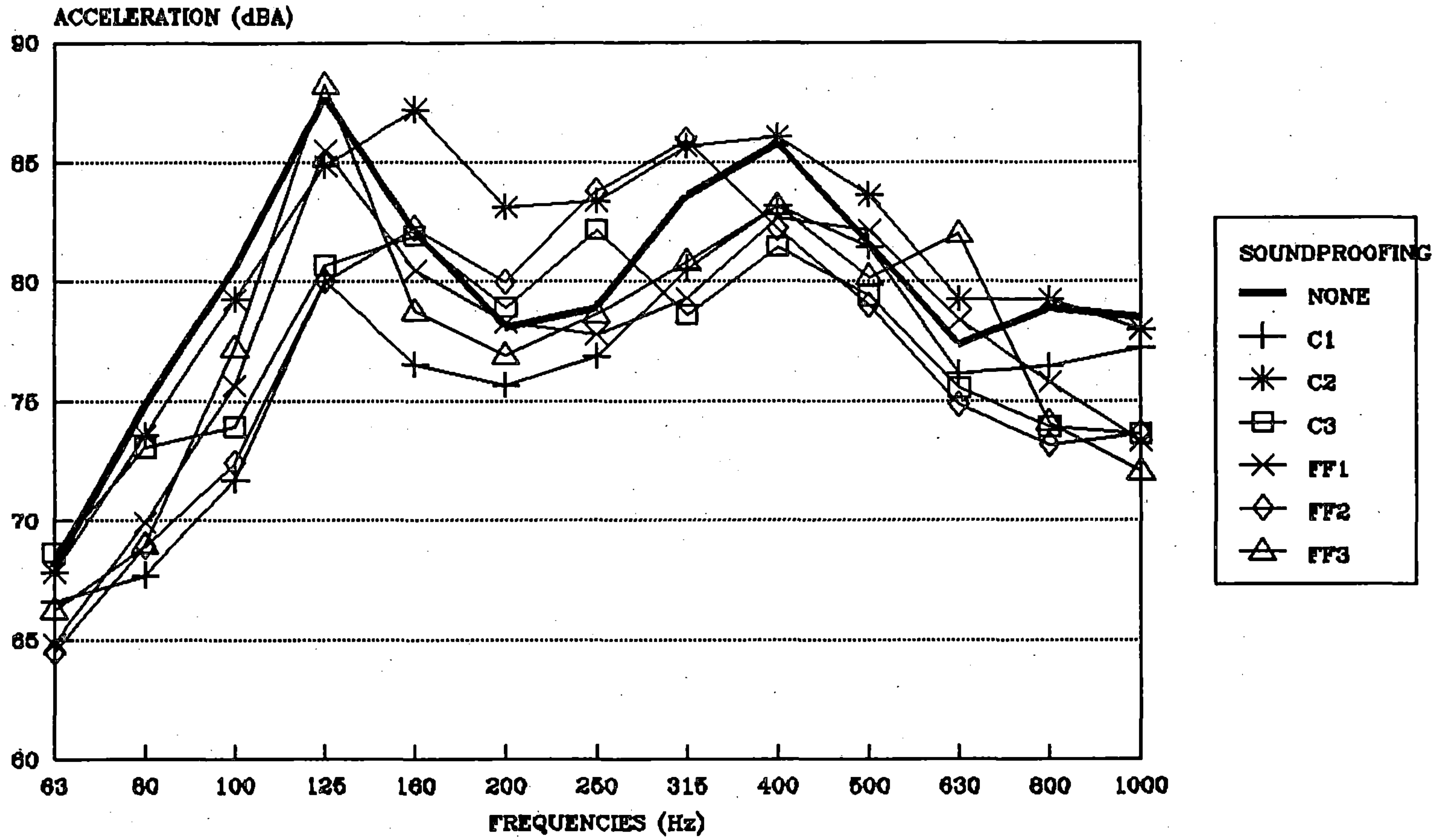

FIG. E6 – WASHING MACHINE TESTS
(SERIES 1)

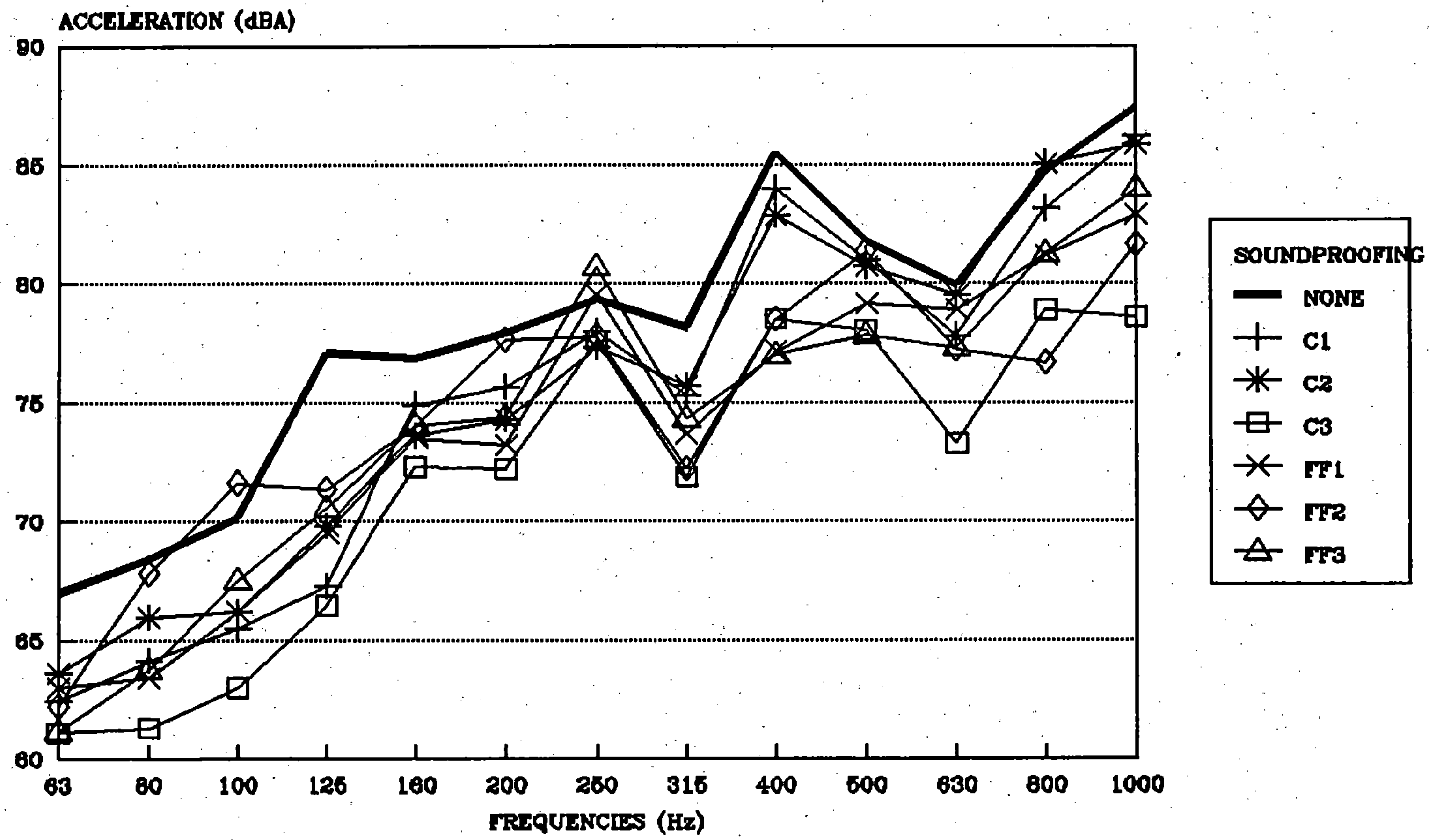

FIG. E7 – DRYER TESTS
(SERIES 1)

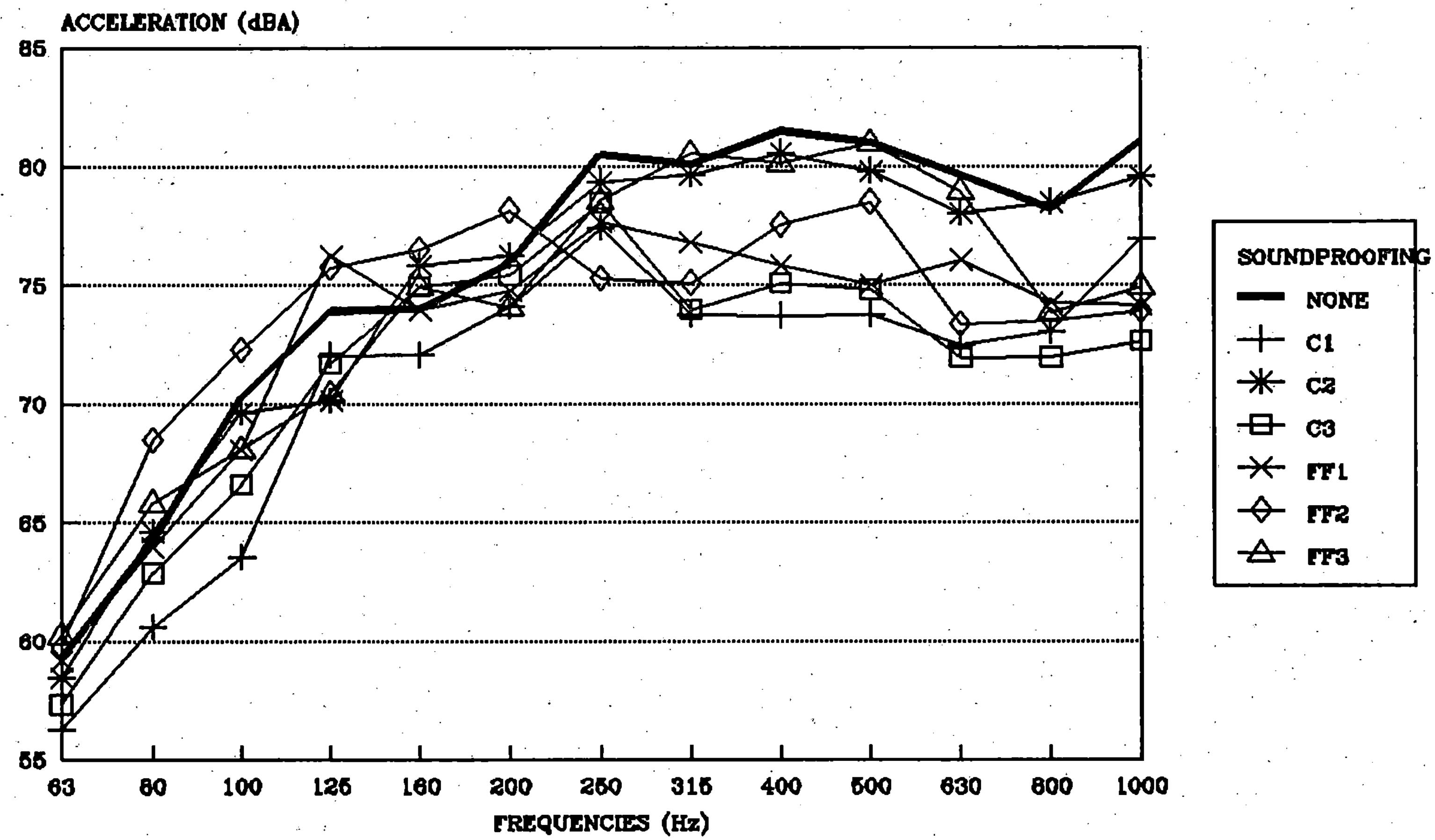

FIG. E8 – DISHWASHER TESTS
(SERIES 1)

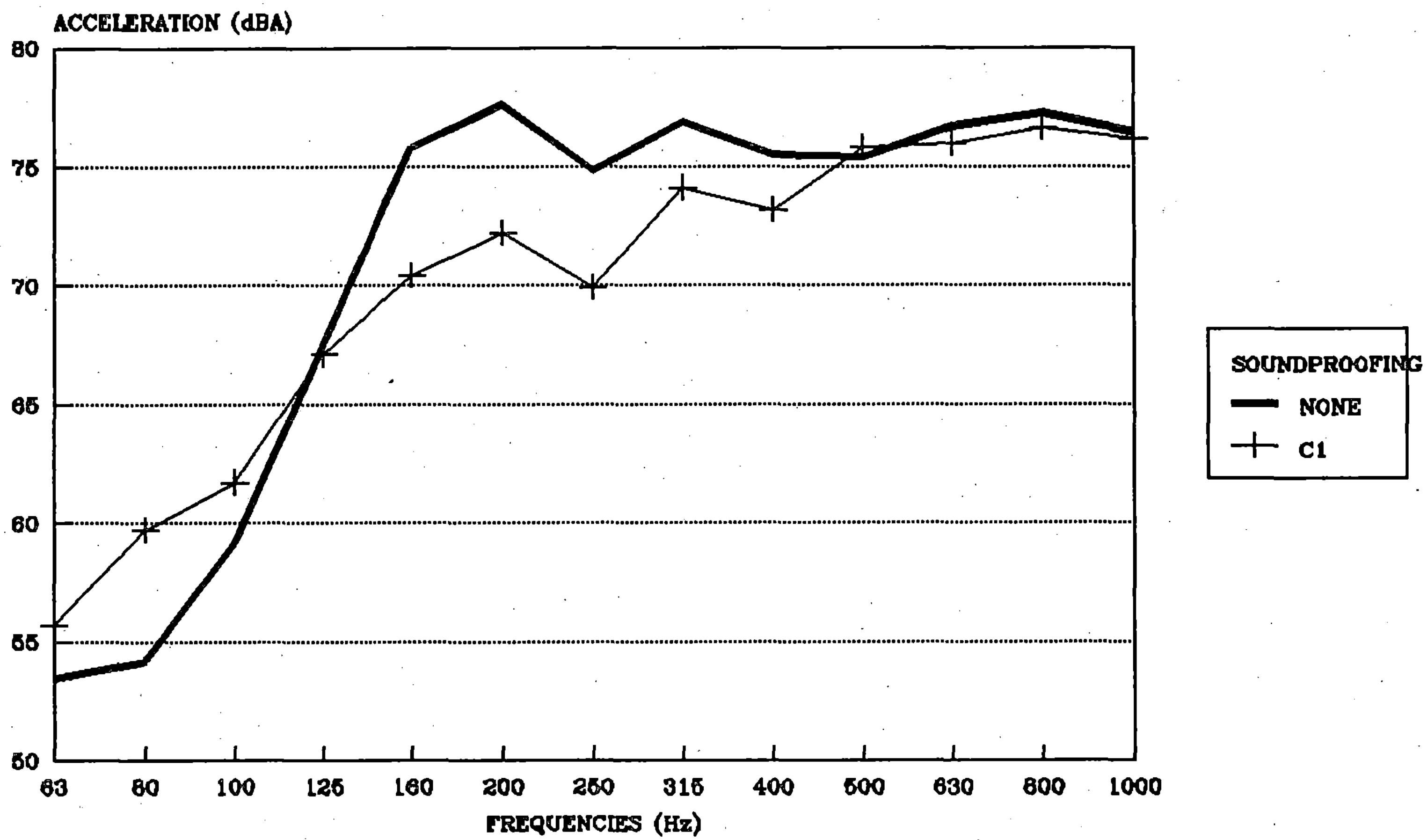

FIG. E9 – BATHTUB TESTS
(SERIES 1)

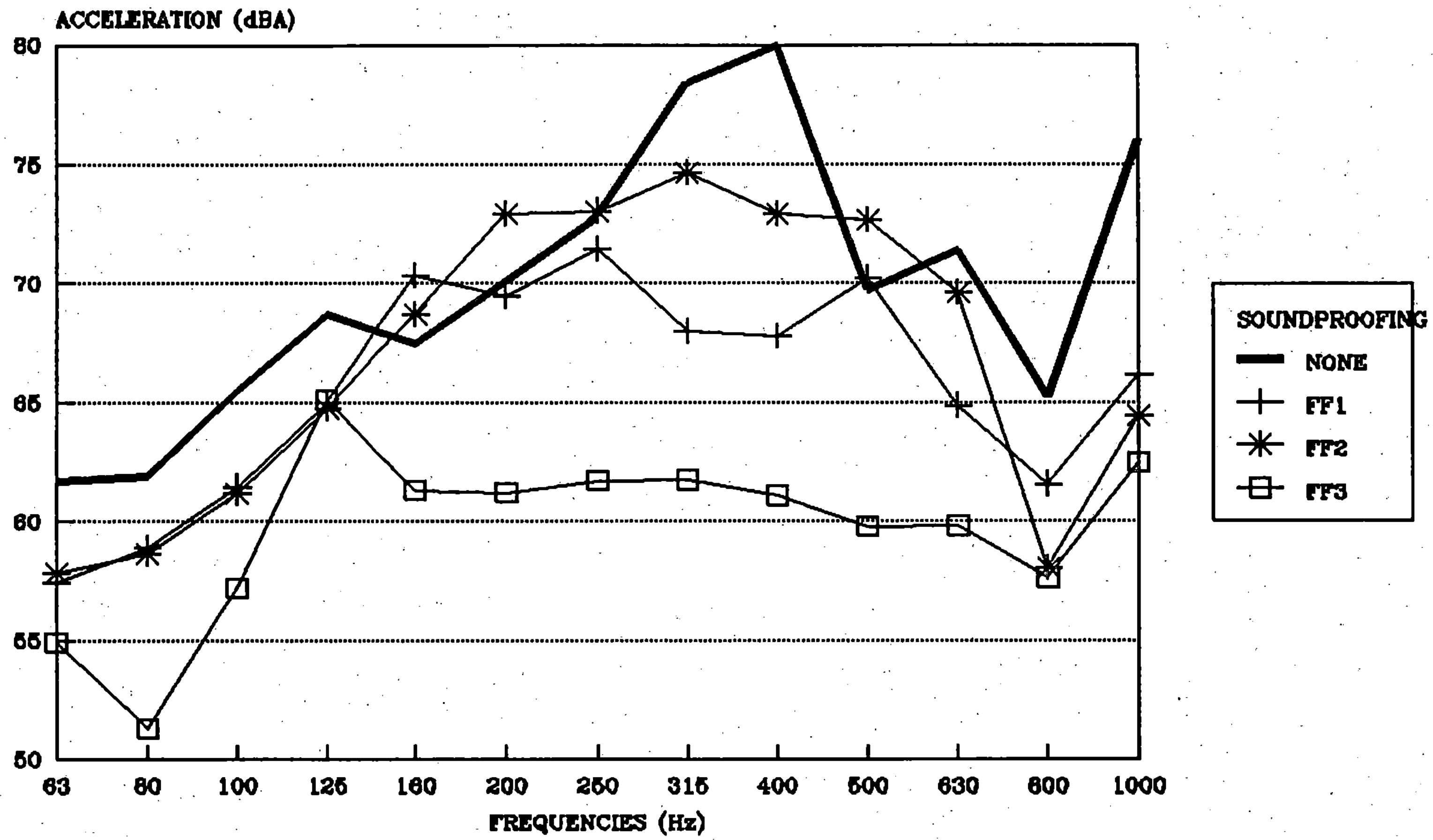

FIG. E10 – TOILET TESTS
(SERIES 1)

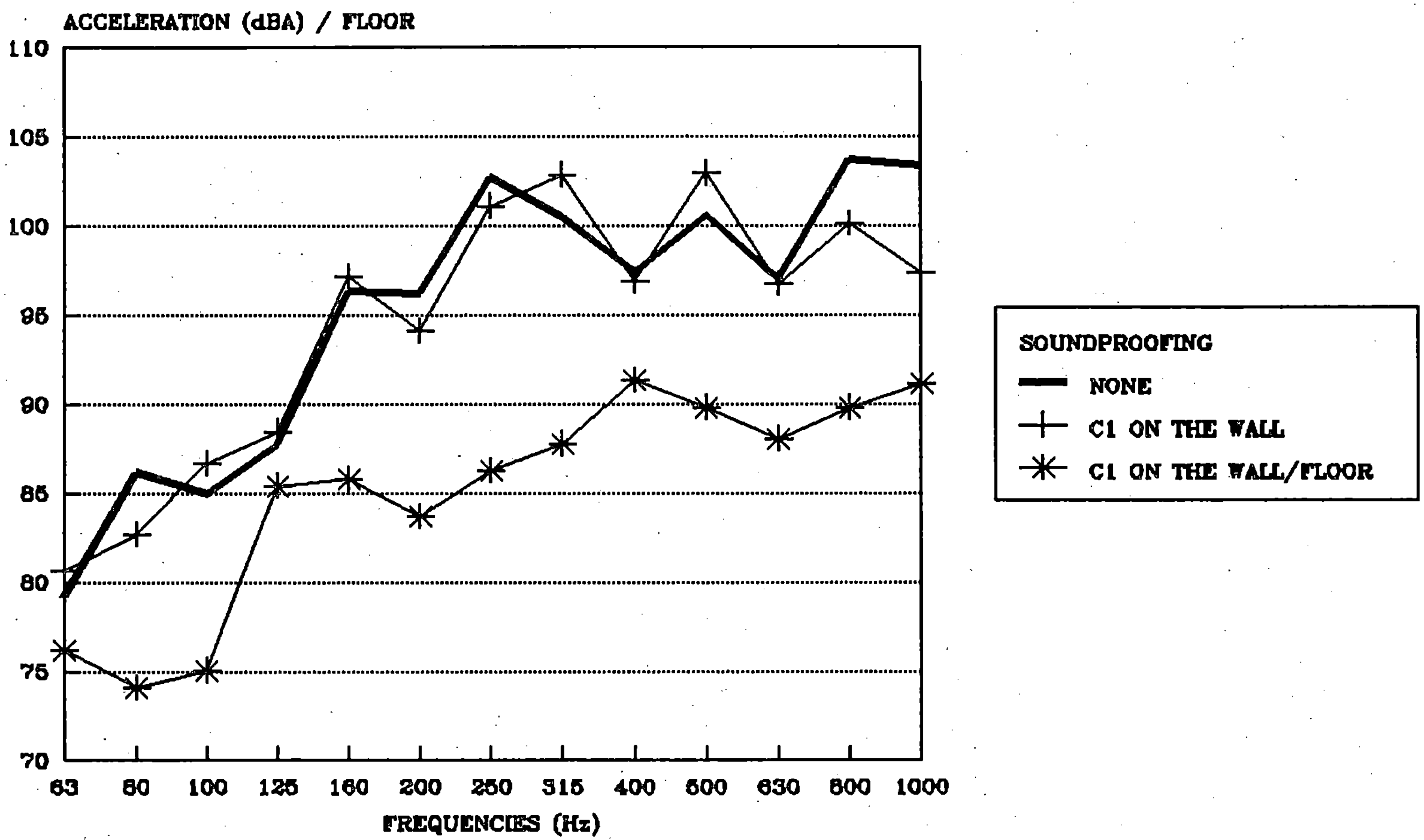

FIG. E11 – COUNTER TESTS
(SERIES 1)

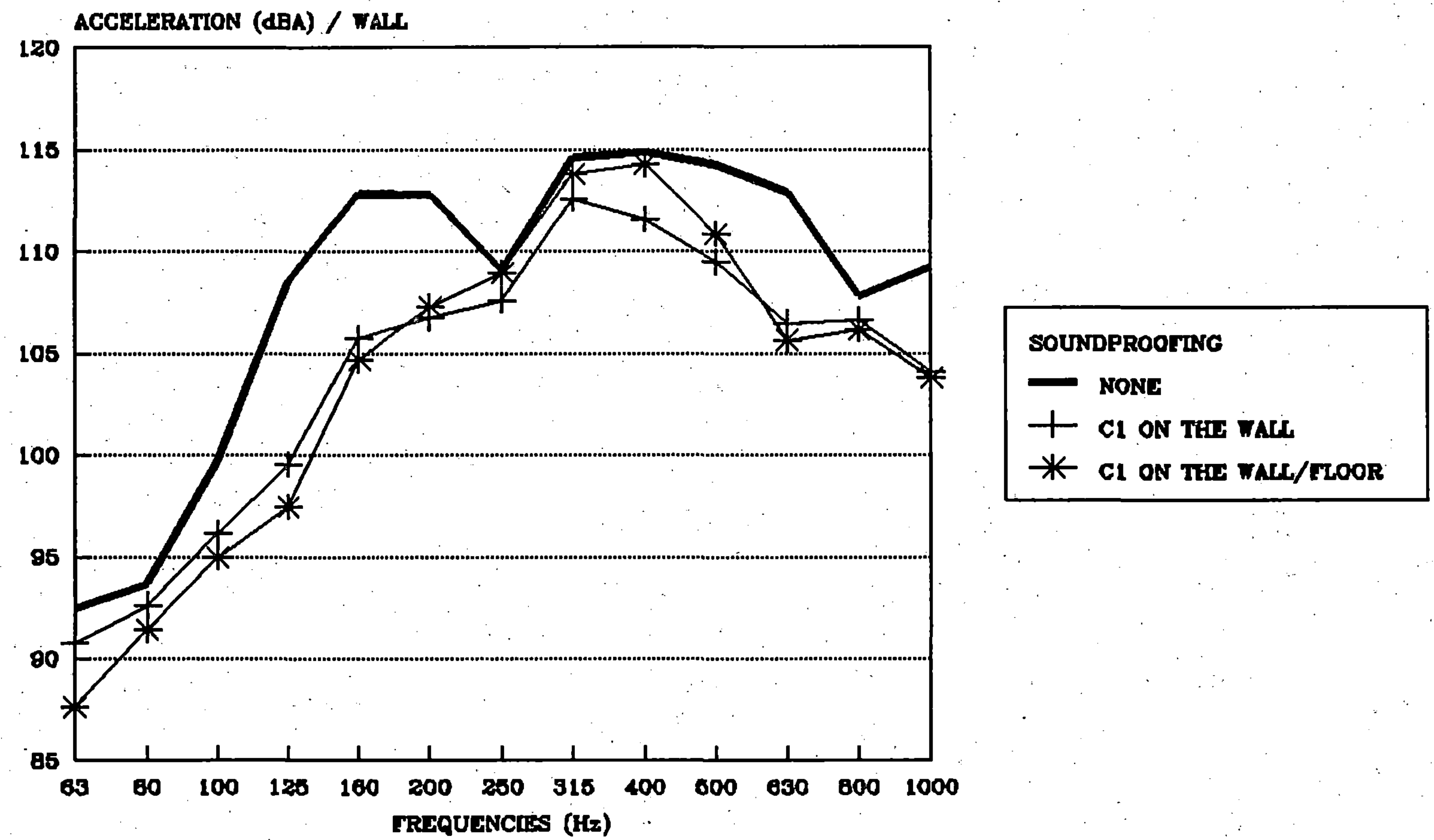

FIG. E12 – COUNTER (WALL) TESTS
(SERIES 1)

APPENDIX F

Test Results
Measurement Series #2

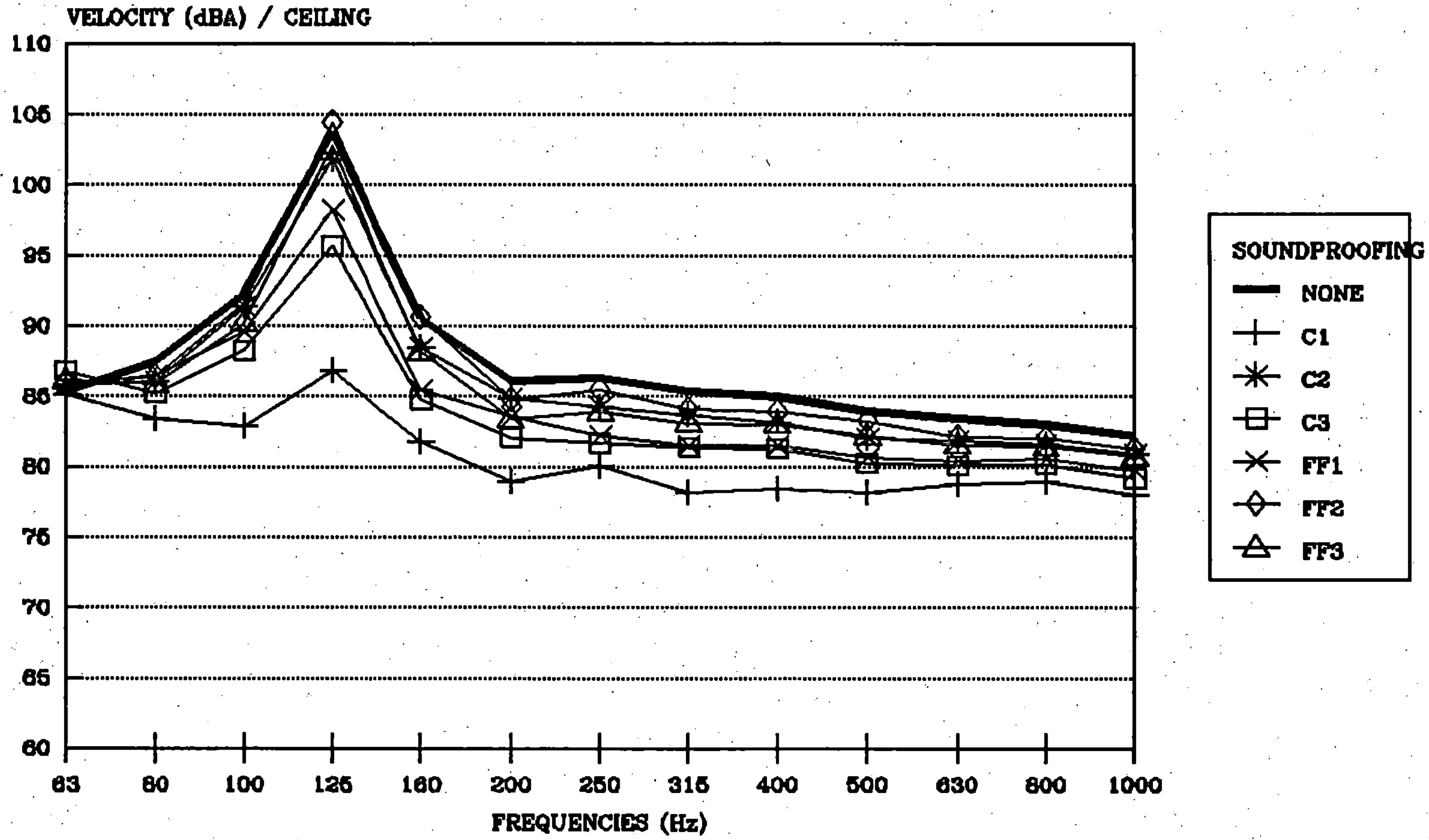

FIG. F1 – WASHING MACHINE TESTS
(SERIES 2)

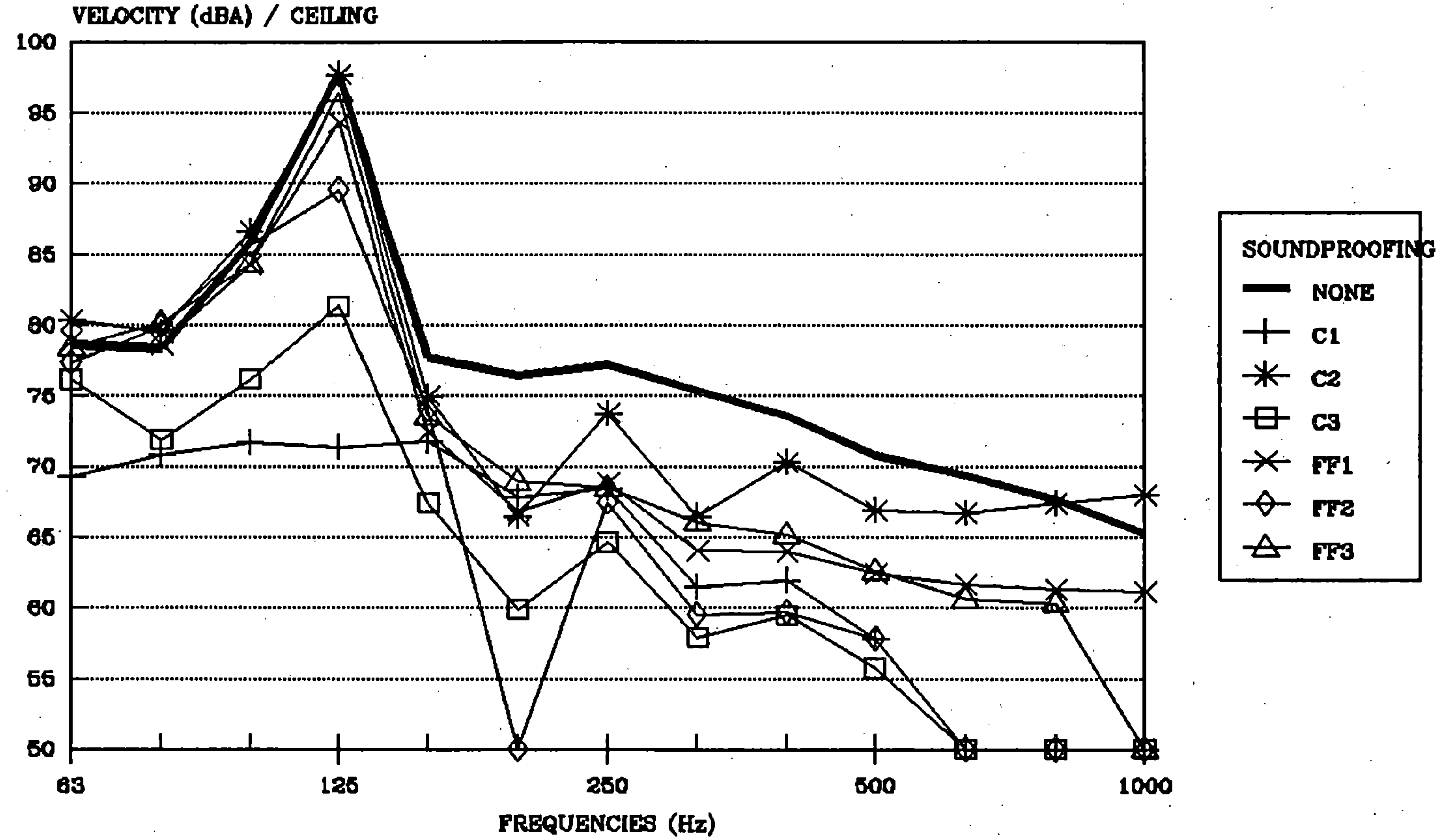

FIG. F2 – DRYER TESTS
(SERIES ·

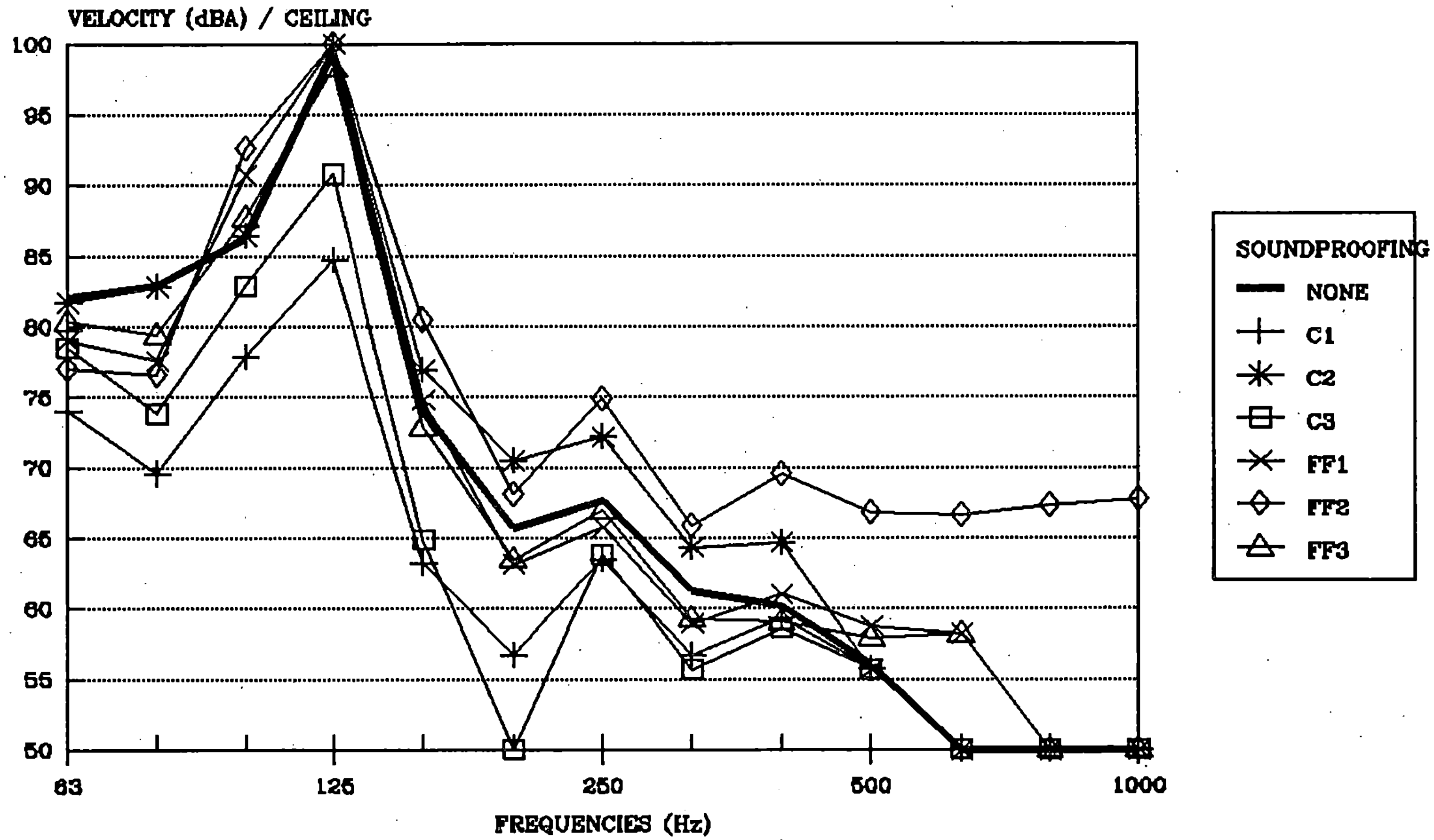

FIG. F3 – DISHWASHER TESTS
(SERIES 2)

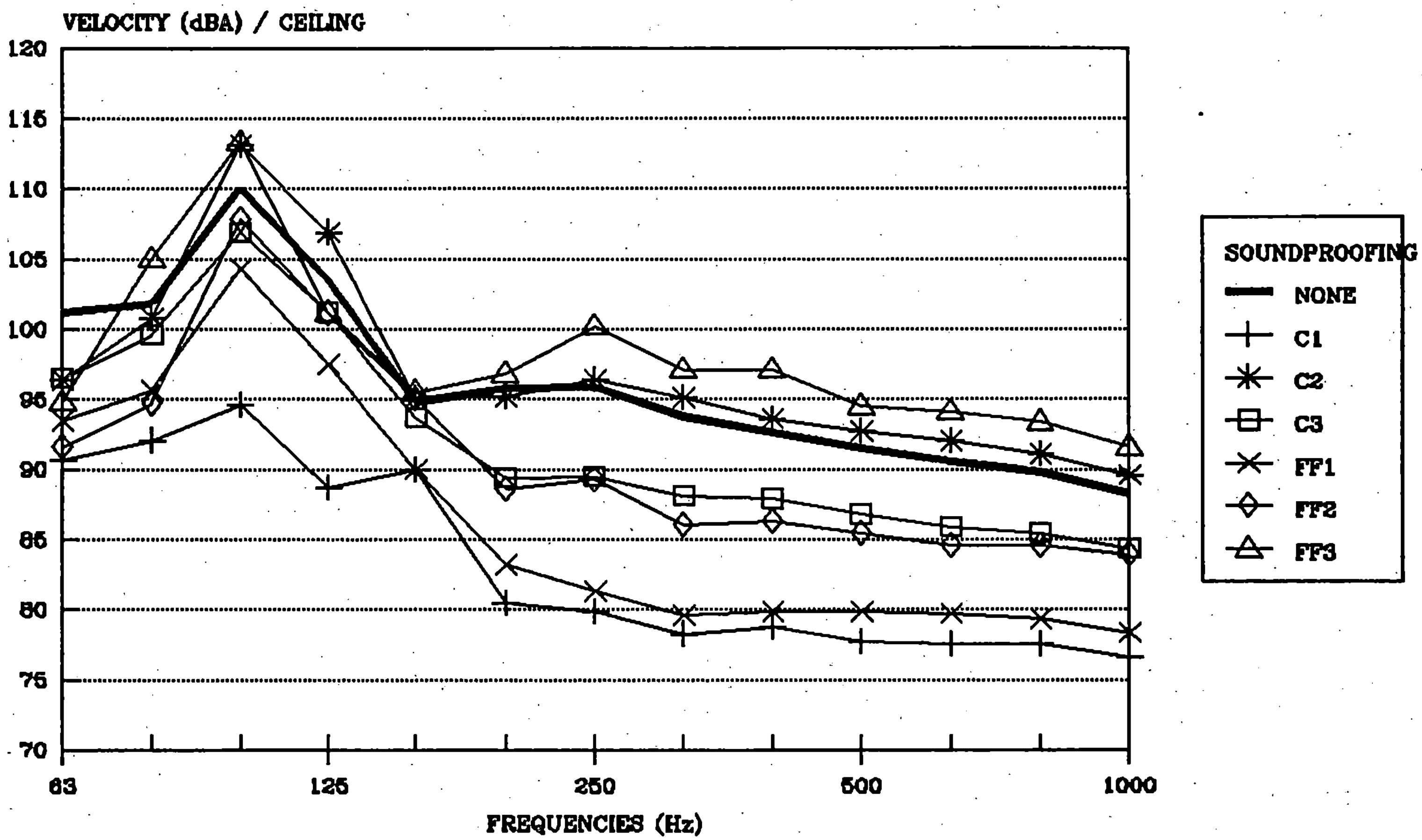

FIG. F4 – COUNTER TESTS
(SERIES 2)

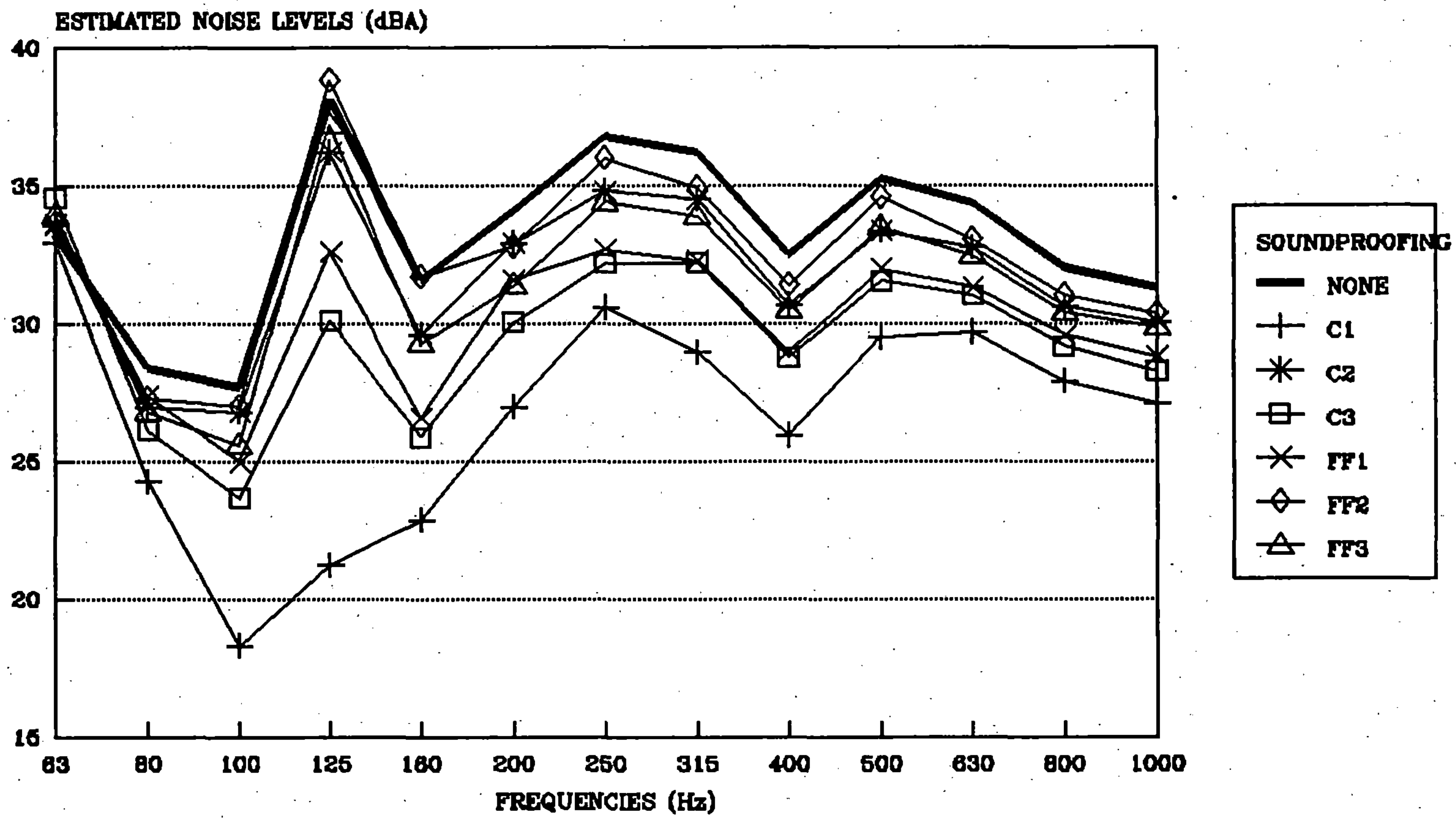

FIG. F5 – WASHING MACHINE ESTIMATED NOISE LEVELS (SERIES 2)

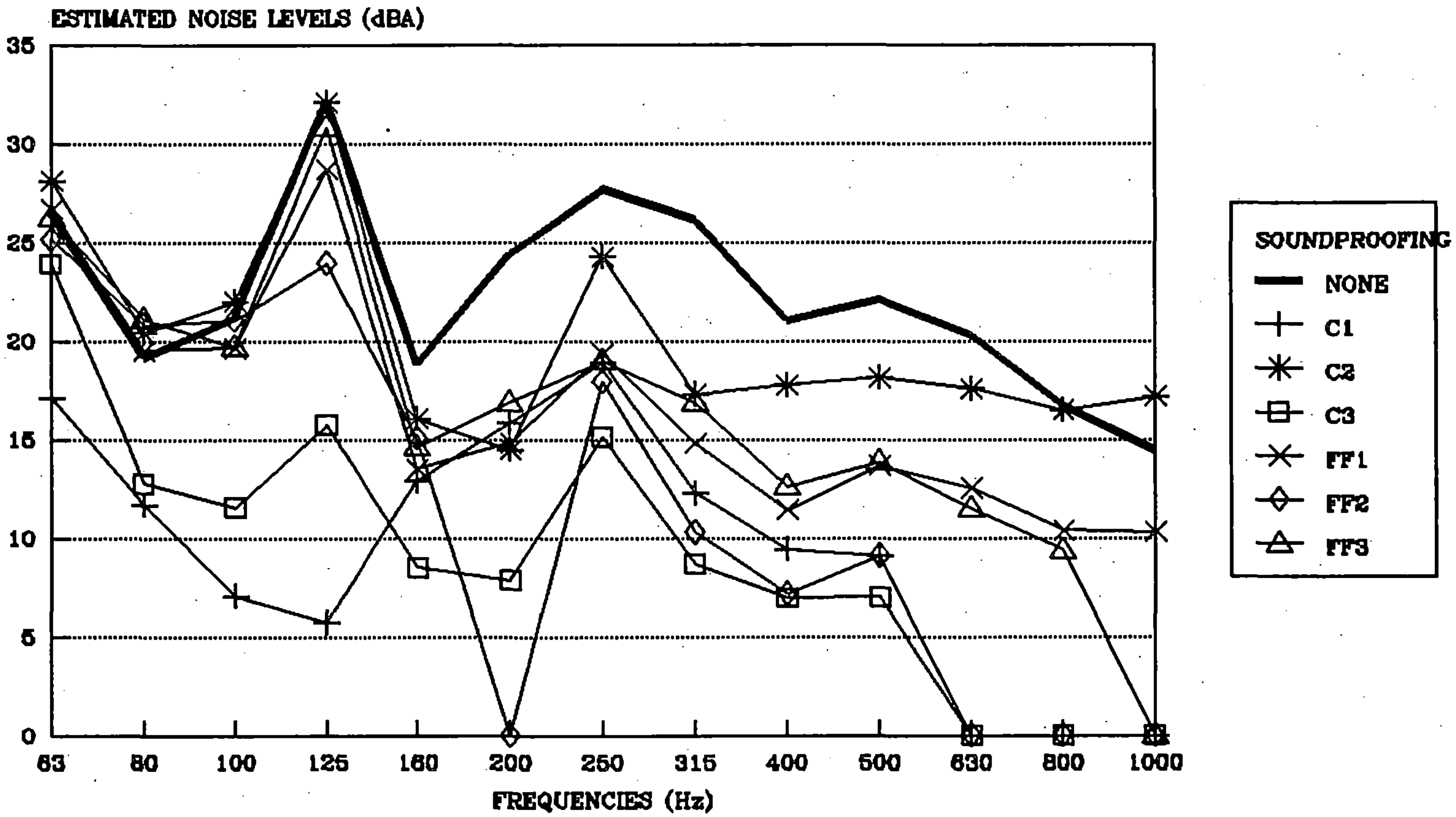

FIG. F6 – DRYER
ESTIMATED NOISE LEVELS
(SERIES 2)

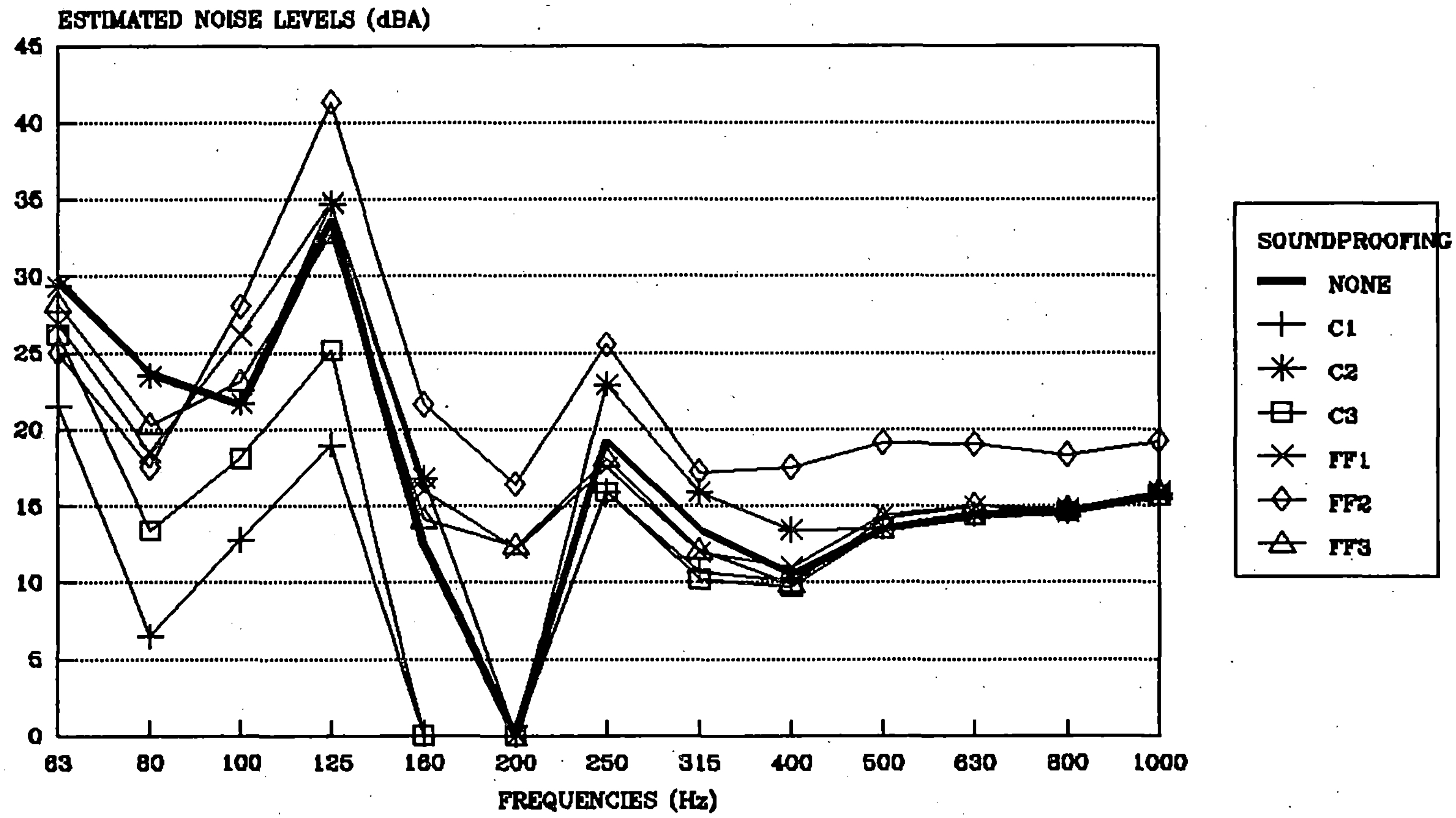

FIG. F7 – DISHWASHER ESTIMATED NOISE LEVELS (SERIES 2)

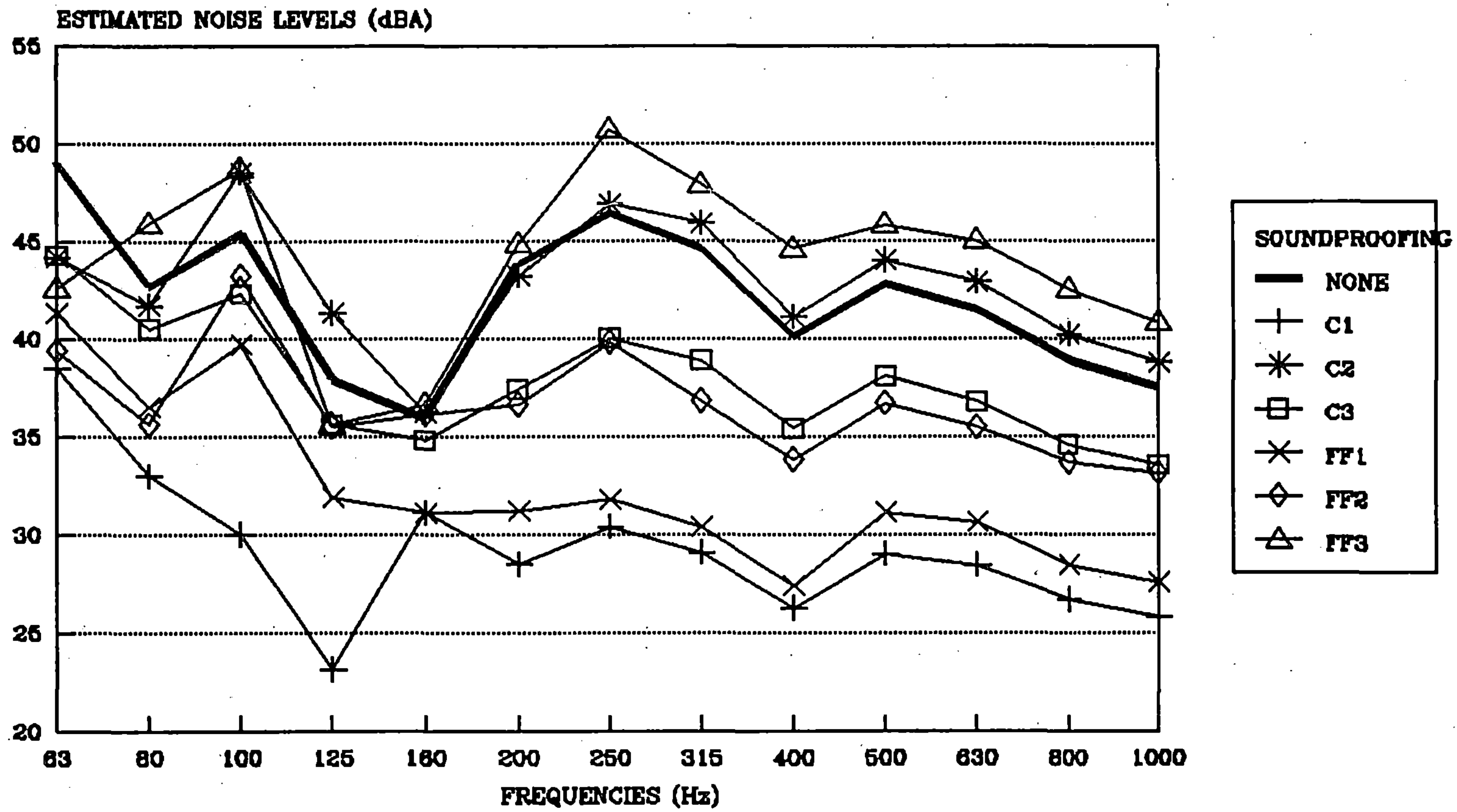

FIG. F8 – COUNTER
ESTIMATED NOISE LEVELS
(SERIES 2)