

# Report

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## **Measurement of Drum Noise – A Pilot Project NT 1597-02**

**Client: Nordtest**

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incl. Annex A-C

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**Summary**

Drum noise from floors and floorings has been a building acoustics issue for many years although an international standardized measurement method has never been made.

In this pilot project NT 1597-02 the possibilities of developing a Nordtest method for drum noise measurements of floorings were studied. Knowledge of the use of survey measurements of drum noise from floorings was collected from the Nordic countries and other countries, and laboratory measurements with examples of modified tapping machines on different kinds of floorings were performed by DELTA.

It is concluded that there is a strong need for a standardized measurement method for drum noise from floorings, and proposals to be considered in the standardization work are given.

DELTA, 13 February 2004



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Dan Hoffmeyer  
Acoustics & Vibration

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## **1. Preface**

This pilot project has been partly supported by Nordtest (NT project no. 1597-02).

The Nordic project group consisted of:

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Anders Homb  
Norwegian Building Research Institute  
Norway

Mark Kartous  
SP Swedish National Testing and Research Institute  
Acoustics  
Sweden

There has been one project group meeting in Kgs. Lyngby, Denmark. Additionally, the members of the group have contributed with national data concerning drum noise measurements. All tests were performed by DELTA in the building acoustics laboratories at the Technical University of Denmark. The sponsored floorings for the tests were obtained by LTH, Lund University.

The pilot project is coordinated with the later Nordtest project NT 1636-03 “Measurement of drum noise” which is carried out by LTH, Lund University. This means that:

- the established project group is the same
- the project group meeting in the pilot project was the start-up meeting in the later project as well
- the floorings used in the pilot project measurement series are the same as to be used in the later project
- the results of the pilot project are to be used directly in the later project

## **2. Introduction**

The aim of this pilot project is to study the possibilities of developing a Nordtest method for drum noise measurements of floorings for both laboratory and field use. The impact source should be mechanical as for example a modified tapping machine.

The approach was to collect knowledge of the use of survey measurements of drum noise from floorings from the Nordic countries and other countries, where drum noise is a known issue. Furthermore, there has been an exchange of drum noise knowledge with LTH, Lund University including comparison of objective measurements and subjective observations.

Additionally, laboratory measurements with examples of modified tapping machines on different kinds of floorings were performed by DELTA.

The collected data were discussed at the project group meeting and general advice on the development of a drum noise measurement method is given.

## **3. Drum Noise from Floors**

In this project drum noise from floors or floorings is defined as the noise generated by walking or tapping on the floor and experienced or measured in the same room.

Drum noise from floors and floorings has been a building acoustics issue for many years although there has never been an international, standardized measurement method.

In Denmark the first study on drum noise from floors dates from 1952 [1]. In this study objective measurements of frequency spectra were carried out on a number of floors, when excited by a standardized tapping machine. The tapping machine was partly modified by a

reduction of the impact frequency in order to lower the inherent noise from the tapping machine.

The measurement results were compared and the effect of different flooring materials, ad-here or loose mounting, floors on joists, soft underlay, and soft covering was shown. Many of the materials used are not up-to-date, but the main tendency of the results is still valid.

During the 60'es and 70'es the use of carpets and linoleum or vinyl floorings on concrete reduced the problems with drum noise in many buildings and consequently led to lack of interest in drum noise measurements and know-how of keeping the drum noise level low.

The increased use of wooden floorings in offices, schools, day-care centres, etc., reestablished the interest in these topics in Denmark during the 80'es.

Since then there has been an increasing interest in drum noise from floorings in the Nordic countries and in some other European countries as well, especially concerning documentation of drum noise of floorings in the laboratory and to a minor extent also concerning the possibilities of setting up requirements for drum noise levels in buildings.

The popular combination of hard-surfaced floorings and open-plan areas has underlined the need for drum noise measurement methods.

In order to fulfil product requirements from building owners and designers, some flooring manufacturers asked for laboratory tests of drum noise from their floorings.

Subsequently, some Nordic and European laboratories have offered survey measurements of drum noise from floorings, mostly using the standardized tapping machine.

At Lund University work including objective measurements and subjective listening tests has been made [2]. The preliminary results indicate that it is possible to rank drum noise from floorings and get an agreement between objective and subjective test results using loudness [3] instead of dB(A)-values or single number values evaluated from a reference curve as in EN ISO 717-2 [4]. Findings from this work will be a part of the later Nordtest project NT 1636-03.

Working for the laminate flooring industry, Lund University has prepared a measurement method [5] based on measurements with the standardized tapping machine in a semi-anechoic room (see Section 4.2.2).

A French standard has been prepared, too [6]. It is based on measurements with the standardized tapping machine as well, but in a normal building acoustic reverberant test chamber (see Section 4.2.2).

Up till now there has obviously been an open market for drum noise measurement methods leading to confusion and unserious competition among manufacturers of floorings.

In 2003 the work leading to an EN measurement method of walking noise (drum noise) was started in an ad-hoc group under CEN TC 126 WG 1 (see Section 4.3).

## **4. Drum Noise Measurement Methods**

### **4.1 Proposed and/or Used Measurement Methods**

The knowledge of the survey methods used for drum noise measurements in the Nordic countries was collected using a questionnaire sent out in 2003. The questionnaire and the answers from the Nordic project group are given in Annex A. The members of the Nordic project group were additionally asked three questions concerning:

- Knowledge of use of requirements for drum noise in specific buildings
- Interest or use of measurements of drum noise from floorings
- Viewpoints regarding future measurement method (NT ACOU or EN ISO)

Below a brief summary is given of the answers to these questions and to the questionnaire about used survey methods for each country.

#### **4.1.1 Denmark**

There are no reported requirements for drum noise levels in specific buildings, but the issue has come up several times, especially with regard to office buildings, also including laboratory measurements prior to the construction on site.

Flooring suppliers and designers have a moderate interest in drum noise measurements.

There is a need for a standardized method for use in the normal reverberant building acoustics facilities in Europe and based on measurements with a standardized tapping machine – modified in some way or other, if necessary.

In Denmark DELTA has used a method like EN ISO 140-8 [7] since 1985. In a reverberant room approx. 10 m<sup>2</sup> of the flooring under test is placed on the 140 mm standard concrete floor. A standardized tapping machine is used. Reverberation time correction is applied, and the normalized drum noise level per 1/3-octave is given as the result without evaluation of any single number values.

#### **4.1.2 Finland**

Requirements for drum noise levels in specific buildings are not used.

Only a few manufacturers of wooden floorings have been interested in testing.

VTT in Finland has used methods similar to EN ISO 140-8 [7] in the late 90'es and in a research project in 2002. The laboratory tests in the reverberant room are carried out with approx. 12 m<sup>2</sup> flooring placed on the 160 mm standard concrete floor. No correction is used. The drum noise level per 1/3-octave measured with a standardized tapping machine is given as the result without evaluation of any single number values.

#### **4.1.3 Iceland**

There is no knowledge of drum noise requirements used in specific buildings.

Flooring manufacturers' interest in drum noise measurements has suddenly increased.

It is very important to have a standardized measurement and evaluation method, preferably using the standardized tapping machine. Results in dB(A) or other weighted values. Loudness might be used, if necessary.

IBRI Island from 2003 uses a method similar to EN ISO 140-8 [7] with a standardized tapping machine with an additional cover. A 10.9 m<sup>2</sup> flooring on the 160 mm standard concrete floor in the reverberant test room is used. Reverberation time correction is applied, and the normalized drum noise level per 1/3-octave is given as the result together with the A-weighted level.

#### **4.1.4 Norway**

There is no knowledge of specific drum noise requirements, but it is an issue for questions in the design phase, especially regarding public buildings and schools.

Mainly laminate flooring manufacturers have been interested in drum noise.

It would be an advantage to base the measurements on a standardized method. The type of source should not be restricted to one method although the standardized tapping machine should be included. It would be an advantage if it is proved that dB(A) or other known weighted values can be used.

BYGGFORSK Norway from 2001 has used a laboratory method with the standardized tapping machine on 4 m<sup>2</sup> flooring on 120 mm concrete in a reverberant room. Reverberation time correction is not applied, and the drum noise level per 1/3-octave is given as the result together with the A-weighted level.

Additionally, drum noise measurements for comparison purposes have been made in different rooms in the 90'es using practical sources or the standardized tapping machine.

In 2001 a small test box (0.5 m × 0.5 m × 0.5 m) with a single impact steel ball has been used to compare drum noise levels of products per 1/3-octave and in dB(A).

#### **4.1.5 Sweden**

There are no requirements regarding drum noise in buildings, just an interest. Manufacturers use the drum noise as sales argument.

There is a medium to high interest in drum noise in office buildings.

The French method [6] gives problems due to high mechanical noise levels of the tapping machine. The calculations are difficult to understand. The EPLF method [5] is OK, but the calculation of loudness is time-consuming. The need for a semi-anechoic room might be a problem.

SP in Sweden has tried out two methods in 2003, the French standard in a reverberation room and the EPLF norm in a semi-anechoic room. These methods are described in more detail below (see Sections 4.2.1 and 4.2.2).

#### **4.1.6 Other Countries**

Only a few references to measurement methods used in other countries have been found.

At the University of Salford [8] some measurements of sound power levels of floorings when excited by a standardized tapping machine have been made. The measurements were made in a reverberation chamber and the tapping machine had a special cover. The results were given as sound power levels per 1/3-octave only.

At the Technical University of Dresden walking noise and its characterization have been studied [9]. An alternative method for walking noise measurements has been worked out. A walking person starts on a soft carpet and then walks on to the flooring under test. The first step is measured, and this procedure is repeated several times.

### **4.2 Current Standardized Methods**

#### **4.2.1 The French Standard NF S 31-074**

The French standard NF S 31-074 “Laboratory measurement of in room impact noise by floor covering in this room” [6] was approved in 2002. The standard is a further development of an experimental standard from 1995.

The standard is based on EN ISO 140-8 [7] and uses normal reverberant building acoustics test chambers with a standardized concrete floor between the rooms. The standardized tapping machine is used, but a sound-insulating cover to lower the inherent noise of the machine is recommended.

The resulting sound pressure level is corrected for the influence of the standardized bare floor in the laboratory in order to obtain comparable values of the weighted index  $L_{n,e,w}$

among different laboratories. This correction includes measurements of impact levels in the room beneath the standard floor.

The weighted index  $L_{n,e,w}$  is evaluated in accordance with EN ISO 717-2 [4].

Additionally, the standard includes an informative classification system of floorings according to their drum noise level with classes A to D.

An informative Annex also gives detailed description of how to make a sound-insulating cover for the tapping machine.

#### **4.2.2 EPLF NORM 021029-2**

The EPLF NORM 021029-2 “Laminate floor coverings – Determination of drum sound generated by means of a tapping machine” [5] from 2003 is the second edition of the standard from the Association of European Producers of Laminate Flooring.

The measurement method for laminate floorings has been prepared by Lund University and is based on measurements with the standardized tapping machine in a semi-anechoic room. Large rooms or smaller rooms with sufficient absorption on walls and ceiling may be used as well. Guidance to qualify the test room is given in the standard.

A sound-insulating cover has to be used on the tapping machine. Guidance on how to make a cover is given.

The test sample (4.8 m<sup>2</sup>) is to be installed on a concrete floor. The flooring is tested under load. The eight tapping machine positions and the four microphone positions are fixed to give a distance between the tapping machine and the microphone of one metre.

The measured drum noise levels per 1/3 octave (125 Hz to 12500 Hz) are used to calculate the loudness of the sound corresponding to a free-field environment.

### **4.3 Preparation of an EN Standard**

Following a CEN TC 126 resolution an Ad-hoc Group 7 under Working Group 1 has been established to prepare a standard under the work item ”Laboratory measurement of walking noise on floors”.

The work began in 2003 with the scope of harmonizing methods for physical measurement techniques and the psychoacoustic evaluation procedure in the field of assessing walking noise on floors.

The priority of the work has so far been to keep the standardized tapping machine (with or without modification or additional cover) and test room and measurement set-up similar to the EN ISO 140 series.

Input from different projects on drum noise including projects with test series and comparison to subjective listening tests are expected to be considered in the future work of the standardization group.

## **5. Pilot Project Laboratory Measurements**

### **5.1 Aim of the Test Series**

The aim of the test series was to study the influence of a modification of the tapping machine on the measured drum noise of different common floorings, and to find out whether a modified tapping machine would be better than the standardized tapping machine for drum noise measurements. The use of a modification was inspired by the work made in connection with the new standard about impact sound improvement on lightweight floors, [10] and [11]. The procedure should be to put springs or elastic layers between the hammers and the floor, to make the impact more in conformity with the real impact sources (e.g. walking).

The test series should include measurements of drum noise with and without modification of the tapping machine. Additionally, it was decided to include initial tests with different makes and types of tapping machines in the test program as well as to choose which one or ones should be represented in the final tests.

As it was known that different tapping machines as well as the presence of a normal cover, an improved cover, or no cover did influence the drum noise level, seven tapping machine configurations with and without modification were included in the initial tests on two surface types. From the results of these measurements it was decided that the rest of the eight floorings were measured with three tapping machine configurations without modification and three tapping machine configurations with modification.

### **5.2 Description of Measurement Method Used**

The test method used is similar to the method used at DELTA for years, except for some modifications (number of tapping machine positions increased from three to four and frequency range increased to 50-12500 Hz) primarily inspired by the measurement procedure discussed in the ad hoc group under CEN TC 126 WG 1.

The test method is generally based on EN ISO 140-8 [7], and the drum noise level is measured and normalized in a way similar to those methods.

The measurements are performed in a reverberant room placed on top of another reverberant room. The length, width, and height of the rooms are 7.85 m, 6.25 m and 4.95 m, respectively. In a test opening (2.99 m × 3.37 m) between the rooms a standard floor – a re-

inforced concrete slab of a thickness of 140 mm – is placed. When measuring the drum noise level, the floor coverings are installed on this standard floor. The area of the test specimen surface is approx. 10 m<sup>2</sup>. The floorings are tested under load. The uniformly distributed load is approx. 25 kg/m<sup>2</sup>.

In the test room sound-diffusing elements of concrete and of damped steel plate are situated on two of the walls and on the ceiling. The volume of the room is approx. 230 m<sup>3</sup>.

The normalized drum sound pressure level – the drum noise level – is defined as the sound pressure level in the test room – when the flooring under test is excited by the standardized tapping machine – increased by a correction to a reference equivalent absorption area (10 m<sup>2</sup>) of the test room.

The measurements of the normalized drum sound pressure level are performed using a standardized tapping machine provided with steel hammers and meeting the requirements of EN ISO 140-8:1998 Annex A [7]. The tapping machine is adjusted in such a way that the falling height of the hammers on an even surface corresponds to a free fall from a height of 40 mm.

The tapping machine is placed in four positions on the floor under test, and the sound pressure level in the test room is measured with an averaging time of 32 seconds corresponding to two revolutions of a rotation microphone system with sloping path and a radius of approx. 1.25 m. The sound pressure level is measured using a real-time frequency analyzer with 1/3-octave band filters. The total electrical and acoustic background noise level in the test room is measured. The sound pressure level in the test room is corrected for background noise, if affected.

The equivalent absorption area of the test room was determined by means of Sabine's formula by measuring the reverberation time of the room using the moving microphone (traverse time 64 seconds) and six decay measurements. The measurement of the reverberation time was performed with a broadband noise signal emitted by a loudspeaker system placed in a corner of the test room. The 1/3-octave filtered microphone signal was registered during the decay and evaluated in the range approx. 5 dB to approx. 25 dB below the steady-state level.

The normalized drum sound pressure level was determined within frequency bandwidths of 1/3- at the following standardized centre frequencies: 50, 63, 80, 100, 125, 160, 200, 250, 315, 400, 500, 630, 800, 1000, 1250, 1600, 2000, 2500, 3150, 4000, 5000, 6300, 8000, 10000, and 12500 Hz.

$$L_n = L_i + 10 \log_{10} \frac{A_M}{A_0} \text{ and } A_M = \frac{0.163 \cdot V_M}{T_M}$$

- where  $L_n$  = Normalized drum sound pressure level with a reference equivalent absorption area of 10 m<sup>2</sup> [dB re 20 μPa]
- $L_i$  = Sound pressure level in the test room when the flooring under test is excited by the standardized tapping machine [dB re 20 μPa]
- $A$  = Equivalent sound absorption area in the test room [m<sup>2</sup>]
- $A_0$  = Reference equivalent sound absorption area (10 m<sup>2</sup>)
- $V$  = Volume of the test room [m<sup>3</sup>]
- $T$  = Reverberation time in the test room [s]

The temperature and the relative humidity during the measurement are measured.

### **5.3 Floorings**

The tests were performed on eight different floor surfaces. Seven floorings were installed on the concrete floor; one surface was the concrete floor itself.

The floorings are chosen in coordination with Nordtest project NT 1636-03 to be the same in the two projects. The sponsored floorings for the tests were obtained by LTH. The floorings represent a broad spectrum of the normally used floorings in the Nordic countries, but focusing on loose, hard-surfaced floorings.

The test surfaces are numbered (Flooring no.) and described as follows:

1. 22 mm wooden flooring on timber joists
2. 14 mm wooden flooring on soft layer
3. 11 mm laminate flooring with soft layer
4. 8 mm laminate flooring on fibreboard
5. 7 mm wooden flooring on soft layer
6. Concrete floor (140 mm) – no flooring
7. 3 mm glued linoleum with soft layer
8. 8 mm carpet tiles with hard back side

The floorings were installed by DELTA. The cavity in Flooring no. 1 was approx. 80 mm. Only Flooring no. 7 was glued to the concrete floor.

### **5.4 Tapping Machines**

The tests were performed with three different types of tapping machines (I, II, and III). Two of the tapping machines normally include a cover. These tapping machines are used

with their normal cover, but additionally without cover or with an alternative cover with improved sound insulation.

The tapping machines are numbered (Tapping machine no. A to G) and described as follows:

- A. Tapping machine (I) with normal cover
- B. Tapping machine (I) without cover
- C. Tapping machine (I) with improved<sup>1)</sup> cover
- D. Tapping machine (II) with normal cover
- E. Tapping machine (II) without cover
- F. Tapping machine (III) without cover
- G. Tapping machine (II) with improved<sup>2)</sup> cover

1) Improved cover developed in connection with a DTU master thesis [12]

2) Improved cover supplied by the manufacturer

All three tapping machines (I, II, and III) were calibrated using the procedure described in EN ISO 140-8 [7] and Nordtest NT ACOU 071 [13] prior to the beginning of the test program.

## **5.5 Modification**

The standardized tapping machine with its steel hammers normally gives very high and high-frequency dominated drum sound levels when used on hard-surfaced floorings. Hence it is suggested, [10] and [14], that the tapping machine is modified to give lower and more walking noise-like impact, level, and spectra on wooden floorings. So, the test programme of this pilot project is focused on laboratory measurements with examples of modified tapping machines on different kinds of floorings.

The remaining question was how to modify the tapping machines. The possibilities could be (see also EN ISO 140-11 [11]) as follows:

- a) Using rubber feet on the hammers (as earlier supplied for some tapping machines)
- b) Using a soft layer under the hammer area
- c) Using a soft layer under the whole tapping machine

Some tests have been performed in Germany [10] with a thin rubber layer underneath the hammer area, but the characteristics of the material do not seem to be replicable. Instead Dr. Scholl, convener of CEN WG 1 AHG 7 on walking noise, suggested that studies including modified tapping machines could make use of a 25 mm elastic layer as Sylomer L 25 (see Annex B).

This elastic layer and the mounting of the tapping machine as described in Annex B are used consequently in this pilot project. The size of the elastic layer was 750 mm × 350 mm in order to fully support all three types of tapping machines.

The tapping machines modified in this way are numbered (Modified tapping machine no.) and described as follows:

- Am. Tapping machine (I) with normal cover on a 25 mm elastic layer
- Bm. Tapping machine (I) without cover on a 25 mm elastic layer
- Cm. Tapping machine (I) with improved<sup>1)</sup> cover on a 25 mm elastic layer
- Dm. Tapping machine (II) with normal cover on a 25 mm elastic layer
- Em. Tapping machine (II) without cover on a 25 mm elastic layer
- Fm. Tapping machine (III) without cover on a 25 mm elastic layer
- Hm. Tapping machine (II) with improved<sup>2)</sup> cover on a 25 mm elastic layer

<sup>1)</sup> Improved cover developed in connection with a DTU master thesis [12]

<sup>2)</sup> Improved cover supplied by the manufacturer

## **5.6 Results**

The test results are shown graphically in the figures in the following Sections. The graphs show the normalized drum sound pressure level per 1/3-octave in the frequency range from 50 Hz to 12500 Hz. The tabulated values of the test results are given in Annex C.

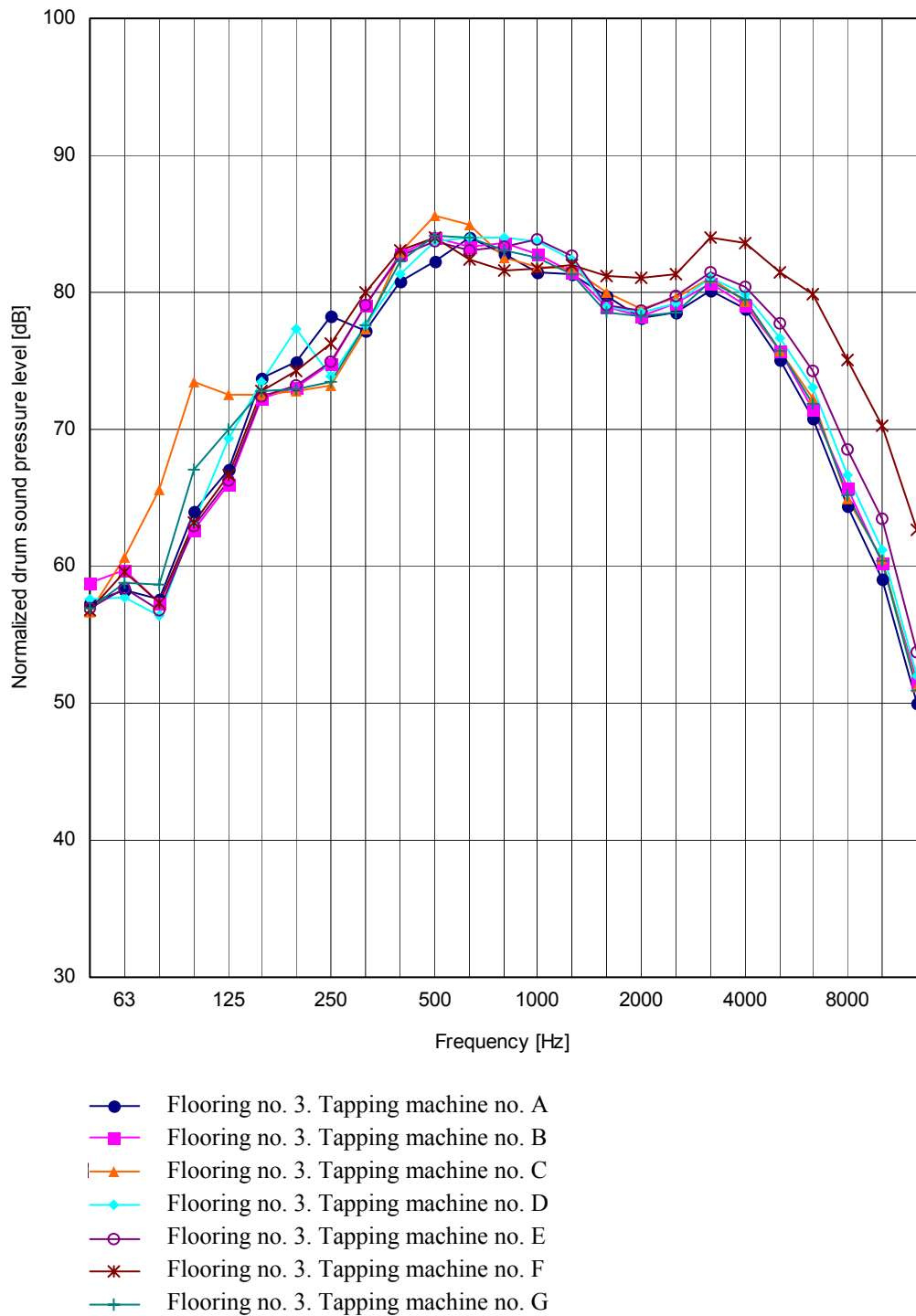
### **5.6.1 Initial Tests on Floorings No. 3 and 6**

The initial tests with different makes and types of tapping machines were included in the test program to make a decision on which tapping machines should be represented in the final tests.

Hence, seven tapping machine configurations with and without modification were included in the initial tests on the two surface types:

- Flooring no. 3: 11 mm laminate flooring with soft layer
- Flooring no. 6: Concrete floor (140 mm), no flooring

The test results for the standardized tapping machines on Flooring no. 3 are shown in Figure 5.1. From the results it is seen that the measured drum noise levels with the different tapping machines on the laminate flooring are very much alike. Only Tapping machines no. C and F have an increased level at low and high frequencies, respectively, compared to the others.



**Figure 5.1**  
Flooring no. 3. Tapping machines no. A, B, C, D, E, F, and G.

For the concrete floor without flooring, the spread between the different machines is increased. The test results for the standardized tapping machines on Flooring no. 6 are shown in Figure 5.2. What could be seen as the inherent noise of the tapping machines is contributing to the level, especially at high frequencies.

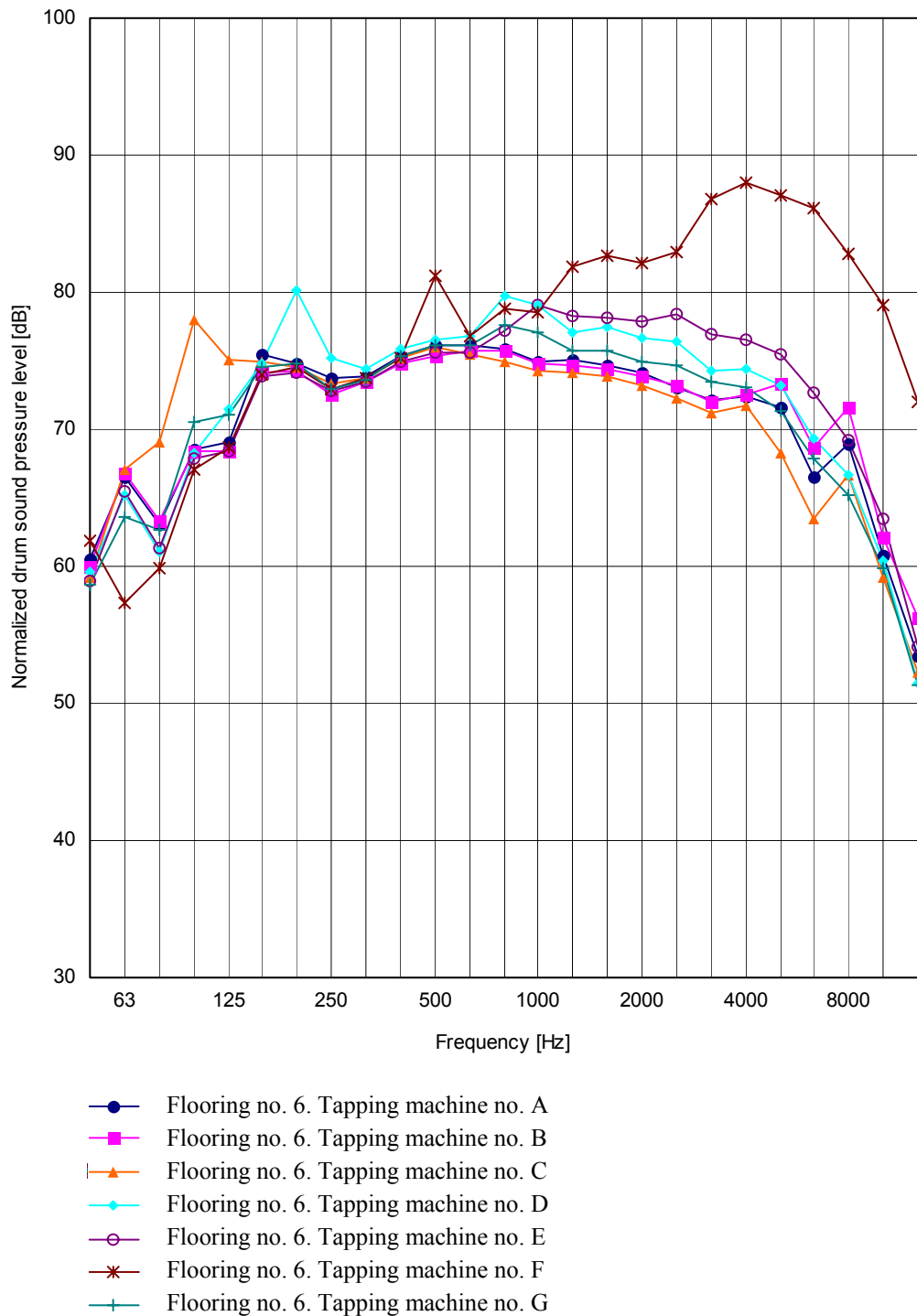
In this project not only hard-surfaced loose floorings were to be measured, so these results lead to the exclusion in the following test series of Tapping machines no. D, E, and F because of their relatively high levels above 800 Hz. Additionally, Tapping machine no. B was left out because it gave more or less the same values as Tapping machine no. A, the same machine with normal cover.

It was decided to use the remaining three Tapping machines no. A, C, and G for the whole test series in order not to restrict the tests to only one type of tapping machine. These machines represent a normal covered machine (Tapping machine no. A), an improved covered machine (Tapping machine no. C), expected to give the lowest drum noise level at high frequencies although the special cover gives an remarkable increase in the frequency range 80-125 Hz, and a different type of tapping machine with an improved cover (Tapping machine no. G).

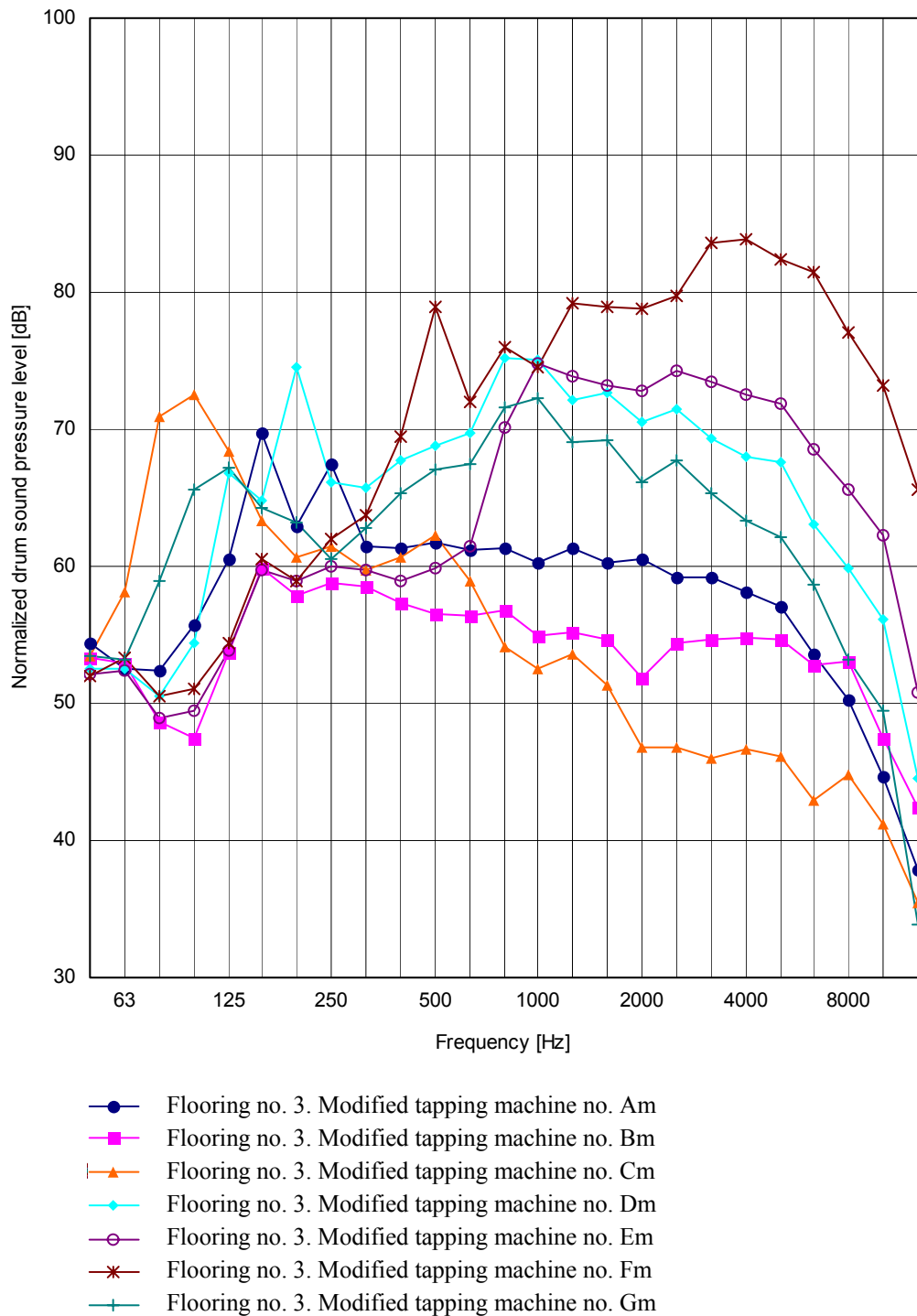
The test results for the modified tapping machines on Flooring no. 3 are shown in Figure 5.3 and the results for Flooring no. 6 in Figure 5.4.

These results show that using the recommended modification with a relatively thick elastic layer under the tapping machine leads to widely varying drum noise levels for the machines under test in almost the whole frequency range. It could be interpreted as if the inherent noise of the tapping machines is totally dominating the drum noise level.

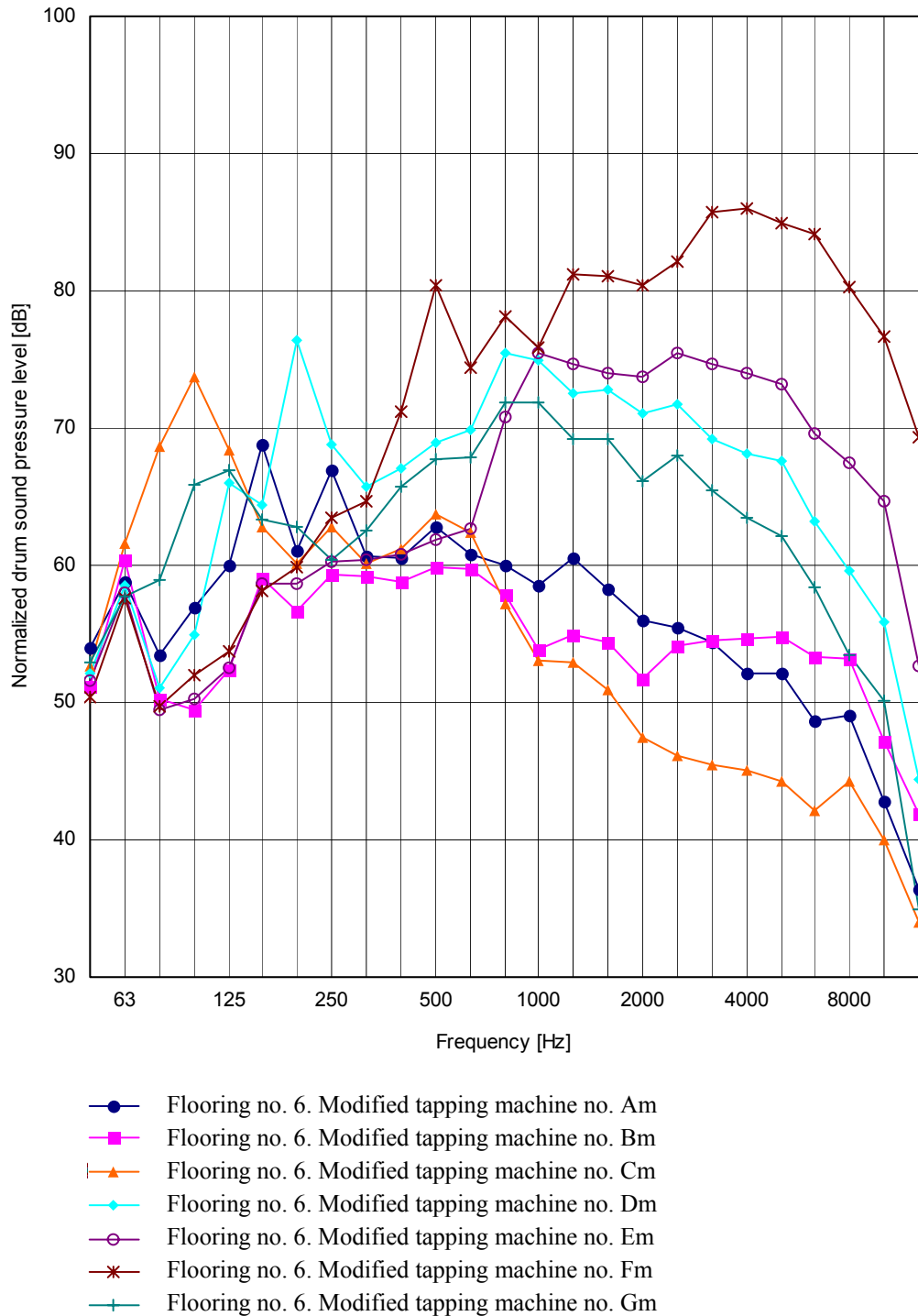
On this background only the tapping machine giving the lowest values should be included, but as no single machine gave the lowest values in the whole frequency range and in order to have more than one type represented, the following tapping machines were chosen for the remaining tests: Modified tapping machine no. Bm because it gives the lowest values up to 800 Hz (no additional inherent noise from the cover), Modified tapping machine no. Cm because it gives the lowest values above 800 Hz (highly improved sound-insulating cover), and Modified tapping machine no. Gm to represent a different type of tapping machine although it gives remarkably higher values in most of the frequency range.



**Figure 5.2**  
Flooring no. 6. Tapping machines no. A, B, C, D, E, F, and G.



**Figure 5.3**  
Flooring no. 3. Modified tapping machines no. Am, Bm, Cm, Dm, Em, Fm, and Gm.



**Figure 5.4**  
Flooring no. 6. Modified tapping machines no. Am, Bm, Cm, Dm, Em, Fm, and Gm.

### **5.6.2 Tests on Flooring No. 1, 2, 4, 5, 7, and 8**

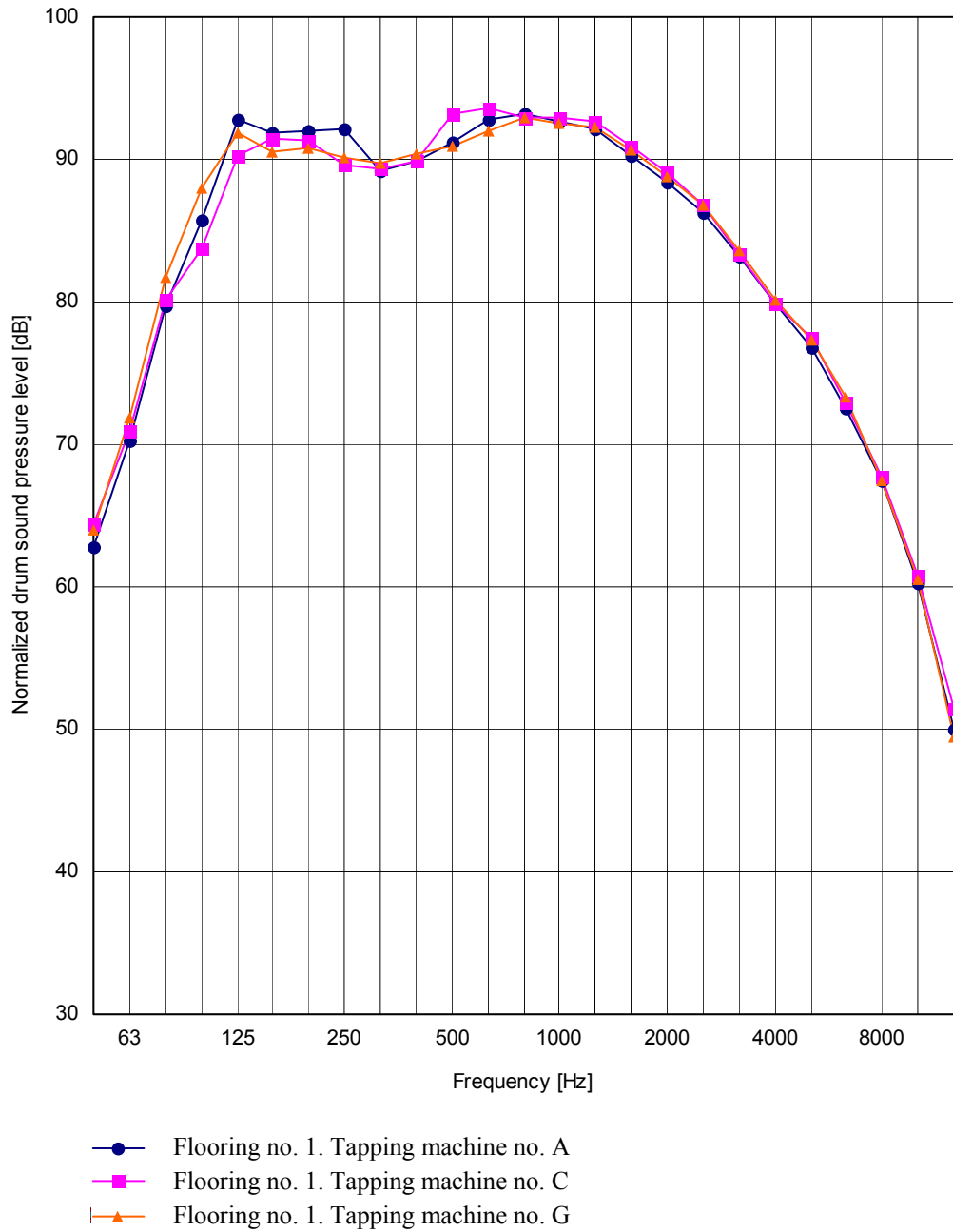
The test results of the remaining floorings are shown in Figure 5.5 to Figure 5.16.

As for Flooring no. 3, Flooring no. 1 shows only a minor influence from the choice of tapping machine. Flooring no. 1 (wooden flooring on joists) has relatively high levels in both the low frequency range due to influence from the cavity beneath the flooring and the rest of the frequency range. Thus, the inherent noise of the tapping machines does not seem to influence the drum noise level.

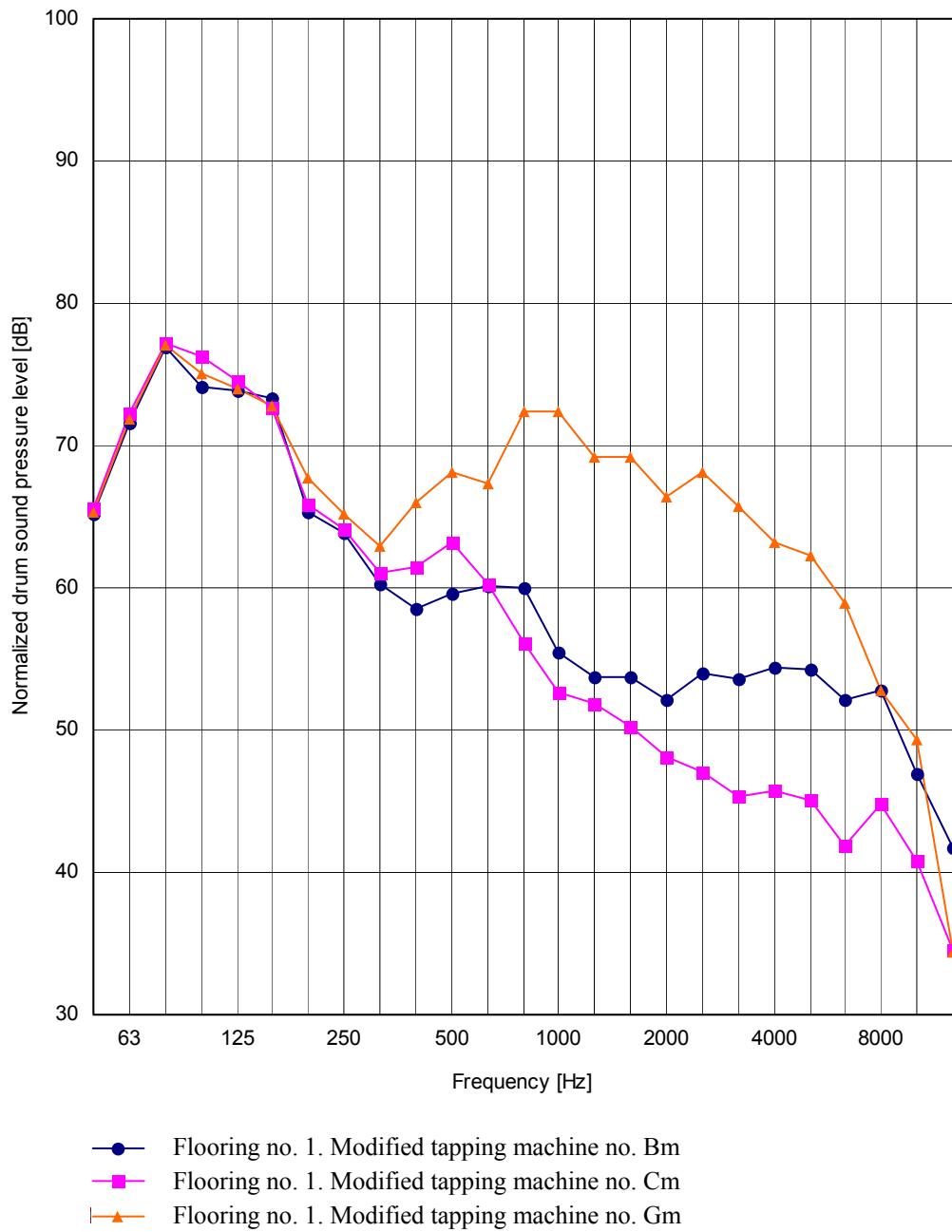
This is the case for the modified tapping machines on Flooring no. 1 at lower frequencies, too. However, at frequencies above 250 Hz the drum noise level is dictated by the inherent noise of the tapping machines, as will be seen to be the case for all tested floorings.

The results for Flooring no. 2, Flooring no. 4, and Flooring no. 5 (all laminate or wooden floorings) almost show the same tendency for the different tapping machines. Tapping machine no. A gives a characteristic peak at 250 Hz probably due to the cover, and similarly Tapping machine no. C gives higher values at 80 and 100 Hz.

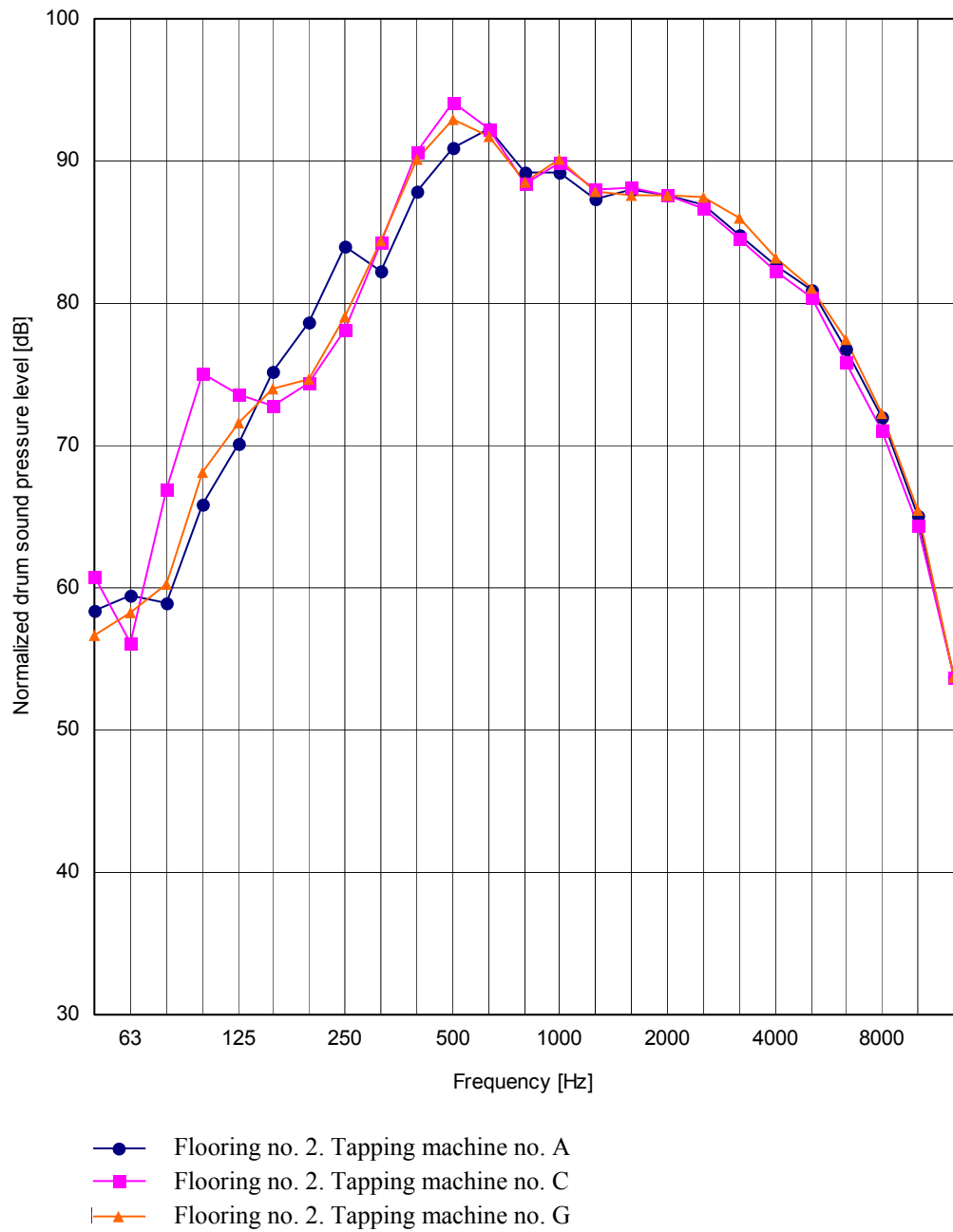
For Flooring no. 7 (glued linoleum) and Flooring no. 8 (carpet tiles) the relatively lower measured drum noise level compared to the hard-surfaced floorings results in the influence from the type of tapping machine being obvious.



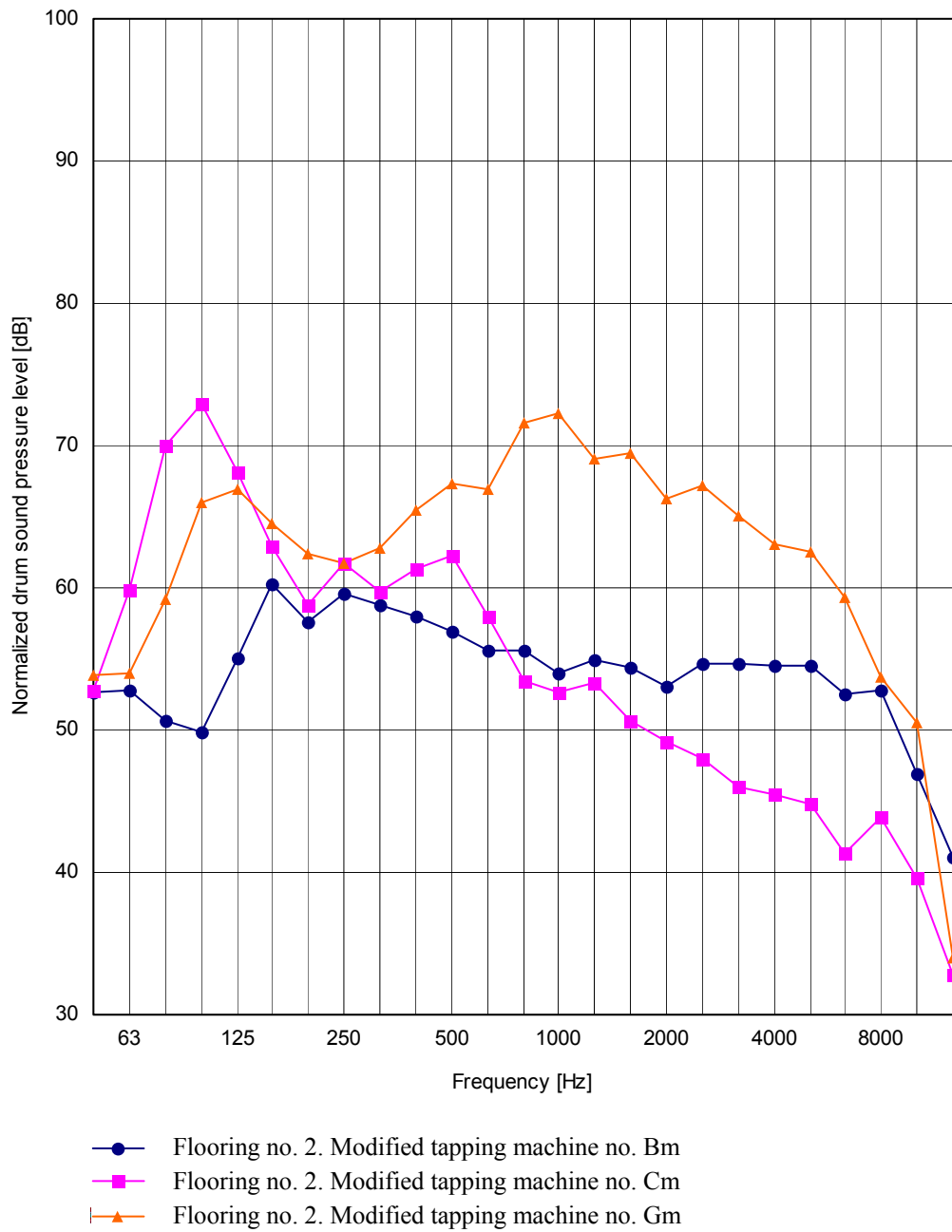
**Figure 5.5**  
Flooring no. 1. Tapping machines no. A, C, and G.



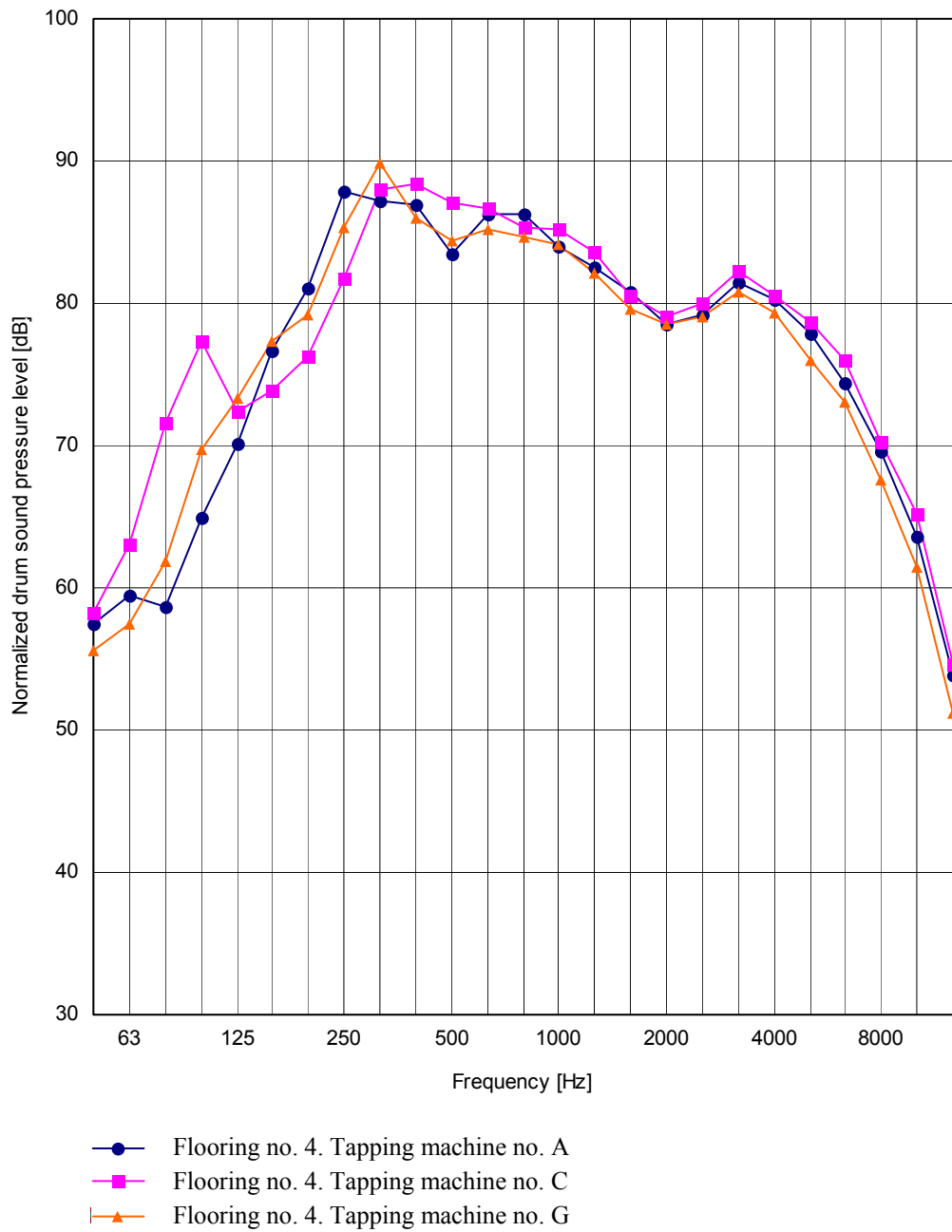
**Figure 5.6**  
Flooring no. 1. Modified tapping machines no. Bm, Cm, and Gm.



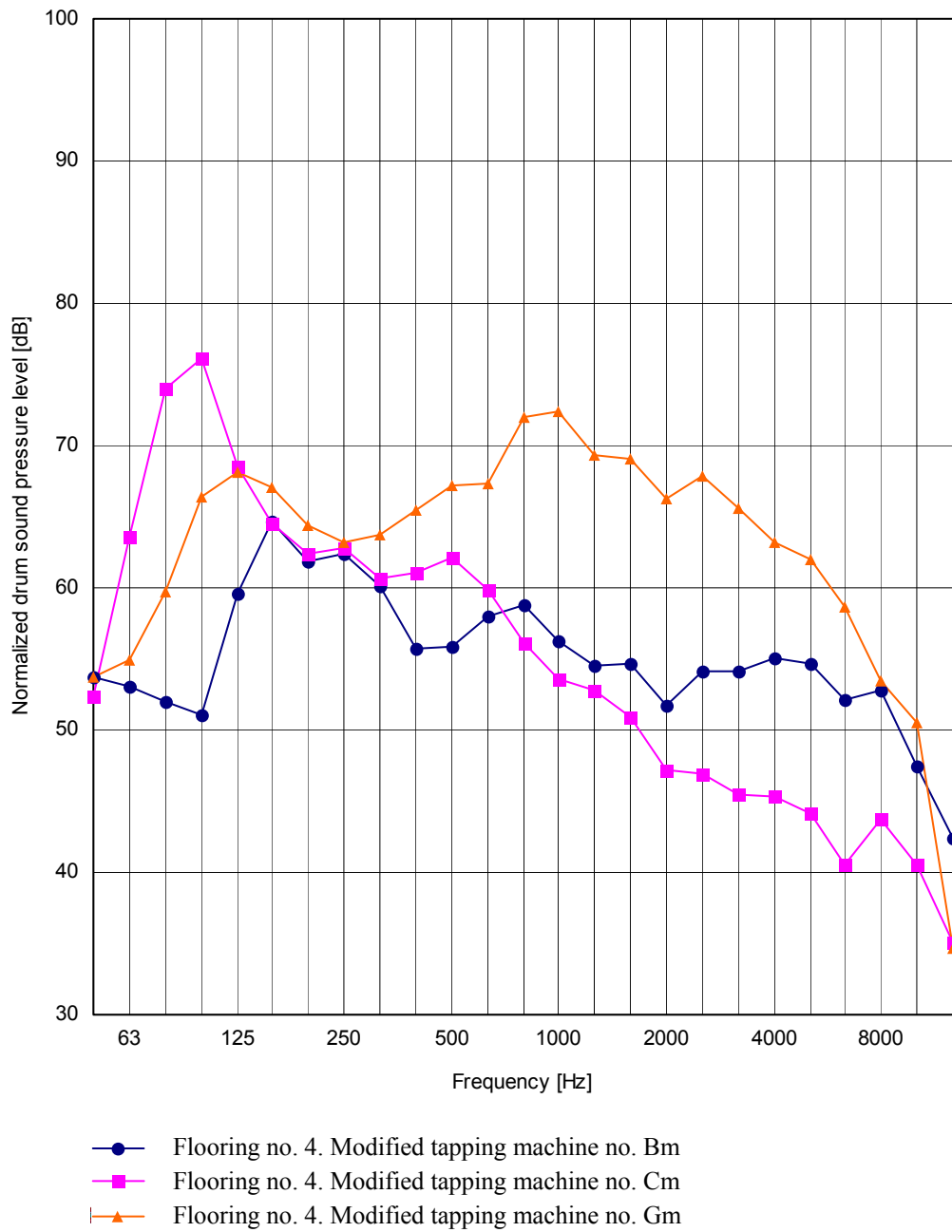
**Figure 5.7**  
*Flooring no. 2. Tapping machines no. A, C, and G.*



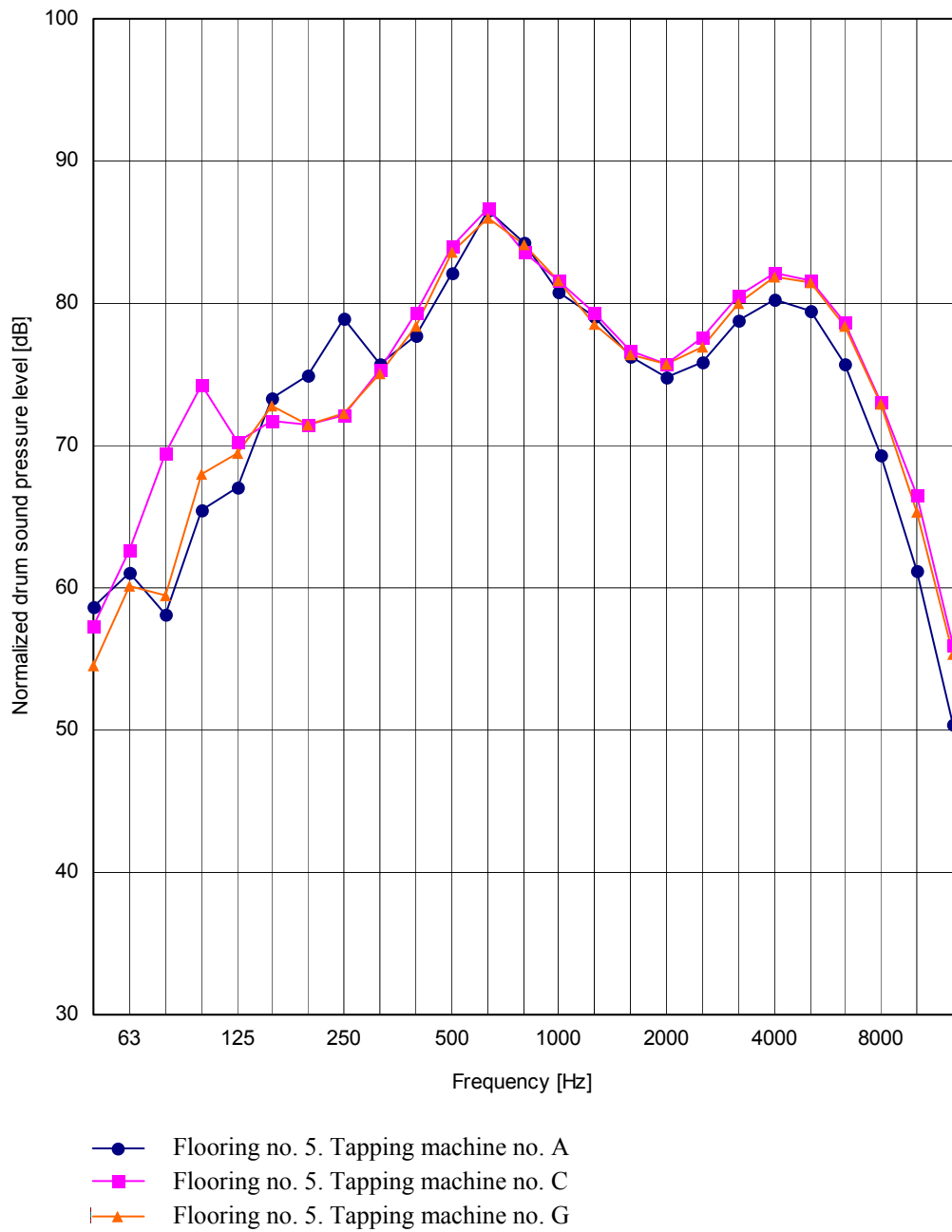
**Figure 5.8**  
*Flooring no. 2. Modified tapping machines no. Bm, Cm, and Gm.*



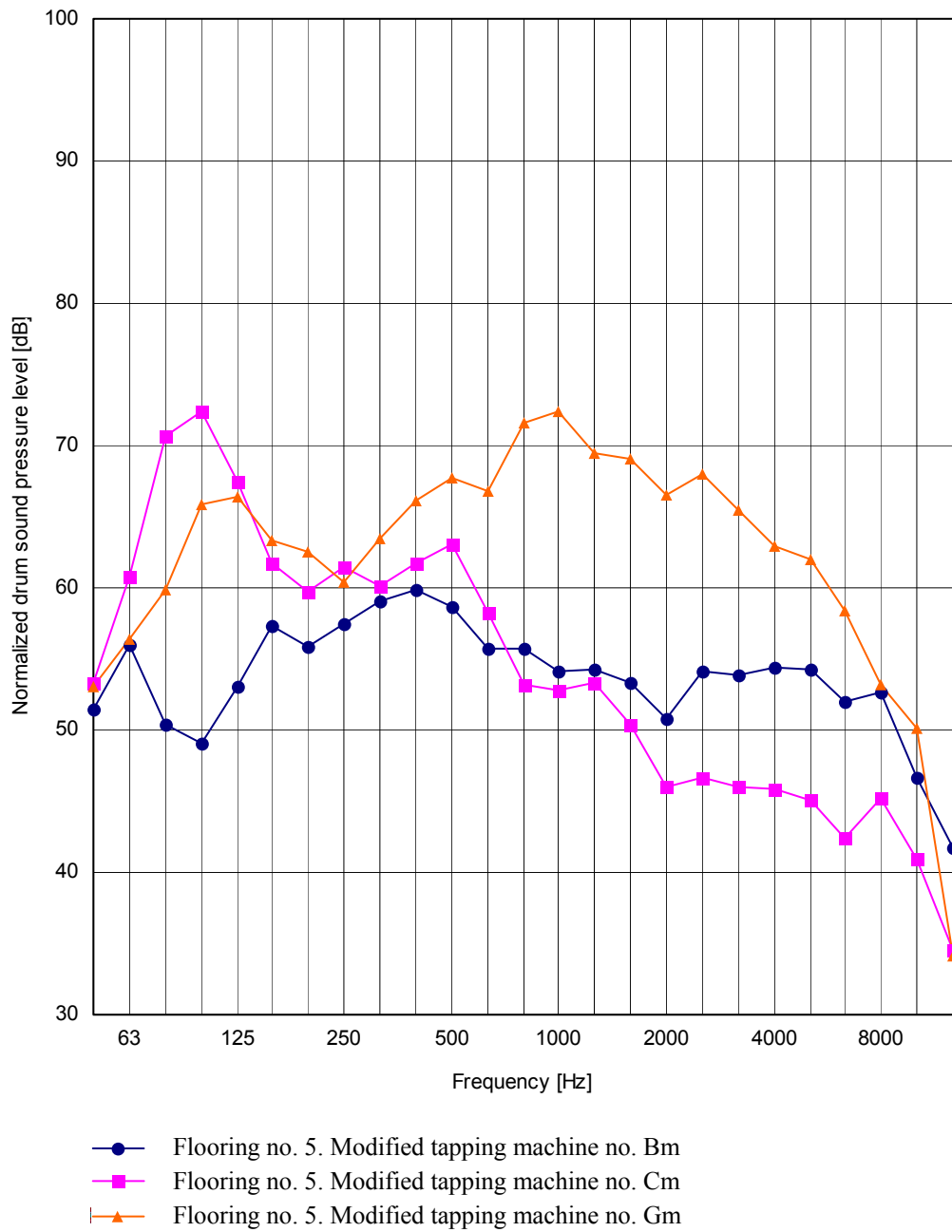
**Figure 5.9**  
Flooring no. 4. Tapping machines no. A, C, and G.



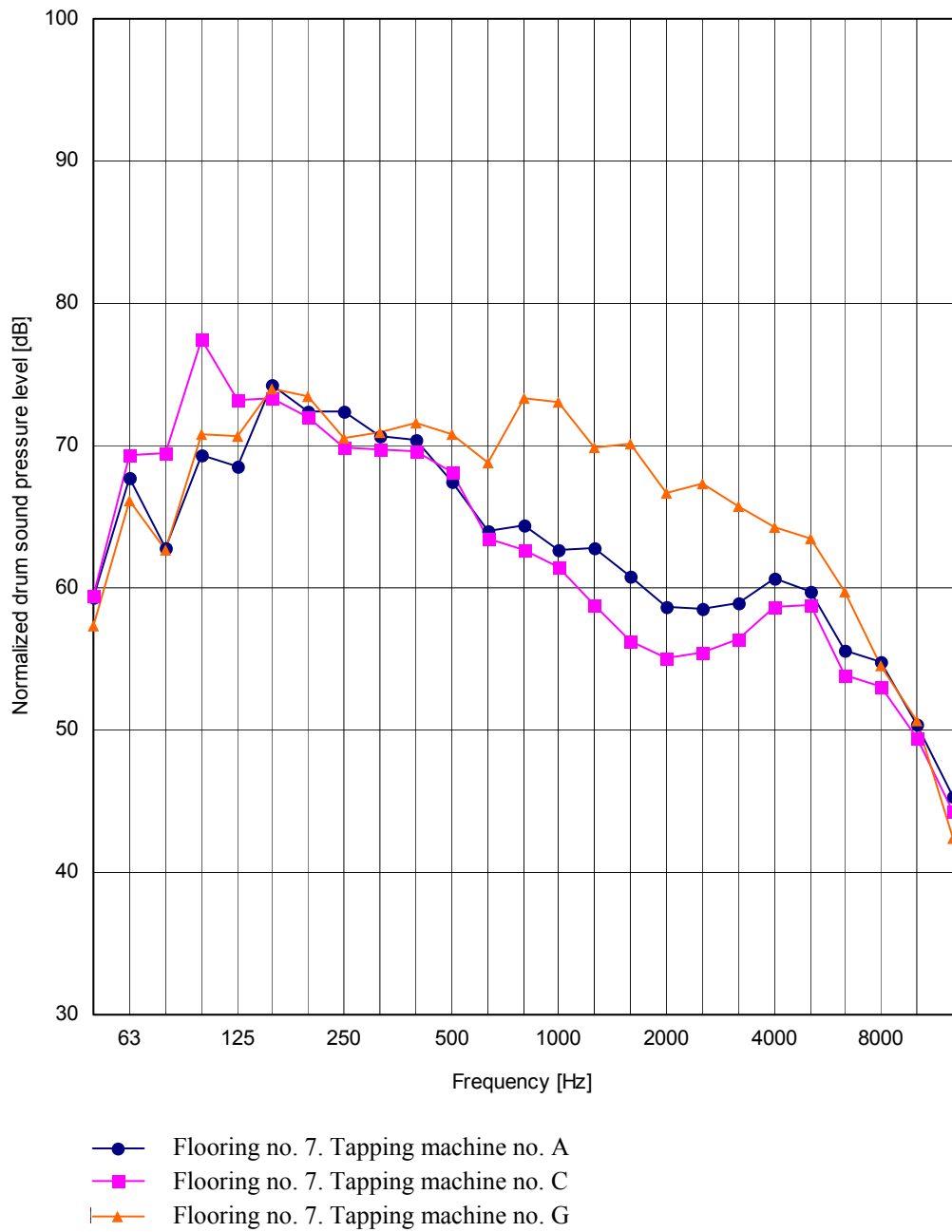
**Figure 5.10**  
*Flooring no. 4. Modified tapping machines no. Bm, Cm, and Gm.*



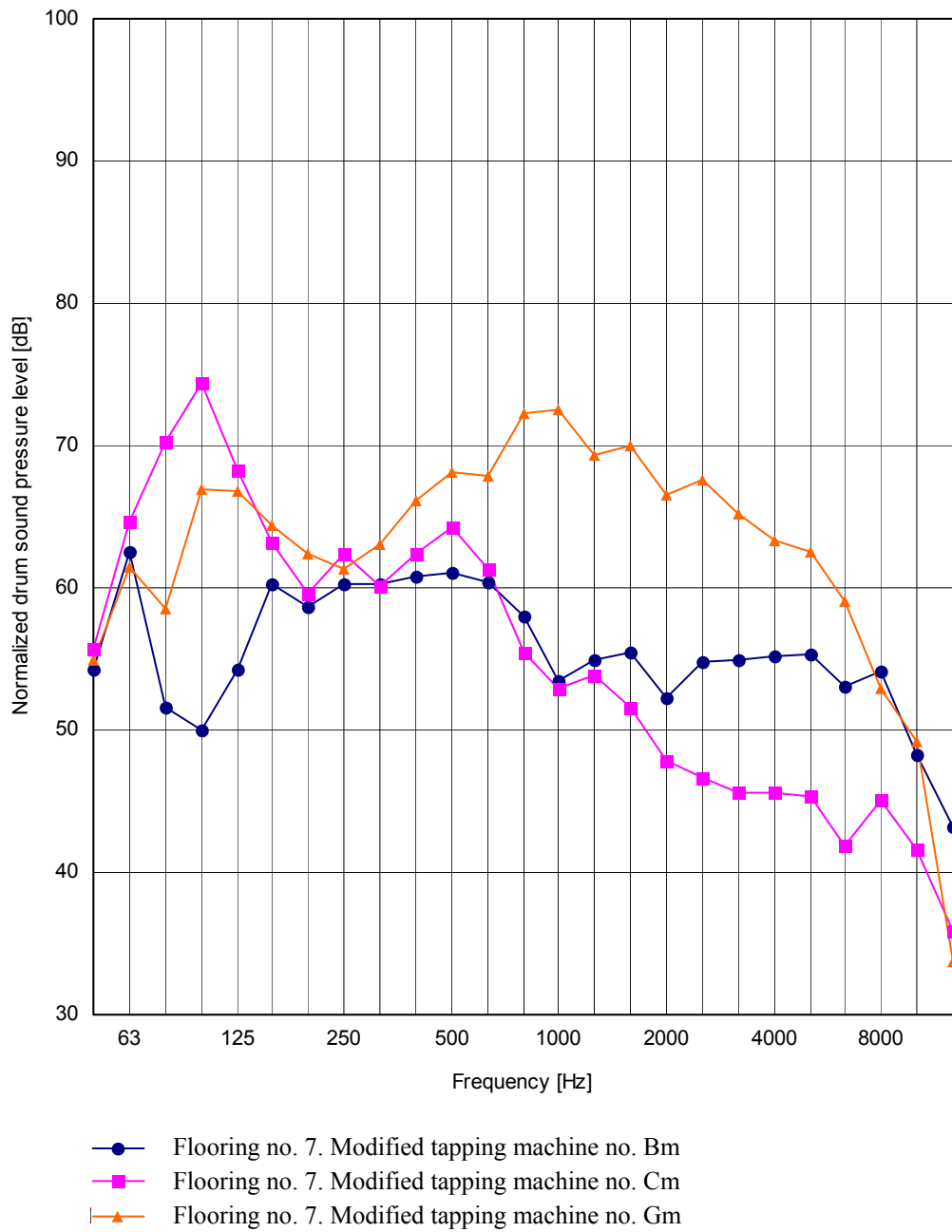
**Figure 5.11**  
*Flooring no. 5. Tapping machines no. A, C, and G.*



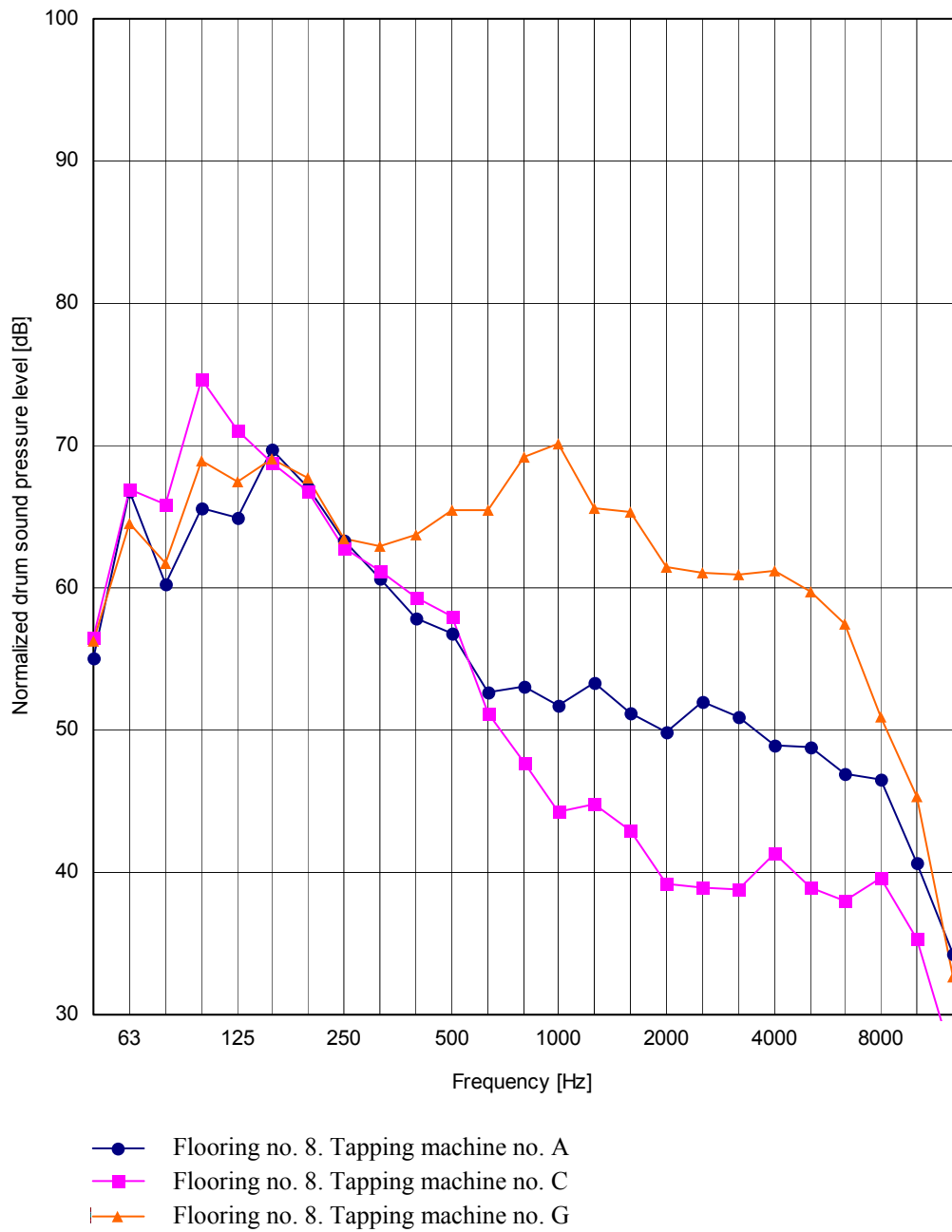
**Figure 5.12**  
*Flooring no. 5. Modified tapping machines no. Bm, Cm, and Gm.*



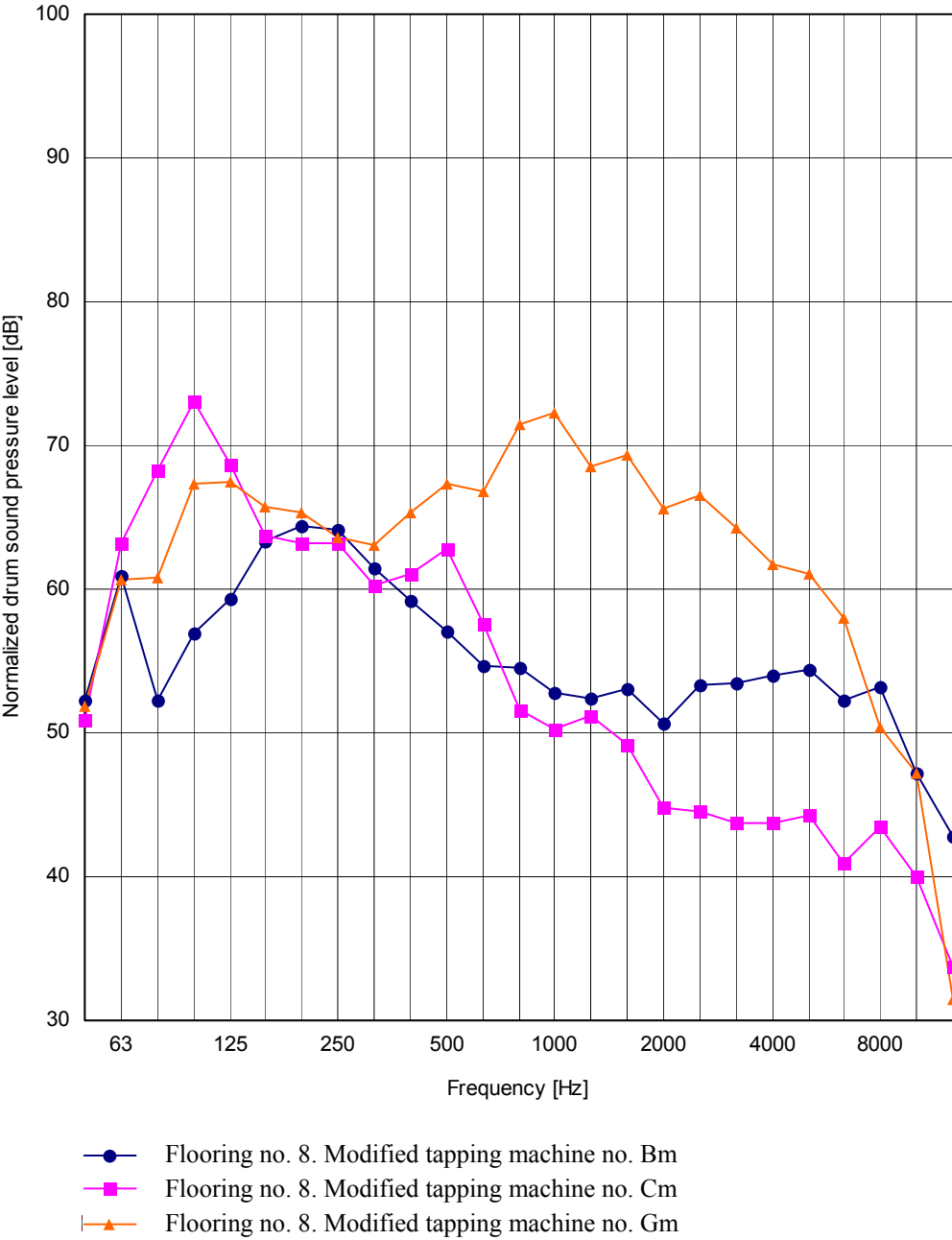
**Figure 5.13**  
Flooring no. 7. Tapping machines no. A, C, and G.



**Figure 5.14**  
*Flooring no. 7. Modified tapping machines no. Bm, Cm, and Gm.*



**Figure 5.15**  
*Flooring no. 8. Tapping machines no. A, C, and G.*



**Figure 5.16**  
*Flooring no. 8. Modified tapping machines no. Bm, Cm, and Gm.*

### **5.6.3 Comparison of Results of Different Floorings Using Standardized Tapping Machines**

As it is not the purpose of this pilot project to evaluate the measured drum noise levels using single number values (like  $L_{n,w}$ ) or making loudness calculations, the comparisons of the measurement results of different floorings obtained by different tapping machines and the preliminary conclusions are made from the overall frequency curves. In the later Nordtest project NT 1636-03 single number value calculations will be carried out for some of the measurements in this pilot project in order to compare the results with measurements using the EPLF-method [5] and results from listening tests.

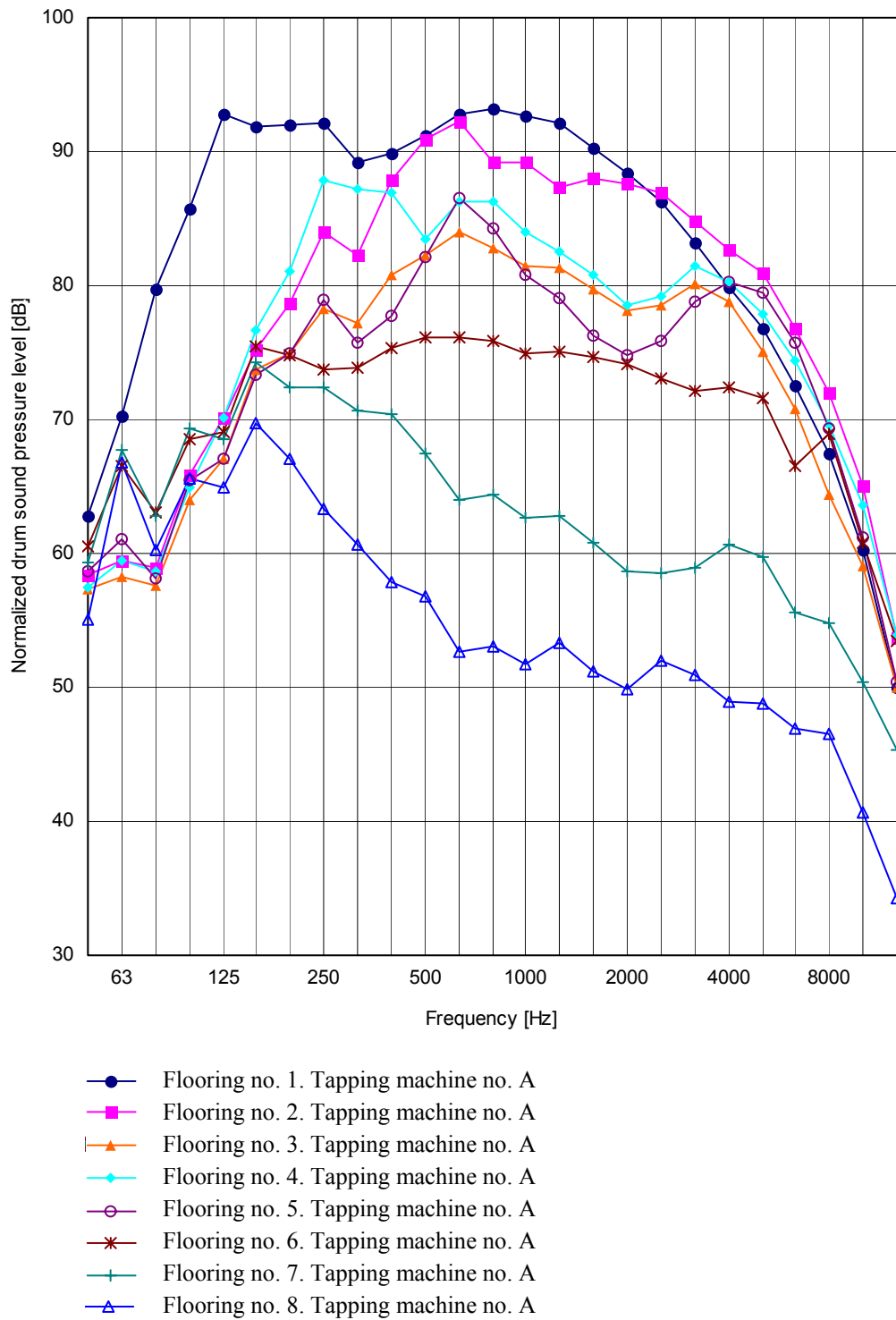
In Figure 5.17 the results for the eight floorings measured with Tapping machine no. A (Tapping machine (I) with normal cover) are compared.

The mutual differences among the five hard-surfaced laminate or wooden floorings are clearly seen, and the differences in relation to the concrete surface and the more soft coverings are evident.

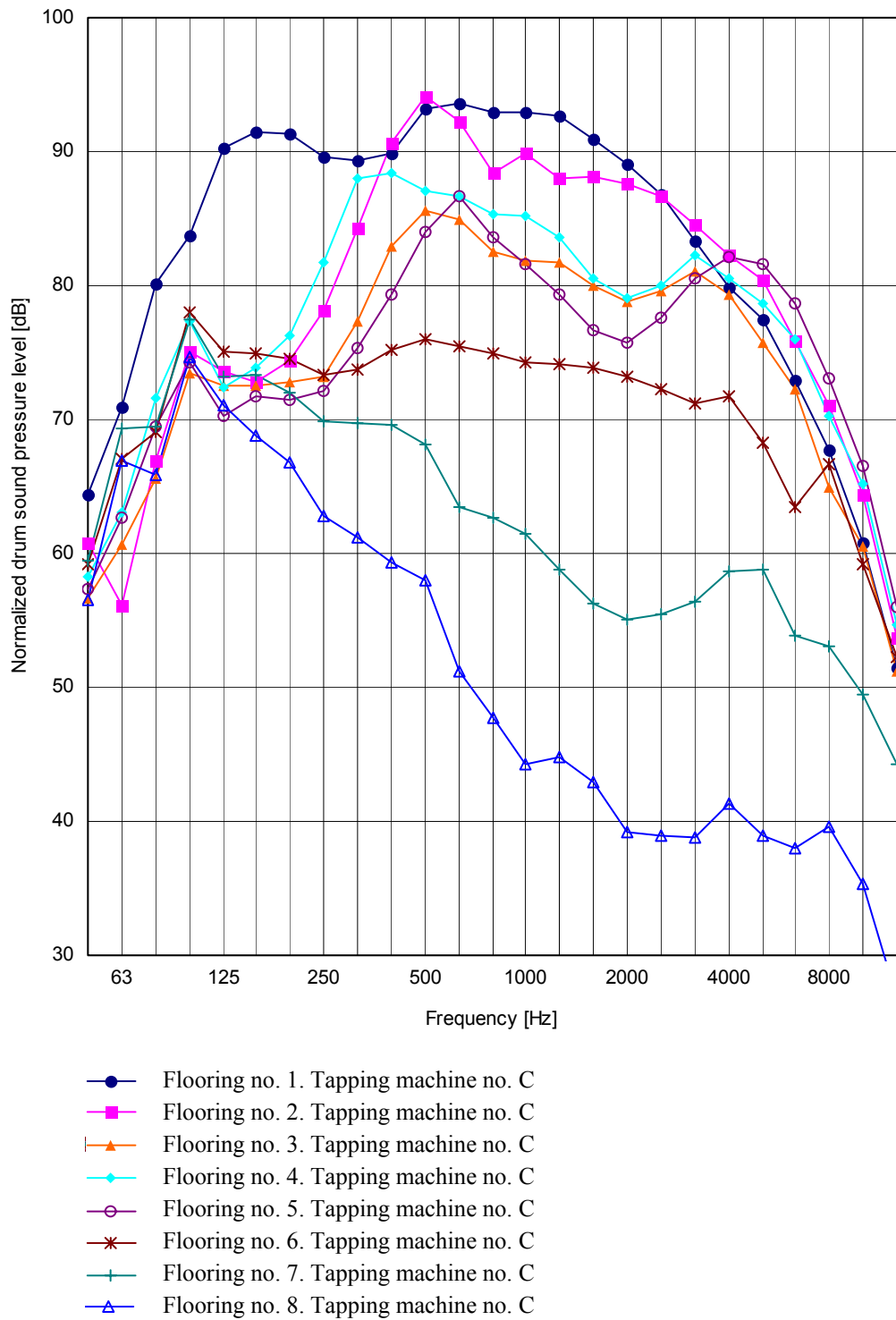
Figure 5.18 with the eight floorings measured with Tapping machine no. C (Tapping machine (I) with improved cover) gives the same picture, but the differences from the more soft coverings, Floorings no. 7 and 8, are more prominent.

For Tapping machine no. G (Tapping machine (II) with improved cover) the difference from the more soft coverings, Floorings no. 7 and 8, seems to be underestimated due to the high inherent noise level of the tapping machine, Figure 5.19.

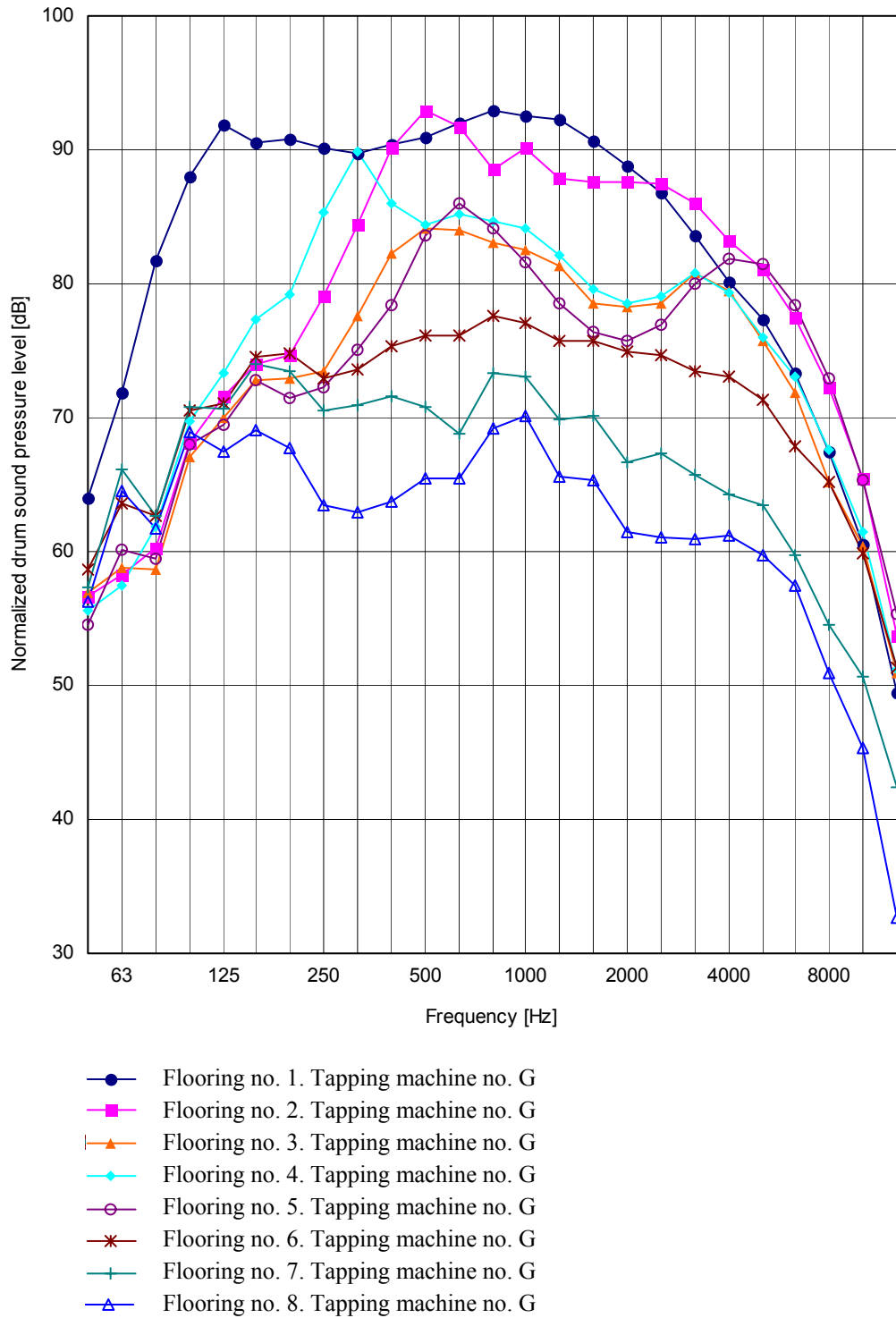
It may be concluded that if small differences between the drum noise levels of the more soft coverings as linoleum and carpets are omitted, Tapping machine no. A could be used, otherwise Tapping machine no. C or even better sound-isolated tapping machines must be used. Tapping machine no. G requires an even better sound-isolated cover in order not to be restricted to loose hard-surfaced floorings.



**Figure 5.17**  
Floorings no. 1-8. Tapping machine no. A.



**Figure 5.18**  
Floorings no. 1-8. Tapping machine no. C.



**Figure 5.19**  
Floorings no. 1-8. Tapping machine no. G.

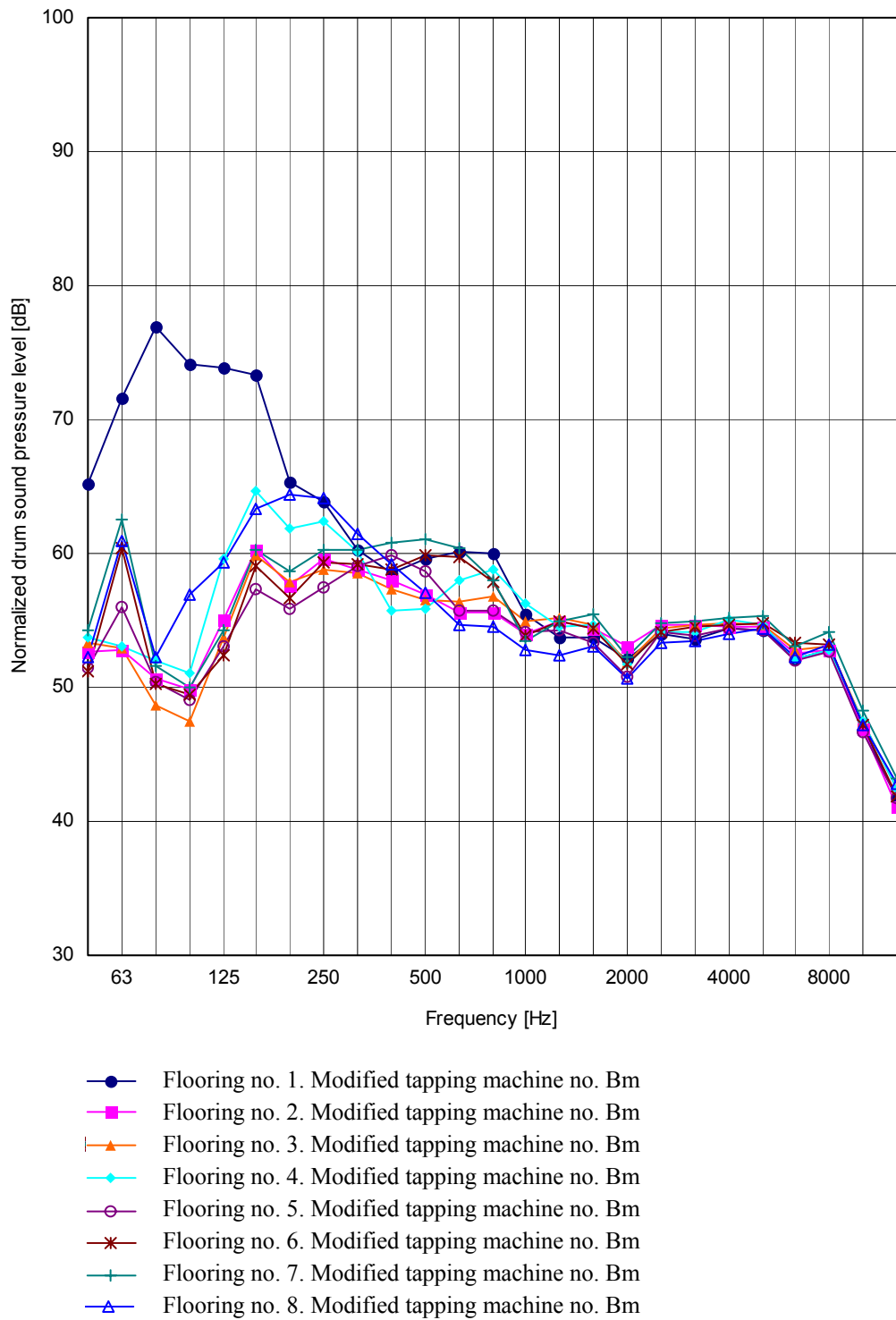
#### **5.6.4 Comparison of Results of Different Floorings Using Modified Standardized Tapping Machines**

Using the modified tapping machines (on the recommended thick soft layer), the whole picture changes. In Figure 5.20 the results for the eight floorings measured with the Modified tapping machine no. Bm (Modified tapping machine (I) without cover) are compared. Obvious differences between the floorings are seen only at low frequencies and primarily for the wooden flooring on joists, for the laminate flooring on fibreboard, and for the carpet tiles with hard reverse side.

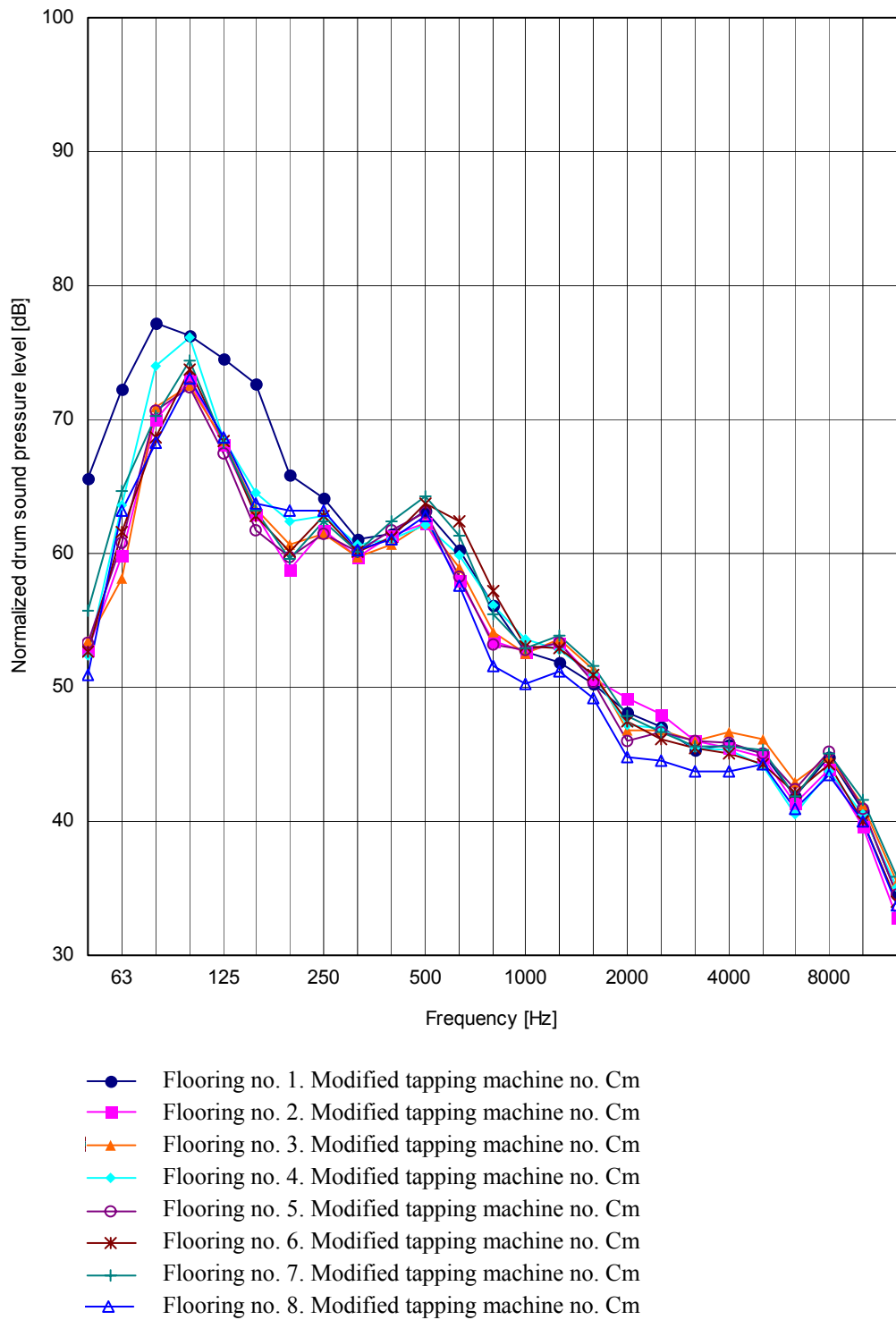
With the Modified tapping machine no. Cm (Modified tapping machine (I) with improved cover), Figure 5.21, the drum noise levels above 800 Hz are lower than measured with the Modified tapping machine no. Bm, but the results up to 800 Hz are higher. The mutual differences between all the floorings are more or less vanished except for the cavity-dominated flooring on joists.

As already mentioned in Section 5.6.1, Modified tapping machine no. Gm (Modified tapping machine (II) with improved cover) gives remarkably higher values in the frequency range above 315 Hz, but although in a wide frequency the drum noise level range is approx. 15 dB higher than for Modified tapping machine no. Cm the picture is the same, Figure 5.22. Mutual differences between the floorings are hard to find except for the lifted floor.

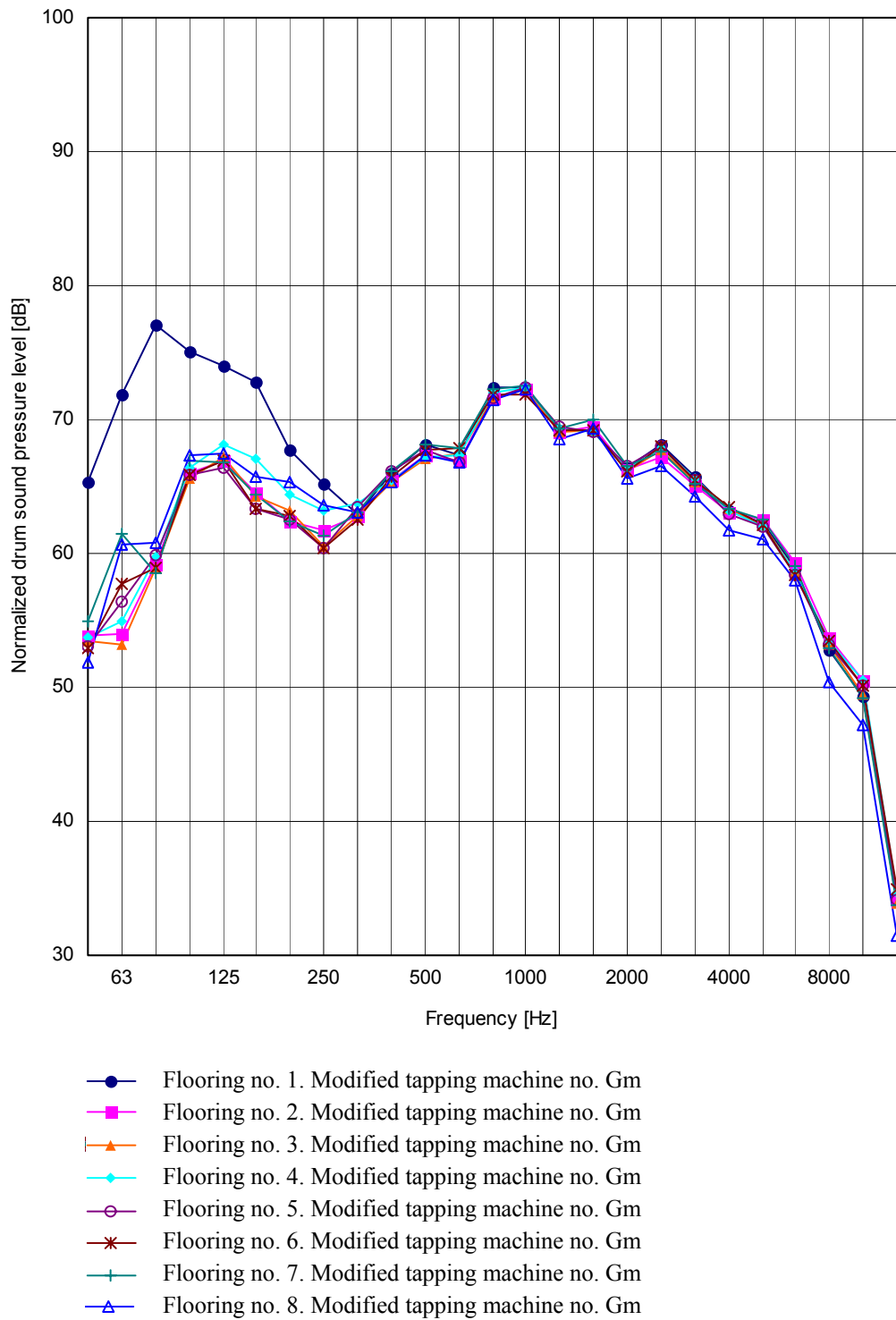
As it is very unlikely that these differences (measured as almost non-existent) between the floorings represent the differences in drum noise levels from the floorings in question, the proposed modification of the standardized tapping machine does not seem to be workable for drum noise measurements.



**Figure 5.20**  
*Floorings no. 1-8. Modified tapping machine no. Bm.*



**Figure 5.21**  
*Floorings no. 1-8. Modified tapping machine no. Cm.*



**Figure 5.22**  
*Floorings no. 1-8. Modified tapping machine no. Gm.*

## **6. Conclusions**

The conclusions of the pilot project and the project group meeting can be summarized as follows:

- Although specific requirements for drum noise in buildings are not yet used, drum noise problems are an issue in many public, school, and office buildings.
- Consequently, flooring manufacturers and building designers take an interest in drum noise reduction and measurements.
- The answers to the questionnaire showed that each laboratory has their own way or ways of making drum noise measurements.
- There is a strong need for a measurement method for drum noise of floorings.
- A standardized method could bring down the confusion about drum noise and the unse-rious competition among manufacturers of floorings, caused by the differences in the survey methods in use.
- Once a standardized laboratory method has been defined, it should be adopted to field conditions as well.
- The measurements showed the following:
  - It is possible to use a method based on EN ISO 140-8 in a reverberant room with a standardized tapping machine with normal cover to find significant differences be-tween different loose hard, wooden or laminate floorings.
  - On concrete, glued linoleum, and soft coverings differences have clearly been indi-cated between the types of tapping machines. Measurements on these materials (in-cluding other glued floorings) require more silent tapping machines.
  - For the existing types of tapping machines, better sound-insulating covers must be developed.
  - The modified tapping machines – in this project modified as suggested using a soft layer under the whole tapping machine in order to bring the impact in agreement with that of a walking person – are not a workable possibility. Most of the differ-ences between the floorings are vanished.
- The findings at LTH, Lund University concerning agreement between objective meas-urements and subjective listening tests will be a part of the later Nordtest project in-volving two sets of laboratory measurements, one at LTH (measured according to EPLF NORM), and one at DELTA (measured according to an EN ISO 140-8 inspired method), and a listening panel. Some of the test results reported in this pilot project will also be a part of the later Nordtest project.

## 6.1 **Proposals for New Measurement Method**

The need for developing a Nordtest or European method for drum noise measurements of floorings for both laboratory and field use has been confirmed.

The presence of two very different methods already standardized in one country and one producers' organisation contributes to the difficulties of getting a general agreement.

The following proposals for a standardized measurement method may be considered:

- In order to combine drum noise measurements with impact noise measurements, a test set-up like in the EN ISO 140 series would be preferable. Measurement in a reverberant chamber would make it possible to use the existing building acoustics laboratories.
- The standardized tapping machine with steel hammers should be kept, but the inherent noise of the machine should be reduced by new and more efficient sound-insulating covers or by noise reduction of the inner parts of the machine, maybe obtained through a change of the impact frequency. The differences as shown in this pilot project between the types of tapping machines should be noticed. Other types of sources may be considered as well.
- If modified tapping machines bringing the impact in agreement with that of a walking person are to be used, less radical modifications than a thick elastic layer under the tapping machine should be studied, e.g. thin soft layers under the hammers.
- Preferably, all kinds of floorings from soft carpets to loose hard-surfaced floorings should fall within the scope of the measurement method. This underlines the need for more silent tapping machines.
- A single number value evaluation must be included in the method. Loudness as well as other possibilities, e.g. A-weighted level or the use of a reference curve should be considered. It should be considered if the evaluation shall focus on the height of the drum noise level or on annoyance.

## 7. **References**

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- [13] NT ACOU 071  
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*Wird das Trittschallverhalten von Gebäudedecken derzeit richtig und ausreichend beschrieben?*  
Sonderdruck aus wksb 44. Jahrgang (1999), Heft 43 (in German)

## Annex A

### Questionnaire and the Answers from the Nordic Project Group

Questionnaire about drum noise measurements.  
NT project nr: 1597- 02

Drum noise  
Survey methods in use or used earlier in your country

#### Laboratory measurements of drum noise

#### DELTA

##### Method

Used at (institution)  
Name?  
Time period

DELTA  
1985 ->

##### Test principle in few words

like ISO 140-8

##### Test room / box

Type  
Dimensions  
Approx. reverberation time at 500 Hz  
Diffusers installed

Reverberant  
7,85x6,25x4,95  
5 sec.  
Yes

##### Test specimen

Test floor  
Size of test specimen  
Load (on assembled coverings with rigid layer)  
Types of floor coverings tested, examples

140 mm standard concrete floor  
approx. 10 m<sup>2</sup>  
approx. 25 kg/m<sup>2</sup>  
Wooden flooring on soft layer  
Wooden flooring glued to concrete  
Wooden flooring on joists  
Linoleum etc. glued to concrete  
Carpets

##### Impact source

Tapping machine  
Modifications  
Additional enclosure  
Other kind of source  
Positions

B&K type 3204  
No  
No - normal cover  
3 "randomly"

##### Microphones

Positions  
Rotating  
Distance between impact source and microphone

1  
Yes  
Min. 1 m

##### Measured Quantity

SPL/averaging time  
Bandwidth  
Frequency range

L1 / 32 sec.  
1/3 octave  
100 Hz - 5000 Hz

##### Corrections

Background noise correction  
Reverberation time correction  
Tapping machine noise correction

Yes  
Yes  
No

##### Evaluation and expression of results

Diagram and/or table (e.g. Ln, LP, Loudness ...)  
Single number value (e.g. LA, 717 ref. Curve, ...)

1/3 octave Ln curve as result  
No

##### Additional information

**Questionnaire about drum noise measurements.**  
NT project nr: 1597- 02

**Drum noise**  
Survey methods in use or used earlier in your country

**Laboratory measurements of drum noise**

<b>Method</b>	Laboratory	Laboratory/Field
Used at (institution)	VTT	VTT
Name?		
Time period	1995-1997	Research project/2002
<b>Test principle in few words</b>	like ISO 140-8	like ISO 140-8
<b>Test room / box</b>		
Type	Reverberant	
Dimensions	5,7x4,7x3,7	
Approx. reverberation time at 500 Hz	2 sec.	under 2 sec
Diffusers installed	Yes	no
<b>Test specimen</b>		
Test floor	160 mm standard concrete floor	160 mm standard concrete floor/hollow core conc.floor
Size of test specimen	approx. 12 m <sup>2</sup>	
Load (on assembled coverings with rigid layer)	approx. 20-25 kg/m <sup>2</sup>	
Types of floor coverings tested, examples	Wooden flooring on soft layer	Lifted floors
<b>Impact source</b>		
Tapping machine	B&K type 3204	B&K type 3204
Modifications	No	No
Additional enclosure	No - normal cover	No - normal cover
Other kind of source		
Positions	3 "randomly"	3 "randomly"
<b>Microphones</b>		
Positions		
Rotating	Yes	Yes
Distance between impact source and microphone	Min. 1 m	Min. 1m
<b>Measured Quantity</b>		
SPL/averaging time	Li / 32 sec.	Li / 32 sec.
Bandwidth	1/3 octave	1/3 octave
Frequency range	100 Hz - 5000 Hz	20-200 Hz
<b>Corrections</b>		
Background noise correction	No	No
Reverberation time correction	No	No
Tapping machine noise correction	No	No
<b>Evaluation and expression of results</b>		
Diagram and/or table (e.g. Ln, LP, Loudness ...)	1/3 octave Ln curve as result	1/3 octave Ln curve as result
Single number value (e.g. LA, 717 ref. Curve, ...)	No	LA
<b>Additional information</b>	Tests carried out very limitedly (2-3 ti	Tests carried ou for research purposes (noises from the heels of shoes not included)

**Questionnaire about drum noise measurements.**  
**NT project nr: 1597- 02**

**Drum noise**  
**Survey methods in use or used earlier in your country**

**Laboratory measurements of drum noise**

**Example**

**Method 1**

**Method**

Used at (institution)  
Name?  
Time period

DELTA	IBRI
1985 ->	2003 ->

**Test principle in few words**

like ISO 140-8	like ISO 140 - 8
----------------	------------------

**Test room / box**

Type  
Dimensions  
Approx. reverberation time at 500 Hz  
Diffusers installed

Reverberant	Reverberant
AxBxC	7.25 x 4.50 x 2.54 = 82,9 m <sup>3</sup>
5 sec.	approx. 1.5 sec
Yes	Yes

**Test specimen**

Test floor  
Size of test specimen  
Load (on assembled coverings with rigid layer)  
Types of floor coverings tested, examples

140 mm standard concrete floor	160 mm standard concrete floor
approx. 10 m <sup>2</sup>	2.6 x 4.2 = 10.9 m <sup>2</sup>
approx. 25 kg/m <sup>2</sup>	approx. 25 kg/m <sup>2</sup>
Wooden flooring on soft layer Wooden flooring glued to concrete Wooden flooring on joists Linoleum etc. glued to concrete Carpets	Wooden floor on a soft layer Wooden floor glued to concrete Wooden floor glued to a soft layer Linoleum etc. loose on concrete Carpets loose on concrete

**Impact source**

Tapping machine  
Modifications  
Additional enclosure  
  
Other kind of source  
Positions

B&K type 3204	Norsonics Type 211
No	No
No - normal cover	Box of plywood, lined with foam on the inside -resting on rubber tubes
3 "randomly"	4 random pos ( 2 on each mic pos)

**Microphones**

Positions  
Rotating  
Distance between impact source and microphone

1	2
Yes	Yes
Min. 1 m	Min 1m

**Measured Quantity**

SPL/averaging time  
Bandwidth  
Frequency range

L1 / 32 sec.	30 sec
1/3 octave	1/3 octave
100 Hz - 5000 Hz	50-5000 Hz

**Corrections**

Background noise correction  
Reverberation time correction  
Tapping machine noise correction

Yes	Background noise check
Yes	Yes
No	No

**Evaluation and expression of results**

Diagram and/or table (e.g. Ln, LP, Loudness ...)  
Single number value (e.g. LA, 717 ref. Curve, ...)

1/3 octave Ln curve as result	1/3 octave Ln - curve and table
No	L <sub>A</sub>

**Additional information**

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**Questionnaire about drum noise measurements.**  
NT project nr: 1597- 02

**Drum noise**  
Survey methods in use or used earlier in your country

NT project nr: 1597- 02

**Laboratory measurements of drum noise**

**Method 1**

**Method 2**

**Method**

Used at (institution)  
Name?  
Time period

BYGGFORSK	BYGGFORSK
Laboratory	Test room
2001 - >	1994

**Test principle in few words**

ISO Tapping machine	ISO Tapping machine
---------------------	---------------------

**Test room / box**

Type  
Dimensions  
Approx. reverberation time at 500 Hz  
Diffusers installed

Reverberant	Reverberant
5.5 x 4.7 x 3.05 = 80 m <sup>3</sup>	> 60 m <sup>3</sup>
4.4 sec.	0.8 sec.
Yes	No

**Test specimen**

Test floor  
Size of test specimen  
Load (on assembled coverings with rigid layer)  
Types of floor coverings tested, examples

120 mm concrete on min.wool	200 mm concrete
~ 4 m <sup>2</sup>	~ 2 m <sup>2</sup>
8 x 10 kg	No
Wooden parquet on soft layers Laminate floor covering on soft layers Wooden parquet on stiff layer (moisture separating function) Laminate floor covering on stiff layer (moisture separating function)	Wooden parquet on different layers

**Impact source**

Tapping machine  
Modifications  
Additional enclosure  
Other kind of source  
Positions

Norsonic type 211	Norsonic type 211
No	No
No - normal cover	No - normal cover
No	No
4 - distributed	2

**Microphones**

Positions  
Rotating  
Distance between impact source and microphone

2 ( x 4)	2 ( x 2)
No	No
> 1 m	> 1 m

**Measured Quantity**

SPL/averaging time  
Bandwidth  
Frequency range

L <sub>i</sub> / 10 sec.	L <sub>i</sub> / 5 sec.
1/3 octave	1/3 octave
50 - 5000 Hz	100 - 3150 Hz

**Corrections**

Background noise correction  
Reverberation time correction  
Tapping machine noise correction

Yes	Background noise check
No (but R1-values exist)	No
No	No

**Evaluation and expression of results**

Diagram and/or table (e.g. Ln, LP, Loudness ...)  
Single number value (e.g. LA, 717 ref. Curve, ...)

1/3 octave L <sub>i</sub> curve	1/3 octave L <sub>i</sub> curve
L <sub>A</sub>	No

**Additional information**

Comparison of different products. Results convertible to L <sub>n</sub> or similar values.	Comparison measurements. Results not convertible to single number values.
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**Questionnaire about drum noise measurements.**  
NT project nr: 1597- 02

**Drum noise**  
Survey methods in use or used earlier in your country

NT project nr: 1597- 02

**Laboratory measurements of drum noise**

**Method 3**

**Method 4**

**Method 5**

**Method**

Used at (institution)  
Name?  
Time period

BYGGFORSK	BYGGFORSK	BYGGFORSK
Test-box	School test-room	Public areas
2001	1998	1994 - >

**Test principle in few words**

Single impact	Practical sources	Practical sources & ISO Tapping machine
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**Test room / box**

Type  
Dimensions  
Approx. reverberation time at 500 Hz  
Diffusers installed

Chamber	Reverberant	Reverberant
0.5 x 0.5 x 0.5 m	> 60 m <sup>3</sup>	5.5 x 4.7 x 3.05 = 80 m <sup>3</sup>
-	0.8 sec.	4.4 sec.
No	No	Yes

**Test specimen**

Test floor  
Size of test specimen  
Load (on assembled coverings with rigid layer)  
Types of floor coverings tested, examples

22 mm particle board on 20 mm plywood	Concrete element (approx. 200 mm)	120 mm concrete on min.wool
0.25 m <sup>2</sup>	2 x 5 m <sup>2</sup> (with and without polish)	2.8 m <sup>2</sup> ( 1 x 2.8 m)
No	No (except the noise sources)	No (except the noise sources)
Laminate floor covering on different sub-layers	Vinyl covering on different sub-layers Linoleum covering on different sub-layers	Slates Clincer tiles Glazed and unglazed ceramic tiles - all products on 50 mm mortar

**Impact source**

Tapping machine  
Modifications  
Additional enclosure  
Other kind of source, I  
Other kind of source, II  
Other kind of source, III  
Positions

No	No	Norsonic type 211
-	-	No
Transparent covering, PMMA-sheet	-	No - normal cover
Steel ball ø 32 mm, 300 mm falling height	Moving chairs, constant velocity	Female walking, stiff heel shoes (pumps)
	Walking person, shoes with different heel stiffness	Male walking, stiff heel shoes
	Pencil drop	Rolling suitcase (approx. 8 kg)
1 fixed	Test area	Test area

**Microphones**

Positions  
Rotating  
Distance between impact source and microphone

1	2	1
No	No	Yes
~ 0.25 m	> 1 m	> 1 m

**Measured Quantity**

SPL/averaging time  
Bandwidth  
Frequency range

Spectrum from Fourier transformation	Only L <sub>A</sub> / I = 2 sec. II = 20 sec, III = max	L <sub>i</sub> / 30 sec.
1/3 octave (result presentation)	No	1/3 octave
50 - 5000 Hz, recommended frequency range above about 1000 Hz	-	50 - 5000 Hz

**Corrections**

Background noise correction  
Reverberation time correction  
Tapping machine noise correction

No (covering)	Background noise check	Background noise check
No	No	No (but R1-values exist)
-	-	-

**Evaluation and expression of results**

Diagram and/or table (e.g. L<sub>n</sub>, L<sub>P</sub>, Loudness ...)  
Single number value (e.g. L<sub>A</sub>, 717 ref. Curve, ...)

1/3 octave spectrum	No	1/3 octave L <sub>i</sub> curve
L <sub>A</sub>	L <sub>A</sub>	L <sub>LIN</sub>

**Questionnaire about drum noise measurements.**  
NT project nr: 1597- 02

**Drum noise**  
Survey methods in use or used earlier in your country

**Laboratory measurements of drum noise**

**Example**

**Method 1**

**Method 2**

**Method**

Used at (institution)  
Name?  
Time period

DELTA	SP	SP
	NF S 31-074 French	EPLF Norm 021029-1
1985 ->		2003

**Test principle in few words**

like ISO 140-8	Like ISO140-8	measurement
----------------	---------------	-------------

**Test room / box**

Type  
Dimensions  
Approx. reverberation time at 500 Hz  
Diffusers installed

Reverberant	Rev.	Semi-anechoic
AxBxC	3,4x6,10x5,2 m	3,9x5,5x4,8 m
5 sec.		< 0.01
Yes	N	N

**Test specimen**

Test floor  
Size of test specimen  
Load (on assembled coverings with rigid layer)

140 mm standard concrete floor	140mm standard conc. Floor	Not spec. 230mm floor used
approx. 10 m <sup>2</sup>	Various Small/large 13,4 m <sup>2</sup>	4,8 m <sup>2</sup>
approx. 25 kg/m <sup>2</sup>	? Possible	None

Types of floor coverings tested, examples

Wooden flooring on soft layer	Y	Y
Wooden flooring glued to concrete	N	N
Wooden flooring on joists	N	N
Linoleum etc. glued to concrete	Y	N
Carpets	Y	N

**Impact source**

Tapping machine  
Modifications  
Additional enclosure  
Other kind of source  
Positions

B&K type 3204	BK 3204	BK 3204
No	Yes sound insulation hood	Yes hood removed
No - normal cover	Yes sound insulation hood	Yes hood removed
	N	N
3 "randomly"	Min. 3 random	8 fixed

**Microphones**

Positions  
Rotating  
Distance between impact source and microphone

1	Min. 3 Min. 6 measurements	4 fixed
Yes	Y	N
Min. 1 m	Min. 1m	100 cm fixed

**Measured Quantity**

SPL/averaging time  
Bandwidth  
Frequency range

L1 / 32 sec.	L1/64 sec.	L1/30 sec.
1/3 octave	1/3 octave	1/3 octave
100 Hz - 5000 Hz	100-5000 Hz	125-12500 Hz

**Corrections**

Background noise correction  
Reverberation time correction  
Tapping machine noise correction

Yes	Y	Y
Yes	Y	N
No	(Y)	N

**Evaluation and expression of results**

Diagram and/or table (e.g. Ln, LP, Loudness ...)  
Single number value (e.g. LA, 717 ref. Curve, ...)

1/3 octave Ln curve as result	1/3 octave Ln curve as result	Table 8 measurements
No	4 classes A,B,C,D	Sone average based on four lowest measurements Nm

**Additional information**

	The French method is useless since the tapping machine is having to high mechanical noise levels. The calculations are very woodoo and the result is favouring soft coverings/carpets. The results can not be used for comparison.	The EPLF is an OK method. Straight forward. Good comparability. To time consuming to calculate the loudness. The need for a semi anechoic might be a problem.
--	--	---

## **Annex B**

### **Suggested Specifications for Modified Tapping Machines**

#### How to modify the standard tapping machine:

The standard tapping machine shall be placed on an elastic layer. Put 1 mm steel plates under the feet of the tapping machine to prevent the tapping machine from sinking into the elastic layer. Adjust the falling height of the hammers to 40 mm above the surface of the elastic layer. The elastic layer could be Sylomer L 25, green, thickness 25 mm (dynamic stiffness about  $s' = 31 \text{ MN/m}^3$ ), Producer: Getzner, Austria / Germany.

#### Attention!

Sylomer L 25 is a foam. Foams have fluctuating mechanical characteristics which in addition depend on temperature. It is strongly recommended to check the dynamic stiffness of the piece of layer used by measurement (acc. EN 29052-1) and to record the temperature of the specimen.

W. Scholl, 16.5.2003

## **Annex C**

### **Values of the Drum Noise Test Results of the Measurements in this Pilot Project**

#### **NT 1597 02. Pilot project laboratory measurements of drum noise from floorings**

Normalized drum sound pressure levels per 1/3-octave [dB]

Flooring No. 1. 22 mm wooden flooring on timber joists

T. machine Cover Modification	A normal	Bm without Sylomer	C improved	Cm improved Sylomer	G improved	Gm improved Sylomer
Frequency	1A	1Bm	1C	1Cm	1G	1Gm
50	62,8	65,2	64,4	65,7	64,0	65,3
63	70,3	71,7	71,0	72,3	71,9	71,8
80	79,8	77,0	80,1	77,2	81,8	77,0
100	85,7	74,1	83,8	76,3	88,1	75,0
125	92,8	73,8	90,3	74,6	91,9	74,0
160	91,9	73,3	91,5	72,6	90,6	72,7
200	92,0	65,3	91,3	65,9	90,9	67,7
250	92,1	63,8	89,6	64,2	90,1	65,2
315	89,2	60,3	89,3	61,1	89,7	62,9
400	89,9	58,5	89,8	61,4	90,4	66,0
500	91,2	59,7	93,3	63,2	90,9	68,2
630	92,8	60,2	93,6	60,2	91,9	67,4
800	93,2	59,9	93,0	56,2	93,0	72,5
1000	92,7	55,5	92,9	52,6	92,6	72,4
1250	92,1	53,7	92,7	51,9	92,3	69,2
1600	90,3	53,7	90,9	50,3	90,7	69,3
2000	88,4	52,1	89,0	48,1	88,9	66,5
2500	86,2	54,0	86,8	47,1	86,8	68,2
3150	83,2	53,6	83,3	45,3	83,6	65,8
4000	79,9	54,4	79,8	45,7	80,2	63,2
5000	76,7	54,2	77,5	45,1	77,4	62,3
6300	72,5	52,2	72,9	41,9	73,3	58,9
8000	67,5	52,8	67,7	44,8	67,4	52,9
10000	60,3	47,0	60,9	40,8	60,6	49,3
12500	50,0	41,7	51,5	34,5	49,5	34,3

**NT 1597 02. Pilot project laboratory measurements of drum noise from floorings**

Normalized drum sound pressure levels per 1/3-octave [dB]

Flooring No. 2. 14 mm wooden flooring on soft layer

T. machine Cover Modification	A normal	Bm without Sylomer	C improved	Cm improved Sylomer	G improved	Gm improved Sylomer
Frequency	2A	2Bm	2C	2Cm	2G	2Gm
50	58,4	52,7	60,8	52,8	56,7	53,9
63	59,5	52,8	56,2	59,9	58,3	54,0
80	59,0	50,7	67,0	70,1	60,2	59,2
100	65,9	49,9	75,1	73,0	68,2	66,0
125	70,2	55,1	73,6	68,2	71,6	67,0
160	75,2	60,2	72,8	63,0	74,0	64,5
200	78,7	57,7	74,5	58,8	74,7	62,4
250	84,0	59,6	78,2	61,7	79,0	61,8
315	82,3	58,9	84,3	59,8	84,4	62,9
400	87,8	58,0	90,7	61,4	90,2	65,4
500	91,0	57,0	94,1	62,3	92,9	67,3
630	92,3	55,6	92,3	58,0	91,8	67,0
800	89,2	55,6	88,4	53,4	88,6	71,6
1000	89,2	54,0	89,9	52,6	90,1	72,3
1250	87,3	54,9	88,0	53,4	87,8	69,0
1600	88,0	54,4	88,1	50,7	87,5	69,5
2000	87,6	53,1	87,6	49,2	87,6	66,2
2500	87,0	54,6	86,6	48,0	87,4	67,1
3150	84,8	54,7	84,5	46,0	86,0	65,0
4000	82,6	54,5	82,3	45,5	83,2	63,1
5000	80,9	54,5	80,5	44,9	81,1	62,5
6300	76,8	52,6	75,9	41,3	77,4	59,4
8000	72,0	52,8	71,1	43,9	72,3	53,8
10000	65,1	47,0	64,4	39,5	65,4	50,5
12500	53,8	41,1	53,7	32,8	53,8	34,0

**NT 1597 02. Pilot project laboratory measurements of drum noise from floorings**

Normalized drum sound pressure levels per 1/3-octave [dB]

Flooring No. 3. 11 mm laminate flooring with soft layer

T. machine Cover Modification	A normal	Am normal Sylomer	B without	Bm without Sylomer	C improved	Cm improved Sylomer	D normal
Frequency	3A	3Am	3B	3Bm	3C	3Cm	3D
50	57,3	54,4	58,8	53,3	56,6	53,5	57,6
63	58,3	52,5	59,7	52,9	60,7	58,2	57,8
80	57,6	52,4	57,3	48,7	65,6	71,0	56,5
100	64,1	55,8	62,7	47,5	73,5	72,5	63,2
125	67,1	60,6	66,1	53,7	72,5	68,4	69,3
160	73,8	69,7	72,2	59,9	72,5	63,3	73,5
200	75,0	62,9	73,1	57,9	72,8	60,7	77,3
250	78,3	67,4	74,9	58,8	73,2	61,5	73,9
315	77,2	61,5	79,0	58,5	77,4	59,7	77,6
400	80,8	61,4	82,8	57,3	82,9	60,7	81,3
500	82,3	61,8	84,0	56,5	85,6	62,3	83,7
630	84,0	61,2	83,3	56,4	85,0	59,0	84,0
800	82,8	61,4	83,7	56,8	82,6	54,2	84,0
1000	81,5	60,2	82,8	54,9	81,9	52,6	83,8
1250	81,3	61,3	81,4	55,1	81,8	53,7	82,4
1600	79,8	60,2	79,0	54,6	80,0	51,3	79,0
2000	78,1	60,5	78,3	51,8	78,8	46,8	78,6
2500	78,6	59,2	79,2	54,4	79,6	46,8	79,2
3150	80,2	59,2	80,7	54,7	81,1	46,0	81,1
4000	78,8	58,1	79,1	54,8	79,3	46,7	79,9
5000	75,1	57,1	75,7	54,6	75,8	46,1	76,6
6300	70,9	53,7	71,5	52,9	72,3	42,9	73,1
8000	64,5	50,3	65,8	53,0	65,0	44,9	66,6
10000	59,1	44,6	60,2	47,5	60,6	41,2	61,3
12500	50,0	37,9	51,6	42,4	51,2	35,4	52,0

**NT 1597 02. Pilot project laboratory measurements of drum noise from floorings**

Normalized drum sound pressure levels per 1/3-octave [dB]

Flooring No. 3. 11 mm laminate flooring with soft layer

T. machine Cover Modification	Dm normal Sylomer	E without	Em without Sylomer	F without	Fm without Sylomer	G improved	Gm improved Sylomer
Frequency	3Dm	3E	3Em	3F	3Fm	3G	3Gm
50	52,5	57,0	52,2	56,9	52,1	56,9	53,4
63	52,6	58,4	52,4	59,5	53,4	58,8	53,2
80	50,5	56,8	48,9	57,4	50,6	58,7	59,0
100	54,4	62,9	49,5	63,2	51,1	67,1	65,5
125	66,8	66,3	53,9	66,7	54,3	70,0	67,2
160	64,8	72,4	59,8	72,8	60,5	72,8	64,3
200	74,5	73,2	58,9	74,2	59,0	73,0	63,2
250	66,1	74,9	60,0	76,3	62,0	73,4	60,5
315	65,8	79,1	59,7	80,0	63,8	77,6	62,9
400	67,7	82,7	59,0	83,1	69,4	82,2	65,4
500	68,8	83,7	59,9	84,1	78,9	84,1	67,1
630	69,7	83,0	61,4	82,4	72,0	84,0	67,4
800	75,2	83,3	70,2	81,7	76,0	83,1	71,7
1000	75,1	83,9	74,8	81,7	74,5	82,6	72,2
1250	72,1	82,7	73,9	82,0	79,2	81,3	69,1
1600	72,7	79,0	73,2	81,2	79,0	78,5	69,1
2000	70,6	78,7	72,8	81,1	78,8	78,2	66,1
2500	71,5	79,8	74,3	81,3	79,8	78,6	67,7
3150	69,3	81,5	73,5	84,0	83,6	80,8	65,3
4000	68,0	80,4	72,6	83,6	83,9	79,5	63,3
5000	67,6	77,8	71,8	81,5	82,4	75,7	62,1
6300	63,1	74,3	68,5	79,9	81,5	71,9	58,7
8000	59,8	68,6	65,6	75,1	77,1	65,2	53,3
10000	56,2	63,4	62,2	70,3	73,2	60,4	49,4
12500	44,6	53,7	50,8	62,7	65,7	51,0	33,9

**NT 1597 02. Pilot project laboratory measurements of drum noise from floorings**

Normalized drum sound pressure levels per 1/3-octave [dB]

Flooring No. 4. 8 mm laminate flooring on fibreboard

T. machine Cover Modification	A normal	Bm without Sylomer	C improved	Cm improved Sylomer	G improved	Gm improved Sylomer
Frequency	4A	4Bm	4C	4Cm	4G	4Gm
50	57,5	53,8	58,2	52,4	55,6	53,8
63	59,4	53,0	63,1	63,6	57,5	55,0
80	58,7	52,0	71,6	74,0	61,9	59,7
100	64,9	51,0	77,4	76,2	69,7	66,4
125	70,1	59,6	72,4	68,5	73,4	68,1
160	76,6	64,7	73,8	64,5	77,4	67,1
200	81,1	61,9	76,3	62,4	79,2	64,4
250	87,9	62,4	81,7	62,8	85,3	63,2
315	87,2	60,2	88,0	60,7	89,9	63,7
400	86,9	55,7	88,4	61,0	86,0	65,5
500	83,4	55,9	87,1	62,1	84,4	67,2
630	86,2	58,0	86,7	59,8	85,2	67,4
800	86,2	58,8	85,4	56,2	84,6	72,0
1000	84,0	56,2	85,2	53,6	84,1	72,4
1250	82,5	54,6	83,6	52,8	82,1	69,3
1600	80,8	54,6	80,5	51,0	79,7	69,0
2000	78,6	51,7	79,0	47,2	78,6	66,3
2500	79,2	54,1	80,0	46,9	79,0	67,9
3150	81,5	54,1	82,2	45,5	80,8	65,6
4000	80,2	55,1	80,6	45,4	79,3	63,2
5000	77,9	54,6	78,7	44,1	76,0	62,1
6300	74,5	52,2	76,0	40,6	73,0	58,7
8000	69,6	52,8	70,3	43,8	67,6	53,4
10000	63,6	47,5	65,2	40,6	61,5	50,5
12500	53,8	42,5	54,7	35,0	51,2	34,7

**NT 1597 02. Pilot project laboratory measurements of drum noise from floorings**

Normalized drum sound pressure levels per 1/3-octave [dB]

Flooring No. 5. 7 mm wooden flooring on soft layer

T. machine Cover Modification	A normal	Bm without Sylomer	C improved	Cm improved Sylomer	G improved	Gm improved Sylomer
Frequency	5A	5Bm	5C	5Cm	5G	5Gm
50	58,6	51,5	57,4	53,4	54,6	53,1
63	61,1	56,0	62,7	60,8	60,1	56,4
80	58,1	50,4	69,5	70,7	59,4	59,9
100	65,4	49,0	74,2	72,4	68,0	65,9
125	67,0	53,1	70,3	67,5	69,5	66,3
160	73,3	57,4	71,8	61,8	72,8	63,3
200	74,9	55,8	71,5	59,8	71,5	62,6
250	78,9	57,5	72,1	61,5	72,3	60,4
315	75,7	59,1	75,4	60,1	75,1	63,5
400	77,7	59,8	79,3	61,7	78,4	66,1
500	82,1	58,7	84,0	63,1	83,6	67,7
630	86,6	55,7	86,7	58,2	86,0	66,8
800	84,2	55,7	83,6	53,1	84,2	71,7
1000	80,8	54,1	81,6	52,8	81,6	72,4
1250	79,0	54,2	79,3	53,4	78,6	69,4
1600	76,2	53,3	76,6	50,4	76,3	69,1
2000	74,8	50,9	75,7	46,0	75,7	66,5
2500	75,9	54,1	77,6	46,7	76,9	68,0
3150	78,8	53,9	80,5	46,0	80,0	65,4
4000	80,3	54,4	82,1	45,8	81,9	62,9
5000	79,5	54,2	81,7	45,1	81,5	62,0
6300	75,7	52,0	78,7	42,5	78,4	58,4
8000	69,3	52,6	73,1	45,1	72,9	53,2
10000	61,3	46,6	66,5	40,9	65,4	50,1
12500	50,4	41,7	56,0	34,5	55,4	34,1

**NT 1597 02. Pilot project laboratory measurements of drum noise from floorings**

Normalized drum sound pressure levels per 1/3-octave [dB]

Flooring No. 6. Concrete floor (140 mm) – no flooring

T. machine Cover Modification	A normal	Am normal Sylomer	B without	Bm without Sylomer	C improved	Cm improved Sylomer	D normal
Frequency	6A	6Am	6B	6Bm	6C	6Cm	6D
50	60,5	54,0	60,0	51,2	59,1	52,7	59,6
63	66,5	58,8	66,8	60,4	67,0	61,6	65,3
80	63,1	53,5	63,3	50,3	69,1	68,7	61,1
100	68,6	56,9	68,5	49,5	78,0	73,8	68,3
125	69,0	60,0	68,4	52,4	75,1	68,4	71,5
160	75,5	68,7	74,1	59,0	75,0	62,8	74,8
200	74,9	61,1	74,2	56,7	74,5	60,1	80,2
250	73,8	67,0	72,6	59,3	73,4	62,8	75,1
315	73,9	60,7	73,5	59,2	73,7	60,2	74,4
400	75,3	60,6	74,9	58,8	75,3	61,2	75,9
500	76,1	62,7	75,3	59,9	76,1	63,8	76,6
630	76,1	60,8	75,7	59,8	75,5	62,5	76,7
800	75,8	60,0	75,8	57,8	74,9	57,2	79,8
1000	74,9	58,6	74,8	53,9	74,2	53,1	79,1
1250	75,1	60,6	74,7	54,9	74,1	52,9	77,0
1600	74,6	58,2	74,5	54,4	73,9	50,9	77,5
2000	74,2	56,1	73,8	51,7	73,2	47,5	76,7
2500	73,0	55,5	73,2	54,2	72,2	46,2	76,4
3150	72,1	54,4	72,0	54,6	71,2	45,4	74,3
4000	72,4	52,1	72,6	54,6	71,7	45,1	74,4
5000	71,6	52,1	73,4	54,8	68,3	44,3	73,2
6300	66,6	48,7	68,7	53,4	63,5	42,1	69,3
8000	69,0	49,0	71,5	53,3	66,6	44,3	66,6
10000	60,8	42,9	62,2	47,2	59,2	40,1	60,5
12500	53,5	36,4	56,2	41,9	52,3	34,0	51,5

**NT 1597 02. Pilot project laboratory measurements of drum noise from floorings**

Normalized drum sound pressure levels per 1/3-octave [dB]

Flooring No. 6. Concrete floor (140 mm) – no flooring

T. machine Cover Modification	Dm normal Sylomer	E without	Em without Sylomer	F without	Fm without Sylomer	G improved	Gm improved Sylomer
Frequency	6Dm	6E	6Em	6F	6Fm	6G	6Gm
50	52,1	59,0	51,6	61,9	50,4	58,7	52,9
63	58,5	65,5	58,0	57,3	57,6	63,6	57,8
80	51,0	61,4	49,5	59,9	49,8	62,6	59,0
100	54,9	67,9	50,3	67,1	52,0	70,6	65,9
125	66,0	68,4	52,6	68,7	53,8	71,1	66,9
160	64,5	73,9	58,6	74,0	58,2	74,5	63,3
200	76,4	74,2	58,6	74,5	59,9	74,9	62,7
250	68,8	72,8	60,3	73,0	63,4	73,0	60,4
315	65,7	73,4	60,4	73,7	64,6	73,6	62,6
400	67,1	74,9	60,8	75,2	71,2	75,3	65,8
500	68,9	75,6	61,9	81,2	80,4	76,1	67,7
630	69,9	75,7	62,7	76,8	74,4	76,2	67,9
800	75,4	77,2	70,8	78,8	78,1	77,6	71,9
1000	75,0	79,1	75,5	78,6	75,8	77,0	71,9
1250	72,5	78,3	74,7	81,9	81,2	75,7	69,2
1600	72,7	78,2	74,0	82,7	81,0	75,8	69,2
2000	71,0	77,9	73,7	82,2	80,4	75,0	66,2
2500	71,8	78,4	75,5	82,9	82,1	74,7	68,0
3150	69,2	77,0	74,7	86,8	85,7	73,4	65,4
4000	68,2	76,6	74,1	88,0	86,1	73,1	63,4
5000	67,6	75,5	73,1	87,1	84,9	71,3	62,1
6300	63,1	72,6	69,7	86,2	84,1	67,9	58,4
8000	59,6	69,2	67,5	82,8	80,3	65,2	53,5
10000	55,9	63,5	64,7	79,1	76,6	59,9	50,1
12500	44,4	54,2	52,7	72,0	69,4	51,3	34,9

**NT 1597 02. Pilot project laboratory measurements of drum noise from floorings**

Normalized drum sound pressure levels per 1/3-octave [dB]

Flooring No. 7. 3 mm glued linoleum with soft layer

T. machine Cover Modification	A normal	Bm without Sylomer	C improved	Cm improved Sylomer	G improved	Gm improved Sylomer
Frequency	7A	7Bm	7C	7Cm	7G	7Gm
50	59,3	54,2	59,5	55,7	57,3	54,9
63	67,7	62,5	69,3	64,7	66,2	61,5
80	62,8	51,6	69,5	70,3	62,7	58,6
100	69,3	50,0	77,5	74,4	70,9	67,0
125	68,5	54,3	73,2	68,3	70,7	66,8
160	74,3	60,2	73,3	63,1	73,9	64,4
200	72,4	58,7	72,0	59,6	73,5	62,4
250	72,3	60,2	69,9	62,4	70,6	61,4
315	70,7	60,2	69,8	60,2	70,9	63,1
400	70,4	60,7	69,6	62,3	71,6	66,1
500	67,5	61,1	68,1	64,3	70,8	68,1
630	64,0	60,4	63,5	61,4	68,8	67,8
800	64,4	58,0	62,6	55,5	73,3	72,3
1000	62,7	53,5	61,4	52,9	73,1	72,6
1250	62,8	54,9	58,8	53,9	69,9	69,3
1600	60,8	55,5	56,2	51,6	70,1	70,0
2000	58,7	52,3	55,1	47,8	66,7	66,5
2500	58,6	54,7	55,5	46,7	67,4	67,6
3150	58,9	55,0	56,4	45,6	65,8	65,3
4000	60,6	55,1	58,7	45,6	64,3	63,3
5000	59,8	55,4	58,8	45,3	63,4	62,5
6300	55,7	53,1	53,9	41,9	59,8	59,1
8000	54,8	54,1	53,0	45,1	54,5	52,9
10000	50,4	48,3	49,5	41,7	50,7	49,2
12500	45,3	43,2	44,3	35,9	42,4	33,8

**NT 1597 02. Pilot project laboratory measurements of drum noise from floorings**

Normalized drum sound pressure levels per 1/3-octave [dB]

Flooring No. 8. 8 mm carpet tiles with hard back side

T. machine Cover Modification	A normal	Bm without Sylomer	C improved	Cm improved Sylomer	G improved	Gm improved Sylomer	B without
Frequency	8A	8Bm	8C	8Cm	8G	8Gm	8B
50	55,1	52,3	56,5	51,0	56,3	51,8	55,6
63	66,8	60,9	66,9	63,2	64,5	60,6	67,2
80	60,3	52,3	65,9	68,3	61,8	60,7	60,9
100	65,5	57,0	74,6	73,1	68,9	67,3	65,4
125	65,0	59,4	71,1	68,7	67,5	67,4	65,0
160	69,8	63,3	68,8	63,8	69,0	65,7	68,5
200	67,1	64,4	66,9	63,2	67,8	65,3	66,6
250	63,3	64,1	62,8	63,1	63,5	63,6	62,0
315	60,7	61,5	61,2	60,2	62,9	63,1	60,2
400	57,9	59,2	59,3	61,0	63,8	65,3	56,3
500	56,8	57,1	58,1	62,9	65,5	67,3	52,3
630	52,7	54,7	51,2	57,7	65,4	66,8	48,4
800	53,1	54,5	47,8	51,6	69,2	71,5	48,1
1000	51,7	52,9	44,3	50,3	70,1	72,3	44,6
1250	53,3	52,5	44,9	51,2	65,6	68,5	47,1
1600	51,2	53,1	42,9	49,2	65,3	69,3	48,6
2000	49,9	50,6	39,2	44,8	61,5	65,6	46,7
2500	52,0	53,3	39,0	44,5	61,1	66,5	51,9
3150	51,0	53,5	38,8	43,8	60,9	64,2	53,0
4000	48,9	54,0	41,3	43,8	61,2	61,8	53,1
5000	48,7	54,4	39,0	44,3	59,8	61,1	54,1
6300	47,0	52,3	38,0	40,9	57,5	58,1	54,2
8000	46,6	53,3	39,6	43,4	50,9	50,4	53,3
10000	40,6	47,2	35,3	40,0	45,4	47,2	47,5
12500	34,3	42,8	26,8	33,7	32,7	31,5	42,6