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"Nordic Intercomparison Programme in the Field of Acoustics"
3. Measurement:
Field measurements of airborne sound insulation
Title
“Nordic Intercomparison Programme in the Field of Acoustics”

3. Measurement: Field measurements of airborne sound insulation

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<th>Ref.no.</th>
<th>Our ref.</th>
<th>Date of test</th>
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<tr>
<td>P 8704a</td>
<td>DH-JAC-HSO/Ian</td>
<td>August, 1995</td>
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Clients ref.
Nordtest Project No 1023-92

Résumé
An intercomparison concerning field measurements of airborne sound insulation has been carried through by five participating laboratories from the 22nd to the 25th August 1995. Three different test methods were used: The traditional ISO 140-4 method, a proposed new simple survey method and an intensity scanning method.

For the measurements carried out according to ISO 140-4 the reproducibility shows good agreement with the reference values stated in ISO 140-2.

With the survey method a surprisingly good reproducibility is obtained even for the more difficult room types.

The achieved reproducibility for the intensity method is acceptable. During the measurements some proposals for improvement of the intensity method were found.
## CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Foreword</td>
<td>5</td>
</tr>
<tr>
<td>2. Summary</td>
<td>6</td>
</tr>
<tr>
<td>3. Introduction</td>
<td>7</td>
</tr>
<tr>
<td>3.1. Background</td>
<td>7</td>
</tr>
<tr>
<td>3.2. Objective</td>
<td>7</td>
</tr>
<tr>
<td>3.3. Approach</td>
<td>8</td>
</tr>
<tr>
<td>4. ISO 140-4 Measurements</td>
<td>10</td>
</tr>
<tr>
<td>4.1. Introduction</td>
<td>10</td>
</tr>
<tr>
<td>4.2. Description of test objects</td>
<td>10</td>
</tr>
<tr>
<td>4.3. Instrumentation</td>
<td>11</td>
</tr>
<tr>
<td>4.4. Calculation</td>
<td>11</td>
</tr>
<tr>
<td>4.5. Test procedure</td>
<td>11</td>
</tr>
<tr>
<td>4.6. Results and analysis of the results</td>
<td>12</td>
</tr>
<tr>
<td>5. Survey method measurements</td>
<td>19</td>
</tr>
<tr>
<td>5.1. Introduction</td>
<td>19</td>
</tr>
<tr>
<td>5.2. Description of test objects</td>
<td>19</td>
</tr>
<tr>
<td>5.3. Instrumentation</td>
<td>19</td>
</tr>
<tr>
<td>5.4. Test procedure</td>
<td>20</td>
</tr>
<tr>
<td>5.5. Results and analysis of the results</td>
<td>20</td>
</tr>
<tr>
<td>6. Intensity measurements</td>
<td>30</td>
</tr>
<tr>
<td>6.1. Introduction</td>
<td>30</td>
</tr>
<tr>
<td>6.2. Description of test objects</td>
<td>30</td>
</tr>
<tr>
<td>6.3. Instrumentation</td>
<td>31</td>
</tr>
<tr>
<td>6.4. Calculation</td>
<td>31</td>
</tr>
<tr>
<td>6.5. Test procedure</td>
<td>32</td>
</tr>
<tr>
<td>6.6. Results and analysis of the results</td>
<td>33</td>
</tr>
<tr>
<td>6.7. Comparison with traditional ISO 140-4 measurement</td>
<td>41</td>
</tr>
<tr>
<td>7. Conclusion</td>
<td>42</td>
</tr>
<tr>
<td>7.1. ISO 140-4 measurements</td>
<td>42</td>
</tr>
<tr>
<td>7.2. Survey method measurements</td>
<td>42</td>
</tr>
<tr>
<td>7.3. Intensity measurements</td>
<td>42</td>
</tr>
<tr>
<td>8. References</td>
<td>44</td>
</tr>
</tbody>
</table>
Enclosures:

1.1-1.18 Reference [1]
2.1-2.27 Reference [2]
3.1-3.20 Reference [3]
4.1-4.3 Drawings
5.1-5.4 Test and calculation results of the ISO 140-4 measurements
6.1-6.3 Test and calculation results of the survey method measurements
7.1-7.5 Comparison between results from survey method and ISO 140-4
8.1-8.4 Test and calculation results of the intensity method measurements
1. FOREWORD

This project has been financially supported by Nordtest (project 1023-92).

Measurements were carried out by the following laboratories:

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IS-112 Reykjavik
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S-501 15 Borås
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Project leader: Henrik S. Olesen

C. G. Jensen A/S has kindly allowed us to use two terrace houses under construction for some of the measurements.
2. SUMMARY

An intercomparison concerning field measurements of airborne sound insulation has been carried through by five participating laboratories. Three different test methods were used: The traditional ISO 140-4 method [1], a proposed new simple survey method [2] and an intensity scanning method [3].

The intercomparison was planned not to include differences in test results caused by the type of measurement equipment. Therefore all laboratories used the same equipment.

The reproducibility has been estimated for all measurements and compared with the reproducibility values stated in ISO 140-2. The measurements according to ISO 140-4 and the survey method were performed between rooms in two terrace houses. For the measurements carried out according to ISO 140-4 the reproducibility shows good agreement with the ISO 140-2 values apart from measurements including a small bathroom.

With the survey method a surprisingly good reproducibility is obtained even for the more difficult room types.

The intensity method was used for measurements on a door combined with a window section. The achieved reproducibility is acceptable. During the measurements some proposals for improvement of the intensity method were found.
3. INTRODUCTION

3.1. Background

Nordtest has decided to support three intercomparisons in the field of acoustics, one in each of the years 1993, 1994 and 1995. In the Nordtest action programme for 1992-1994 intercomparison is one of the items with a high priority.

Intercomparison is an important method of improving the quality and accuracy of measurements and furthermore the only possibility to obtain an estimate of the inter-laboratory reproducibility. A high degree of agreement between test results obtained by different laboratories when testing identical test objects is of great importance to prevent trade barriers.

The measurements dealt with in the first intercomparison in 1993 were laboratory measurements of the sound absorption of a suspended ceiling [7]. In 1994 the intercomparison concerned laboratory measurements of impact sound insulation of floor coverings on a standard floor [8].

3.2. Objective

As a part of Nordtest project 879-90, "Determination of sound reduction indices using intensity techniques in the field"[3] an intercomparison was carried through in Trondheim. Field measurements were performed with the conventional ISO 140 method and with the proposed new intensity method. The measurements were carried out in an empty old peoples home, partly between a reception and a foyer and partly between a corridor and an office.

The agreement between the results from the four participating laboratories was not satisfactory neither for the traditional measurements nor for the intensity measurements. It was concluded that the different types of noise sources and their positions had an influence on the results. It shall be mentioned that the rooms in which the measurements were performed were irregular and a "difficult case", but on the other hand not unrealistic.

On this background it was decided by the Nordtest expert group "Acoustics and noise" that an intercomparison of field measurements of airborne sound insulation should be repeated. Both the traditional ISO 140 method and the proposed intensity method should be included. Furthermore Nordtest extended the financial support to make it possible to include measurements with a new simple survey method prepared by CEN/TC 126/WG 1. The working group has a need for results where the survey method is compared with the ISO 140 method.
3.3. Approach

Measurements have been carried out between rooms in two-storeyed terrace houses partly by use of the traditional ISO 140-4 method [1] and partly by the survey method [2]. Intensity measurements [3] have been carried out on a door combined with a window section installed between a corridor and a small office. (Located on DTU).

The standards and test methods used are included in enclosures 1-3. Some of the laboratories used supplementary the additional guidelines given in “Measurements of the acoustical properties of buildings - additional guidelines” (not enclosed) [4].

It was decided that all laboratories should use the same measurement equipment for the ISO 140 measurements as for the intensity measurements. For the survey method the laboratories used their own sound level meter, but the same loudspeaker. (The equipment used is stated in the chapters 4.3, 5.3 and 6.3). The reason for choosing this approach is - e.g. based on the results from Trondheim - that an intercomparison only comprising the measurement procedure, and not influenced by possible defects in measurement equipment, is of particular interest. The essential parameter influencing the reproducibility (*) is the measurement procedure i.e. number and positions of loudspeakers and microphones, limitation of receiving room volume etc.

For all measurements a dodecahedron loudspeaker has been used. The reason for using this loudspeaker type is that in the proposal for the new ISO 140-4 and for the survey method quite restrictive requirements regarding the directivity index of the loudspeaker are stated. Only few loudspeaker constructions can fulfil these requirements and it must be foreseen that in future a dodecahedron type will be the preferred sound source.

In this report the calculated reproducibility in principle has been determined according to ISO 5725 [5]. Within the limits of this project it was not possible to repeat all measurements several times. This implies that the uncertainty in repeating the measurement by the single laboratory (the repeatability (**)) is not included in the reproducibility. This means that the reproducibility calculations are a little too low (too good). Furthermore only one test result and not an average value of several measurements is included for each laboratory in the calculation. Therefore the accuracy of the determination of the reproducibility is increased a little. Normally the repeatability contribution to the reproducibility is small and the reproducibility calculations stated in this report are good estimates of the “true reproducibility” calculated in full accordance with ISO 5725.

(*) The reproducibility is an estimate of the maximum difference between two measurements carried out on the same test object by two different test teams (95% confidence interval).

(**) The repeatability is an estimate of the maximum difference between two measurements carried out on the same test object by the same test team (95% confidence interval).
The calculated reproducibility is compared with reproducibility values for field tests stated in Annex A and Annex B of ISO 140-2 [6].

All standard deviations reported are calculated as sample standard deviations.
4. ISO 140-4 MEASUREMENTS

4.1. Introduction

The ISO 140-4 and the survey method measurements were performed at a building site "Hækmosen" approximately 10 km from DELTA Acoustics & Vibration in Lyngby. The task was to measure the apparent sound reduction index between two terrace houses in three different rooms using both the proposed new ISO 140-4 method [1] and the proposed survey method [2].

The frequency range of the ISO 140-4 measurements should preferably be from 50 Hz to 5000 Hz, but only the measurements in the frequency range from 100 Hz to 5000 Hz were expected to be in compliance with the requirements of the proposal, and the guidance in annex D of the standard should not be followed.

4.2. Description of test objects

All measurements were performed on one partition wall but in three different rooms at three different floor levels.

Horizontal sections of the rooms and a vertical section of the houses can be seen in Enclosure 4.

In this report the following abbreviations will be used for the measuring objects (the Danish wording in brackets correspond to the drawings in Enclosure 4):

"Room": Measurement between two identical rooms (værelse) at the lowest floor level.

"Living room": Measurement between two identical, not laterally reversed living rooms (ophold) in open connection with the staircase volume and through that the kitchen volume.

"Bathroom": Measurement between the bathroom (bad) and the living room/staircase/kitchen.

The partition wall was a solid 240 mm Leca-concrete construction (mass: 1800-1900 kg/m³). The critical frequency lies in the frequency range 160-200 Hz.

The houses were almost finished, and external doors and windows and internal doors were mounted. The rooms were unfurnished.
Diffusing elements 1.0 m x 1.2 m made from 6 mm acrylic were available to the participants.

4.3. Instrumentation

The following instruments were used for the measurements:

Frequency analyzer: Nortronic RTA 830-2
Microphones (2 pcs.): Brüel & Kjær Type 4189
Microphone preamplifier: Brüel & Kjær Type 2619
Microphone preamplifier: Brüel & Kjær Type 2639
Microphone power supply: Brüel & Kjær Type 2804
(with 40 dB amplifier)
Rotating microphone boom (2 pcs.): Brüel & Kjær Type 3923
Sound level calibrator: Brüel & Kjær Type 4231
Equalizer: Harrison GP 130
Power-amplifier: Harrison Xi 600
Loudspeaker: Norsonic 229

4.4. Calculations

The evaluation of the reverberation time and the calculation of the sound reduction index for the ISO 140-4 measurements were performed by the build-in computer programme of the Nortronic analyzer. This programme is developed by DELTA, Aarhus.

4.5. Test procedure

Some short-form information about the used test procedures is given below.
All the participants used pink noise and the equalizer to shape the sound spectrum in the source room.

VTT performed the "bathroom" measurement using the bathroom as source room and the living room as receiving room, as this was expected to be the direction of a possible disturbance. The other laboratories used the living room/staircase/kitchen as source room.

SINTEF used diffusers in the source room. VTT and IBRI used diffusers in both source and receiving room.

### 4.6. Results and analysis of the results

A compilation of the numerical values of all test and calculation results can be seen in Enclosure 5.

#### Room

In Figure 1 the apparent sound reduction index $R'$ for the "room" measurements is given for each laboratory. The weighted sound reduction indices were:

<table>
<thead>
<tr>
<th>Laboratory</th>
<th>Source room</th>
<th>Recieving room</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Loud-speaker positions</td>
<td>Microphone positions</td>
</tr>
<tr>
<td>VTT</td>
<td>2</td>
<td>2 x rot. *a</td>
</tr>
<tr>
<td>SP</td>
<td>2 *b</td>
<td>1 x rot.</td>
</tr>
<tr>
<td>SINTEF</td>
<td>2</td>
<td>2 x 3 pos.</td>
</tr>
<tr>
<td>IBRI</td>
<td>2</td>
<td>2 x 5 pos.</td>
</tr>
<tr>
<td>DELTA</td>
<td>2</td>
<td>1 x rot. *c</td>
</tr>
</tbody>
</table>

*a: 2 fixed pos. in the bathroom
*b: 1 pos. at "bathroom" measurements
*c: 2 x rot. at "living room" measurements
Figure 1. The apparent sound reduction index for the ISO 140-4 "room" measurement.

Figure 1 shows good agreement between the results above 200 Hz, but at 200 Hz the DELTA result seems to be very low. No explanation, except that this is in the critical frequency range of the wall, can be given. Below 160 Hz the results show a wide variation.

The calculated standard deviation and reproducibility of the sound reduction indices for the "room" measurements are shown in Figure 2, together with the reproducibility values stated in ISO 140-2 Annex A. As expected the somewhat lower measurement result from one laboratory at 200 Hz influences the reproducibility as well as the variation at 125 Hz gives an unsatisfying value of the reproducibility that apart from these frequencies is well below the ISO 140-2 curve.
The calculated standard deviation and reproducibility of the integer value $R'_{\infty}$ for the "room" measurement is $0.8$ dB and $2.4$ dB, respectively. Concerning laboratory measurements, the reproducibility will normally be in the range $1$-$3$ dB, cf. the informative Annex B in ISO 140-2.

![Graph](image)

**Figure 2** The calculated standard deviation and reproducibility of the sound reduction indices for the ISO 140-4 measurement and the reproducibility values stated in ISO 140-2 Annex A.

**Living room**

In Figure 3 the apparent sound reduction index $R'$ for the "living room" measurements is given for each laboratory. The weighted sound reduction indices were:
Figure 3. The apparent sound reduction index for the ISO 140-4 "living room" measurement.

Figure 3 shows some systematic variation between the results from VTT and DELTA compared with the results from the other laboratories. The explanation for this may be the fact that VTT and DELTA used a receiving room volume including some of the staircase volume, while SP, SINTEF, and IBRI used a volume limited to the actual living room floor space. Using the combined volume would lower the results of these three laboratories by 1 dB. Below 315 Hz the results show a wide variation.
The calculated standard deviation and reproducibility of the sound reduction indices for the "living room" measurements are shown in Figure 4, together with the reproducibility values stated in ISO 140-2 Annex A. As expected the above-mentioned differences give reproducibility values a little beyond the ISO 140-2 curve even at higher frequencies.

The calculated standard deviation and reproducibility of the integer value $R'_w$ for the "living room" measurement are 1.1 dB and 3.2 dB, respectively.

![Graph showing standard deviation and reproducibility values](https://example.com/graph.png)

**Figure 4.** The calculated standard deviation and reproducibility of the sound reduction indices for the ISO 140-4 "living room" measurement and the reproducibility values stated in ISO 140-2 Annex A.

**Bathroom**

In Figure 5 the apparent sound reduction index $R'$ for the "bathroom" measurements is given for each laboratory. The weighted sound reduction indices were:
ISO 140-4
Bathroom

<table>
<thead>
<tr>
<th></th>
<th>VTT</th>
<th>SP</th>
<th>SINTEF</th>
<th>IBRI</th>
<th>DELTA</th>
</tr>
</thead>
<tbody>
<tr>
<td>$R'_w$ [dB]</td>
<td>59</td>
<td>59</td>
<td>57</td>
<td>59</td>
<td>57</td>
</tr>
</tbody>
</table>

From Figure 5 it is seen that the "bathroom" measurements are varying somewhat more than the "room" and "living room" measurements. Especially the variations at low frequencies are impressive. This might be expected with the difficulties caused by the geometric conditions of the staircase and the bathroom and by the small volume of the bathroom. Furthermore VTT's choice of receiving room, being the living room, might be the reason that their results are systematically, higher at frequencies above 315 Hz.

The calculated standard deviation and reproducibility of the sound reduction indices for the "bathroom" measurements are shown in Figure 6, together with the reproducibility values stated in ISO 140-2 Annex A. The reproducibility is above the ISO 140-2 curve at most frequencies.
The calculated standard deviation and reproducibility of the integer value $R'_{\infty}$ for the "bathroom" measurement are 1.1 dB and 3.1 dB, respectively.

**Figure 6.** The calculated standard deviation and reproducibility of the sound reduction indices for the ISO 140-4 "bathroom" measurement and the reproducibility values stated in ISO 140-2 Annex A.
5. SURVEY METHOD MEASUREMENTS

5.1. Introduction

The ISO 140-4 and the survey method measurements were performed at a building site “Hækmosen” approximately 10 km from DELTA Acoustics & Vibration in Lyngby. The task was to measure the sound reduction index between two terrace houses in three different rooms using both the proposed new ISO 140-4 method [1] and the proposed survey method [2].

The frequency range of the survey method measurements should only be from 125 Hz to 2000 Hz, while the reverberation terms are only given in this frequency range.

5.2. Description of test objects

See chapter 4.2 and the drawings in Enclosure 4.

The constructions in the three unfurnished rooms were:

"Room": Lightweight concrete walls/ceiling, hard timber flooring on a concrete slab.

"Living room": Lightweight concrete walls, gypsum board ceiling, hard timber flooring on a concrete slab.

"Bathroom": Lightweight concrete walls, gypsum board ceiling, tiles on a concrete slab.

5.3. Instrumentation

VTT, SP, IBRI, and DELTA used an

integrating sound level meter with filter

Brüel & Kjær Type 2230
Brüel & Kjær Type 1625

SINTEF used a

real-time frequency analyzer

Norsonic 114
5.4. Test procedure

Most of the participants used one of their source room loudspeaker positions from the ISO 140-4 measurements, hence not quite fulfilling the geometric requirements to the loudspeaker position in the survey method (Front face 1 m from the junction).

All the participants used pink noise and the equalizer to shape the sound spectrum in the source room.

The selected room type leading to the reverberation term in the survey method is given below. For definition of room type "letters" see [2], Enclosure 2.

<table>
<thead>
<tr>
<th>Laboratory</th>
<th>&quot;room&quot;</th>
<th>&quot;living room&quot;</th>
<th>&quot;bathroom&quot;</th>
</tr>
</thead>
<tbody>
<tr>
<td>VTT</td>
<td>h</td>
<td>h</td>
<td>h</td>
</tr>
<tr>
<td>SP</td>
<td>h</td>
<td>g</td>
<td>h</td>
</tr>
<tr>
<td>SINTEF</td>
<td>h</td>
<td>h</td>
<td>h</td>
</tr>
<tr>
<td>IBRI</td>
<td>g</td>
<td>(c+g)/2</td>
<td>g</td>
</tr>
<tr>
<td>DELTA</td>
<td>h</td>
<td>h</td>
<td>h</td>
</tr>
</tbody>
</table>

VTT performed the "bathroom" measurement with the bathroom as source room and the living room as receiving room. The other laboratories used the living room/staircase/kitchen as source room.

5.5. Results and analysis of the results

A compilation of the numerical values of all test and calculation results can be seen in Enclosure 6.

Room

In Figure 7 the apparent sound reduction index R’ for the survey method "room" measurements is given for each laboratory. The weighted sound reduction indices were:
The calculated standard deviation and reproducibility of the integer value $R'_{w}$ for the "room" measurement are 1.4 dB and 4.0 dB, respectively.
Figure 8. The calculated standard deviation and reproducibility of the sound reduction indices for the survey method "room" measurement.

A comparison between the measurement results of the survey method and calculated octave values from the ISO 140-4 1/3 octave measurements is shown in Figure 9 using the mean values of the five laboratories. Corresponding comparisons for each laboratory are to be found in Enclosure 7. The curves indicate that the survey method leads to lower values.

The octave values are calculated from the 1/3 octave values on energy basis using the equation given in ISO 140-4 [1].

The mean integer $R'_{w}$ value of the five laboratories for the survey method "room" measurement is 3 dB below the corresponding ISO 140-4 result.
Figure 9. Comparison between survey method mean values and calculated mean values from the ISO 140-4 measurements ("room" measurements).

Living room

In Figure 10 the apparent sound reduction index $R'$ for the survey method "living room" measurements is given for each laboratory. The weighted sound reduction indices were:

<table>
<thead>
<tr>
<th>Survey method Living room</th>
<th>VTT</th>
<th>SP</th>
<th>SINTEF</th>
<th>IBRI</th>
<th>DELTA</th>
</tr>
</thead>
<tbody>
<tr>
<td>$R'$ [dB]</td>
<td>57</td>
<td>57</td>
<td>58</td>
<td>58</td>
<td>56</td>
</tr>
</tbody>
</table>
Figure 10. The apparent sound reduction index for the survey method "living room" measurement.

The calculated standard deviation and reproducibility of the sound reduction indices for the "living room" measurements are shown in Figure 11. In spite of the use of different receiving room volumes the values are very low.

The calculated standard deviation and reproducibility of the integer value $R'_{\omega}$ for the "living room" measurement are 0.8 dB and 2.4 dB, respectively.
The calculated standard deviation and reproducibility of the sound reduction indices for the survey method "living room" measurement.

A comparison between the measurement results of the survey method and calculated octave values from the ISO 140-4 1/3 octave measurements is shown in Figure 12 using the mean values of the five laboratories. This comparison too indicates that the survey method leads to slightly lower values. Corresponding comparisons for each laboratory are to be found in Enclosure 7.

The mean integer $R'_{\text{w}}$ value of the five laboratories for the survey method "living room" measurement is 2 dB below the corresponding ISO 140-4 result.
Figure 12. Comparison between survey method mean values and calculated mean values from the ISO 140-4 measurements ("living room" measurements).

**Bathroom**

In Figure 13 the apparent sound reduction index \( R' \) for the survey method "bathroom" measurements is given for each laboratory. The weighted sound reduction indices were:

<table>
<thead>
<tr>
<th>Survey method</th>
<th>VTT</th>
<th>SP</th>
<th>SINTEF</th>
<th>IBRI</th>
<th>DELTA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bathroom</td>
<td>57</td>
<td>58</td>
<td>57</td>
<td>58</td>
<td>56</td>
</tr>
</tbody>
</table>
From Figure 13 it is surprisingly seen that the survey method "bathroom" measurements are not varying more than the "room" or "living room" measurements. This is contrary to what was the case for the ISO 140-4 measurements.

The calculated standard deviation and reproducibility of the sound reduction indices for the "bathroom" measurements are shown in Figure 14. The values are once again rather good for a survey method.

The calculated standard deviation and reproducibility of the integer value $R'_{w}$ for the "bathroom" measurement are 0.8 dB and 2.4 dB, respectively.
Figure 14. The calculated standard deviation and reproducibility of the sound reduction indices for the survey method "bathroom" measurement.

A comparison between the measurement results of the survey method and calculated octave values from the ISO 140-4 1/3 octave measurements is shown in Figure 15 using the mean values of the five laboratories. Corresponding comparisons for each laboratory are to be found in Enclosure 7.

The tendency of these curves is not as unambiguous as for the "room" measurements, but anyhow the mean integer $R'_{w}$ value of the five laboratories for the survey method "bathroom" measurement is 1 dB below the corresponding ISO 140-4 result.
Figure 15. Comparison between survey method mean values and calculated mean values from the ISO 140-4 measurements ("bathroom" measurements).
6. INTENSITY MEASUREMENTS

6.1. Introduction

The intensity measurements were performed next to DELTA Acoustic & Vibration in building 355 at the Danish Technical University in Lyngby. The task was to measure the sound reduction index of a door and of a window section on top of the door using intensity technique.

The measurements should be performed in accordance with the proposal for Nordtest Method “Building elements: Sound insulation measurements with an intensity scanning method in situ”[3].

The frequency range should preferably be from 50 Hz to 5000 Hz, but only the measurements in the frequency range from 100 Hz to 5000 Hz were expected to be in compliance with the requirements of the Nordtest Method.

At the briefing before the measurements it was additionally decided, in order to reduce the time consumption of the measurements, only to use a 12 mm spacer between the microphones in the intensity probe, although a 50 mm spacer would be expected to give more reliable results at the lower frequencies.

It was also agreed upon to use averaging on energy basis of the intensity levels from the individual scans, as this was found to be ambiguously in the wording in the Nordtest Method proposal.

6.2. Description of test objects

The door and the window section were situated between a corridor and a small office. A single table was placed in the corridor, while the office was fully furnished. Tables were not to be moved by the participants.

Approximately 1 m³ of mineral wool of different type and shape were available to the participants.

The door was a lightweight, not tight internal door construction. The unopenable window section was single glazed and had a wooden frame construction.

The surrounding wall was a solid brick wall.
A horizontal section of the rooms and an elevation of the test objects can be seen in Enclosure 4.

6.3 Instrumentation

The following instruments were used for the measurements:

Dual channel real-time frequency analyzer: Brüel & Kjær Type 2144
Sound intensity probe: Brüel & Kjær Type 3548
Microphones: Brüel & Kjær Type 4181
Microphone: Brüel & Kjær Type 4165
Microphone preamplifier: Brüel & Kjær Type 2619
Microphone power supply: Brüel & Kjær Type 2804
Sound level calibrator: Brüel & Kjær Type 4230
Pistonphone: Brüel & Kjær Type 4220
Noise generator: Brüel & Kjær Type 1405
Equalizer: Urei 539
Amplifier: Crest c4001
Loudspeaker: Type dodecahedron

The residual pressure-intensity index for the intensity probe and the analyzer was measured before the tests and distributed to the participants.

6.4. Calculations

Due to difficulties with handling the data format of the Brüel & Kjær Type 2144 output files, it was not possible for all the participants to use their normal intensity calculation programmes (being only familiar with the data format of a Nortronic analyzer) as intended during the measurements. In order to keep up with the time schedule it was so decided to cooperate in calculating the apparent intensity sound reduction index and the total field indicator.

Consequently the VTT, SINTEF, and finally - after finding some discrepancies in the first SP results - also SP results were calculated using a SINTEF spreadsheet programme, while the IBRI and DELTA intensity sound reduction indices were calculated using a DELTA spreadsheet programme. Additionally the two spreadsheet programmes were compared by recalculating the IBRI and DELTA results using the SINTEF programme also giving the
total field indicator. This comparison showed that the sound reduction indices calculated using the two different programmes were identical.

6.5. Test procedure

Some short-form information about the used test procedures is given below.

<table>
<thead>
<tr>
<th>Laboratory</th>
<th>Source room</th>
<th>Loud-speaker positions</th>
<th>Microphone positions</th>
<th>Number of sub-areas, door</th>
<th>Number of sub-areas, window</th>
</tr>
</thead>
<tbody>
<tr>
<td>VTT</td>
<td>corridor</td>
<td>2</td>
<td>2 x rot.</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>SP</td>
<td>office</td>
<td>1</td>
<td>1 x rot.</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>SINTEF</td>
<td>office</td>
<td>2</td>
<td>2 x 3 pos.</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>IBRI</td>
<td>office</td>
<td>2</td>
<td>2 x 5 pos.</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>DELTA</td>
<td>office</td>
<td>2</td>
<td>1 x rot.</td>
<td>4</td>
<td>5</td>
</tr>
</tbody>
</table>

SINTEF used white noise as source signal, while the other participants used pink noise. Everyone used the equalizer to shape the sound spectrum in the source room, see the source room level in Figure 16.
All participants used a box shaped measurement surface and two scans per loudspeaker position.

Different amounts and locations of additional absorption in the receiving room were used by the participants. SP tightened the door with tape and placed mineral wool in the door niche, when measuring intensity level from the window.

6.6. Results and analysis of the results

The participants were asked to report the apparent intensity sound reduction index for the door and the window section separately. Additionally the source room level spectra, see Figure 16, should be reported. After the measurements it was decided, instead of reporting the situations (sub-area and frequencies), where the field indicator was more than 10 dB, to report the total field indicator as described in the proposed method.
A compilation of the numerical values of all intensity test and calculation results can be seen in Enclosure 8.

Door

In Figure 17 the apparent intensity sound reduction index for the door is given for each laboratory. The weighted sound reduction indices were:

<table>
<thead>
<tr>
<th>Intensity Door</th>
<th>VTT</th>
<th>SP</th>
<th>SINTEF</th>
<th>IBRI</th>
<th>DELTA</th>
</tr>
</thead>
<tbody>
<tr>
<td>R'_{1,w} [dB]</td>
<td>25</td>
<td>24</td>
<td>23</td>
<td>22</td>
<td>22</td>
</tr>
</tbody>
</table>

![Graph showing the apparent intensity sound reduction index for the door.](www.nordtest.info)

**Figure 17.** The apparent intensity sound reduction index for the door.
From Figure 17 it is seen that the results from VTT are only given from 200 Hz to 4000 Hz. This was a consequence of undefined sound reduction indices as well as of field indicator problems in the lower frequency range. For the same reason SP and SINTEF did not report values below 100 Hz.

In the frequency range 500 Hz to 1600 Hz the results from VTT are consequently higher than the results from the other laboratories. The reason for this is probably that VTT used the opposite measurement direction than the other laboratories, cf. different room geometry, volumes and absorption conditions.

The calculated standard deviation and reproducibility of the sound reduction indices for the door are shown in Figure 18 together with the reproducibility values stated in ISO 140-2 Annex A. As expected the somewhat higher measurement results from one laboratory at 200 Hz as well as in the range 630-1250 Hz influence the reproducibility that apart from these frequencies is well below the ISO 140-2 curve.

The calculated standard deviation and reproducibility of the integer value $R'_{1,w}$ for the door are 1.3 dB and 3.7 dB, respectively.
The calculated standard deviation and reproducibility of the sound reduction indices for the door and the reproducibility values stated in ISO 140-2 Annex A.
Figure 19. The calculated total field indicator for the door measurements compared with the residual pressure-intensity index.

The calculated total field indicators for the door measurements are well below the 10 dB limit except for the VTT measurements at low frequencies (Figure 19). VTT only reported $R'$ values above 200 Hz. As mentioned above VTT used the office as receiving room. In addition VTT used a smaller amount of absorbing materials than the other laboratories.

The residual pressure-intensity index of the 12 mm probe and analyzer was sufficiently high at frequencies beyond 160 Hz for most of the laboratories. Only VTT had differences less than 7 dB up to 315 Hz.

Window

In Figure 20 the apparent intensity sound reduction index for the window is given for each laboratory. The weighted sound reduction indices were:
The apparent intensity sound reduction index for the window.

From Figure 20 it is seen that no results are reported at the frequencies 50 Hz and 63 Hz, and that only results from some laboratories are reported in the frequency range below 200 Hz. This was a consequence of undefined sound reduction indices as well as field indicator problems in the lower frequency range.

The calculated standard deviation and reproducibility of the sound reduction indices for the window are shown in Figure 21 together with the reproducibility values stated in ISO 140-2 Annex A. Apart from the frequencies 200 Hz, 315 Hz, and 630 Hz the reproducibility is well below the ISO 140-2 curve.
The calculated standard deviation and reproducibility of the integer value $R'_{1,w}$ for the window are 0.5 dB and 1.6 dB, respectively.

**Figure 21** The calculated standard deviation and reproducibility of the sound reduction indices for the window and the reproducibility values stated in ISO 140-2 Annex A
The calculated total field indicators for the window measurements are influenced by the fact that there was a sound power flow from the receiving room/door construction into the lower part of the box shaped measurement surface (Figure 22). Although this sub-area was measured with a satisfactory F value the formula in the proposed Nordtest method - using the direction indicator K - gives unfavourable total field indicator values. Only SP’s measurements gave values below the 10 dB limit at all frequencies, probably because SP tightened the door with tape and placed mineral wool in the door niche. VTT did not report R’ values at 125 Hz and 160 Hz.

At several frequencies up to 500 Hz the residual pressure-intensity index of the 12 mm probe and analyzer was too low compared with one or more of the calculated total field indicators, causing differences less than 7 dB.
6.7. Comparison with traditional ISO 140-4 measurement

After the prearranged measurements DELTA was asked to make an ISO 140-4 measurement of the door and the window section together. In Figure 23 the result of this measurement is compared with the calculated composite intensity sound reduction index for the door and the window section. A rather good agreement between the curve shapes is obtained, but the intensity measurement results are approximately 2 dB higher than the ISO 140-4 results. One reason may be that the leak at the bottom of the door was underestimated when scanning the front of the door. Although the surrounding wall construction is a heavy brick wall it should be noticed that the ISO 140-4 measurement unlike the intensity method includes all sorts of flanking transmission. Generally the intensity method is expected to give higher reduction values at high frequencies than the ISO 140-4 method.

The weighted sound reduction indices were $R'_{1,w} = 24$ dB for the intensity method (mean of five laboratories) and $R'_{w} = 22$ dB for the ISO 140-4 method.

![Figure 23](image)

**Figure 23.** Comparison between sound reduction indices from intensity measurements (mean of five laboratories) and ISO 140-4 measurement performed by DELTA on the combined door and window section.
7. CONCLUSION

7.1. ISO 140-4 measurements

In general the results of the field measurements at the building site show a good agreement with the reproducibility curve stated in ISO 140-2, the "bathroom" measurement and the lower frequency range being the exceptions.

Choice of measurement direction between rooms of different size or orientation and definition of receiving room volume in connected rooms have influenced the reproducibility.

Further use/inciporation of the Nordtest Additional Guidelines [4] might lead to more conformity in these aspects.

The reproducibility of the integer single-number $R'_{w}$ values is 2-3 dB thus being in the same range as normally expected concerning laboratory measurements, cf. ISO 140-2, Annex B [5].

7.2. Survey method measurements

The survey method measurements show surprisingly good reproducibility values even for the more difficult room combinations.

In the draft standard [2] the reproducibility limit of the survey method is estimated to exceed the reproducibility limit of the engineering method by 2 dB. This seems not to be the case for the executed measurements, where the reproducibility is well below the ISO 140-2 limit in all octave bands.

The reproducibility of the integer single-number $R'_{w}$ values is 2-4 dB.

Being a survey method, it is considered as an advantage that the integer $R'_{w}$ values of the actual field tests are 1-3 dB lower than the corresponding ISO 140-4 results.

7.3. Intensity measurements

The results from the intensity measurements on the door and the window section show acceptable reproducibility values, although the reproducibility is influenced of the circumstance that one laboratory chose the opposite measurement direction than the others.

The reproducibility of the integer $R'_{i,w}$ values is 2-4 dB.
Some minor problems concerning the content and intention of the proposed Nordtest Method [3] appeared during the project. The project group recommend that Nordtest in a subsequent project look over the proposal regarding the following aspects:

- the choice of source room.
- calculation of averaged intensity values from more than two scans, current eq. using two loudspeaker positions.
- calculation of the total field indicator including sub-areas with negative intensity.
- Waterhouse correction

In addition the measurements including the required calculations showed to be very time consuming. This could support an extension in the form of an annex with a survey method only for ranking and diagnostics.
8. REFERENCES


[5] ISO 5725, Precision of test methods - Determination repeatability and reproducibility by inter-laboratory tests


The revision of this part of ISO 140 was decided in 1986 by ISO/TC 43 and
WG 18 (Convener: Dr. Goydke, Germany) of ISO/TC 43/SC 2 was established to deal
with this work item.

In the meantime, the European Committee CEN/TC 126 also decided to transform
the revised versions of the several parts of ISO 140 into European standards.

During the meeting of ISO/TC 43/SC 2/Wg 18 on 30 and 31 May 1991 in Aarhus
and on 5 December 1991 in Sydney the final versions of ISO 140-1, -4, -5, -6,
-7 and -8 were approved as committee drafts (CD) for circulation to the members
ISO/TC43/SC2/WG18
CEN/TC126/WG1 N

Draft for ISO DIS 140-4
(Seventh working draft - February 1992)

Acoustics - Measurement of sound insulation in buildings and of building elements

Part 4: Field measurements of airborne sound insulation between rooms

1 SCOPE AND FIELD OF APPLICATION

This International Standard specifies field methods for measuring the airborne sound insulation properties of interior walls, floors and doors between two rooms under diffuse sound field conditions in both rooms and for determining the protection afforded to the occupants of the building.

The method gives values for airborne sound insulation which are frequency dependent. They can be converted into a single number characterizing the acoustical performance by application of ISO 717-1.

The results obtained can be used to compare sound insulation between rooms and to compare actual sound insulation with specified requirements.

NOTE 1 - Laboratory measurements of airborne sound insulation of building elements are dealt with in ISO140-3.

NOTE 2 - Field measurements of airborne sound insulation of facade elements and facades are dealt with in ISO140-5.

2 NORMATIVE REFERENCES

The following standards contain provisions which, through reference in this text, constitute provisions of this International Standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this International Standard are encouraged to investigate the possibility of applying the most recent editions of the standards listed below. Members of IEC and ISO maintain registers of currently valid International Standards.


IEC Publication 225: 1985, Octave, half-octave and third-octave band filters intended for the analysis of sounds and vibrations.

IEC Publication 651: 1979, Sound level meters.


OIML R 58: 1984, Sound level meters.


* Organisation International de Métrologie Légale. 11, rue Turgot - 75009 Paris, France.

3 DEFINITIONS

3.1 Average sound pressure level in a room: Ten 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. This quantity is denoted by $L$. For complete definitions see ISO 140-3. In practice usually the sound pressure levels $L_i$ are measured. In this case $L$ is determined by:

$$L = 10 \log \frac{1}{n} \sum_{i=1}^{n} \frac{L_i}{10} \text{dB}, \quad (1)$$

$L_i$ are the sound pressure levels $L_i$ to $L_n$ at $n$ different positions in the room.

3.2 Level difference: The difference in the space and time average sound pressure levels produced in two rooms by one or more sound sources in one of them. This quantity is denoted by $D$:

$$D = L_1 - L_2 \text{ dB} \quad (2)$$

where

$L_1$ is the average sound pressure level in the source room;

$L_2$ is the average sound pressure level in the receiving room.

3.3 Standardized level difference: The level difference corresponding to a reference value of the reverberation time in the receiving room. This quantity is denoted by $D_{\tau T}$:

$$D_{\tau T} = D + 10 \log \frac{T}{T_0} \text{ dB} \quad (3)$$

where

$D$ is the level difference;

$T$ is the reverberation time in the receiving room;

$T_0$ is the reference reverberation time.

For dwellings, $T_0$ is given by

$$T_0 = 0.5 \text{ s} \quad (4)$$
NOTE 3 - The standardizing of the level difference to a reverberation time of 0.5 s takes into account that in dwellings with furniture the reverberation time has been found - nearly independently of the volume and of frequency - to be equal to 0.5 s. With this standardizing, $D_n$ is dependent on the direction of the sound transmission if the two rooms have different volumes.

NOTE 4 - The standardizing of the level difference to the reverberation time in the receiving room of $T_0 = 0.5$ s is equivalent to standardizing the level difference with respect to an equivalent absorption area of:

$$A_0 = 0.32 \, V$$

where

$A_0$ is the equivalent absorption area, in square meters;

$V$ is the volume of the receiving room, in cubic meters.

3.4 Apparent sound reduction index: Ten times the common logarithm of the ratio of the sound power $W_i$ which incidents on a partition under test to the total sound power transmitted into the receiving room, when in addition to the sound power $W_i$, radiated by the specimen, sound power $W_s$, radiated by flanking elements or by other components, has to be regarded.

This quantity is denoted by $R'$:

$$R' = 10 \log \frac{W_i}{W_s + W_i} \quad \text{dB} \quad \text{(5)}$$

NOTE 5 - Being equivalent to apparent sound reduction index the expression apparent transmission loss also is in use.

In general, the sound power transmitted into the receiving room consists of the sum of the following components:

- $W_{p0}$ which has entered the partition directly and is radiated from it directly;
- $W_{r}$ which has entered the partition directly but is radiated from flanking constructions;
- $W_{r}$ which has entered flanking constructions and is radiated from the partition directly;
- $W_{r}$ which has entered flanking constructions and is radiated from flanking constructions;
- $W_{r}$ which has been transmitted (as airborne sound) through leaks, ventilation ducts, etc.

Under the assumption of diffuse sound fields in the two rooms, the apparent sound reduction index in this Standard is evaluated from

$$R' = \frac{S}{A} \left( L_1 - L_2 + 10 \log \frac{W_i}{W_s + W_i} \right) \quad \text{dB} \quad \text{(6)}$$

where

$S$ is the area of the test specimen;

$A$ is the equivalent sound absorption area in the receiving room.

In the case of evaluation of $R'$ of a door $S$ is the area of the free opening in which the door including the frame is mounted. It must be proved that the sound transmission through the rest of the surrounding wall is negligible.

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In the case of staggered or stepped rooms, $S$ is that part of the area of the partition common to both rooms. If the common area is less than 10 m² this must be indicated in the test report.

In the case that no common area exists $S$ shall be taken as 10 m².

NOTE 6 - In general comparison between results from field measurements and those from laboratory measurements should only be done where the common area $S$ is approximately 10 m².

NOTE 7 - In the apparent sound reduction index, the sound power transmitted into the receiving room is related to the sound power incident on the common partition irrespective of actual conditions of transmission.

The apparent sound reduction index is independent of the measuring direction between the rooms if the sound fields are diffuse in both rooms.

4 EQUIPMENT

The equipment shall comply with the requirements of clause 6.

The accuracy of the sound level measurement equipment shall comply with the requirements of accuracy classes 0 or 1 formulated in IEC 651/IEC 804. Diffuse field calibration of the measurement equipment is required unless microphones with the same diffuse field frequency response are used in both the source and the receiving room.

If absolute values of sound pressure levels have to be obtained the complete measuring system including the microphone shall be adjusted before each measurement using a sound calibrator which complies with the requirements of accuracy class 1 formulated in IEC 942 or an equivalent method.

The third-octave band filters shall comply with the requirements defined in IEC 225.

The reverberation time measurement equipment shall comply with the requirements defined in ISO 354.

Requirements for the sound source are given in clause 6.2 and Annex A.

NOTE 8 - For pattern evaluation (type testing) and regular verification tests fulfilsments of equipment requirements are to be regarded. Recommended procedures for sound level meters are given in OIML R58 and R88.

5 TEST ARRANGEMENT

Measurements between empty rooms with identical shape and equal dimensions should preferably be made with diffusers in each room (e.g. pieces of furniture, building boards etc.). The area of a diffuser should be at least 1,0 m²; three or four objects will be normally sufficient.

Guidelines for performing measurements in special measurement situations will be given in an informal Annex which is under consideration.
6 TEST PROCEDURE AND EVALUATION

6.1 General
The field measurements of airborne sound insulation should be made in one-third octave bands. In some field situations, however it may be advantageous to perform the measurements in octave bands. The procedure for octave band measurements is specified in Annex B. When the measurement results are converted to single number quantities the results may not be directly comparable with those from third octave band measurements.

6.2 Generation of sound field in the source room
The sound generated in the source room should be steady and have a continuous spectrum in the frequency range considered. Filters with a bandwidth of at least one-third octave may be used. White noise as source signal is normally recommended. When using broad band noise the spectrum of the noise source may be modified to ensure an adequate signal to noise ratio at high frequencies in the receiving room. The sound spectrum in the source room should not have level differences larger than 6 dB between adjacent one-third octave bands.

The sound power should be sufficiently high for the sound pressure level in the receiving room to be at least 10 dB higher than the level of the background noise in any frequency band (see 6.6 if this is not fulfilled).

If the sound source enclosure contains more than one loudspeaker operating simultaneously, the loudspeakers shall be driven in phase. Multiple sound source may be used simultaneously providing they are of the same type and are driven at the same level by similar, but uncorrelated signals. When using a single sound source it shall be operated in at least two positions. If the rooms are of different volumes the larger one should be chosen as source room when the standardized level difference is to be evaluated and no contradictory procedure is agreed upon. In order to evaluate the apparent sound reduction index the loudspeaker positions may be in the same room or the measurements may be repeated in the opposite direction by changing source and receiving room with one or more source positions in each room.

The loudspeaker enclosure should be placed so as to give a sound field as diffuse as possible and at such a distance from the partition element and the flanking elements influencing the sound transmission, that the direct radiation on these is not dominant. The sound fields in the rooms depend strongly on the type and on the position of the source. Procedures for qualification of the loudspeakers and for the evaluation of suited positions are given in Annex A.

6.3 Measurement of average sound pressure level
6.3.1 General
The average sound pressure level can be obtained by using a single microphone moved from position to position or by an array of fixed microphones or by a continuously moving microphone or by swinging the microphone. The sound pressure levels at the different microphone positions shall be averaged on an energy basis (see formula (1)) for all sound source positions.

6.3.2 Microphone positions
As a minimum five microphone positions shall be used being distributed within the maximum permitted space throughout each room taking in the room space uniformly. When using a moving microphone the sweep radius shall be not less than 0,7 m. The plane of the traverse shall be inclined in order to cover a large proportion of the permitted room space and shall not lie in any plane within 10° of a room surface. The duration of a traverse period shall be not less than 15 s.
The following separating distances are minimum values and should be exceeded where possible:
0.7 m between microphone positions
0.5 m between any microphone position and room boundaries or diffusers
1.0 m between any microphone position and the sound source.

6.3.3. Averaging time
At each individual microphone position the averaging time shall be at least 6 s at each frequency band with midband frequencies below 400 Hz. For bands of higher midband frequencies the time may be decreased to at least 4 s. When using a moving microphone the averaging time must cover a whole number of traverses and shall be at least 30 s.

6.4 Frequency range of measurements
The sound pressure level shall be measured using one-third octave band filters having at least the following center frequencies in Hertz:

<table>
<thead>
<tr>
<th>Frequency (Hz)</th>
<th>Center Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>125</td>
</tr>
<tr>
<td>200</td>
<td>250</td>
</tr>
<tr>
<td>300</td>
<td>350</td>
</tr>
<tr>
<td>400</td>
<td>500</td>
</tr>
<tr>
<td>600</td>
<td>750</td>
</tr>
<tr>
<td>800</td>
<td>1000</td>
</tr>
<tr>
<td>1200</td>
<td>1500</td>
</tr>
<tr>
<td>1600</td>
<td>2000</td>
</tr>
<tr>
<td>2000</td>
<td>2500</td>
</tr>
<tr>
<td>3000</td>
<td>3500</td>
</tr>
</tbody>
</table>

It is recommended to enlarge the frequency range of the measurements by one-third octave filter bands of 4000 and 5000 Hz in order to obtain additional information and to get results comparable to that of laboratory measurements according to ISO 140-3. If additional information in the low frequency range is required, one-third octave band filters with the following center frequencies should be used:

<table>
<thead>
<tr>
<th>Frequency (Hz)</th>
<th>Center Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>50</td>
<td>63</td>
</tr>
<tr>
<td>80</td>
<td>100</td>
</tr>
</tbody>
</table>

For such additional measurements in the low frequency bands guidance is given in Annex D.

6.5 Measurement of reverberation time and evaluation of the equivalent sound absorption area

The correction term of equation (6) containing the equivalent sound absorption area is evaluated from the reverberation time and determined using Sabine's formula:

\[ A = \frac{0.16 \, V}{T} \]

where
- \( A \) is the equivalent sound absorption area, in square meters,
- \( V \) is the receiving room volume, in cubic meters,
- \( T \) is the reverberation time in the receiving room, in seconds.

Following ISO 354 the evaluation of the reverberation time from the decay curve shall begin from a sound pressure level a few decibels lower than that at the beginning of the decay. The range used shall not be less than 20 dB, and should not be so large that the observed decay cannot be approximated by a straight line. The bottom of this range shall be at least 10 dB above the background noise level.
The minimum number of measurements required for each frequency band is six decays. At least 1 loudspeaker position and 3 microphone positions with 2 readings in each case shall be used.

Moving microphones may be used with a traverse time not less than 30 s.

6.6 Correction for background noise

Measurements of background noise levels shall be made to ensure that the observations in the receiving room are not affected by extraneous sound such as noise from outside the test room, electrical noise in the receiving system, or electrical cross-talk between source and receiving systems. To check the last named condition the microphone may be replaced by a dummy microphone. The background level should be at least 6 dB (and preferably more than 10 dB) below the level of signal and background noise combined.

Corrections must be made if the level difference is greater or equal to 6 dB but smaller than 10 dB. The adjusted value of the signal level is given by

$$L = 10 \lg \left( \frac{L_{a,b}}{10^{6/10}} \right) \text{ dB},$$

where

- $L$ is the adjusted signal level,
- $L_{a,b}$ is the level of signal and background noise combined,
- $L_b$ is the background noise level.

If the difference is less than 6 dB in any of the frequency bands the correction shall be 1.3 dB at the most, corresponding to a difference of 6 dB. In that case $D_{1/3}$ and $R'$-values shall be given indicated in the measurement report so that it clearly appears that the reported values are the limit of measurement (see i) of clause 9).

7 PRECISION

It is required that the measurement procedure should give satisfactory repeatability. This can be determined for the instrumentation and in specific cases, for the complete measurement condition in accordance with the method shown in ISO 140-2 and should be checked from time to time, particularly when a change is made in procedure or instrumentation.

NOTE 8 - Numerical requirements for repeatability are given in ISO 140-2.

8 EXPRESSION OF RESULTS

For the statement of the airborne sound insulation of the test specimen, the standardized level difference $D_{1/3}$ or the sound reduction index $R'$ shall be given at all frequencies of measurement to one decimal place in tabular form and/or in the form of a curve. For graphs with the level in decibels plotted against frequency on a logarithm scale, the following dimensions shall be used:

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

The use of a form in accordance with Annex E is requested. Being a short version of the test report all information of importance regarding the test object, the test procedure and the test results shall be stated.
If from the one-third octave band measurements results are needed in one-octave bands, these values shall be calculated from the three one-third octave band values in each one-octave band using the following equation:

\[ D_{nT,\text{oct}} = \frac{-10 \log (\sum_{n=1}^{3} \frac{1}{10})}{10} \, \text{dB}, \quad (9) \]

\[ R_{nT,\text{oct}} = \frac{-10 \log (\sum_{n=1}^{3} \frac{1}{10})}{10} \, \text{dB}, \quad (10) \]

If the test procedure is repeated either in the same or in the opposite measurement direction, the arithmetic mean of all measurement results at each frequency band shall be calculated.

9 TEST REPORT

With reference to this International Standard, the test report shall state:

- a) Name of organization that has performed the measurements.
- b) Name of client.
- c) Date of test.
- d) Description of the building construction and test arrangement.
- e) Volumes of both rooms.
- f) Either the standardized level difference \( D_{nT} \) between the rooms or the apparent sound reduction index \( R' \) of the test specimen as a function of frequency whichever is appropriate.
- g) The area \( S \) used for evaluation of \( R' \).
- h) Brief description of details of procedure and equipment.
- i) Indications of results which are to be taken as limits of measurement. They shall be given as \( D_{nT} \) respectively \( R' = \ldots \) dB. This shall be applied if the sound pressure level in any band is not measurable on account of background noise (acoustic or electrical, see 6.6).
- j) The flanking transmission - if measured (see Annex C) - in the same form as \( R' \). It should be stated as clearly as possible which part of the transmitted sound power are included in the flanking transmission measurement.

For the evaluation of the single figure ratings from the curves \( D_{nT}(f) \) and \( R'(f) \), see ISO 717-1.
ANNEX A (normative)
QUALIFICATION AND POSITIONING OF THE SOUND SOURCE

A.1. QUALIFICATION PROCEDURES FOR LOUDSPEAKERS AND FOR
LOUDSPEAKER POSITIONS RELATIVE TO MICROPHONE POSITIONS

A.1.1 General

The objective of these requirements is to make the sound field in the sending
room which is sampled by the microphones as diffuse as possible. The positions
and the directivity of the source must permit microphone positions to be outside
the direct field of the source and must ensure that the direct radiation from
the source is not dominant on the surface of the walls, floors and ceilings
which contribute to the sound transmission.

Requirements for radiation characteristics of the sound source depend on the
source room dimensions. At least the requirement for separating distances given
in clause 6.3.2. of the Standard must be fulfilled if a source is used which
meets the requirements for uniform omnidirectional radiation given in A.1.3.

A.1.2 Loudspeaker positions with regard to microphone positions

It must be ensured that the microphone positions are outside the direct sound
field of the source. Each fixed microphone position shall lie outside the region
in which levels decrease significantly with distance from the source. For a
moving microphone, no significant level increase shall occur when the path comes
close to the source.

A.1.3 Test procedure for loudspeaker radiation directivity

At all source positions in the free room space it is recommended to use
loudspeakers with the speaker units mounted in a closed cabinet. All speaker
units in the same cabinet must radiate in phase.

Mounting loudspeakers on the surfaces of a polyhedron, preferably a
dodecahedron, gives an adequate approximation of uniform omni-directional
radiation. Also with a hemisphere polyhedron loudspeaker (mounted directly on
the floor) omnidirectional radiation into the room is achievable.

A check of the directional radiation of a source can be performed by measuring
the sound pressure levels around the source at a distance of about 1.5 m in a
free field. The source shall be driven with a noise signal, and measurements
made in one-third octave bands. The level difference between the energetic mean
value for the arc of 360° (L1/60) and the "gliding" mean values of all arcs of
30° (L30) are to be measured. The directivity index is DIi = L1/60 - L30.
Uniform omni-directional radiation can be assumed if the DI values are within
the limits of +/-2 dB in the frequency range from 100 Hz to 630 Hz. In the range
of 630 Hz to 1000 Hz the limits increase from +/-2 dB to +/-8 dB. They are +/-8
dB for frequencies of 1000 Hz to 5000 Hz. The test should be made in different
planes, to ensure inclusion of the "worst case" condition. For a polyhedron
source, testing in one plane is sufficient.
A.2 GUIDANCE FOR THE SELECTION OF OPTIMUM SOURCE POSITIONS

The suitability of source positions also depend on the radiation characteristic of the loudspeaker as well as on the microphone positions (or the microphone path in the case of a moving microphone).

The distance between different loudspeaker positions shall be not less than 0,7 m.

At least two positions must be situated not less than 1,4 m from each other.

The distance between the room boundaries and the loudspeaker shall be not less than 0,5 m. Small irregularities of the room boundaries may be neglected.

Different loudspeaker positions may not be situated within the same planes parallel to the room boundaries.

Especially in small rooms often it is of advantage for the practical execution of the measurements to use loudspeaker positions in the corners of the sending room. Special care must be taken in regard to possible influence on the flanking transmission and in regard to unwanted increase of level fluctuations in the sending room.

ANNEX B (normative)

PROCEDURES FOR THE MEASUREMENT OF SOUND INSULATION IN OCTAVE BANDS

B.1 GENERAL REMARKS

For the field measurements of airborne sound insulation between rooms, the procedure for the measurement in one-third octave bands is specified in the standard. However, because the room volumes in ordinary dwellings are not necessarily so large, sound diffusion in room excited by one-third octave band noise is relatively poor, especially in the low frequency range. To overcome this problem and to secure the accuracy requirements, it is necessary to carry out time-consuming and troublesome measurements. In these situations, it is advantageous to make the measurement in octave bands in order to fulfill the satisfactory repeatability requirements. In this case, this Annex shall be applied.

B.2 GENERATION OF SOUND FIELD IN THE SOURCE ROOM

The sound generated in the source room should be steady and should have a smooth spectrum. This is to be checked by measurements of the sound power levels in one-third octave bands in a reverberation room. The differences between the sound power levels in the one-third octave bands belonging to an octave band shall not be greater than 6 dB in the octave band of 125 Hz, 5 dB in the band of 250 Hz and 4 dB in the bands of higher center frequencies.

Filters with a bandwidth of at least an octave band shall be used. When using broad band noise, the spectrum of the noise source may be modified to ensure an adequate signal to noise ratio at high frequencies in the receiving room.

Other specifications on the sound source are the same with those stated in 6.2 of the standard.

B.3 MEASUREMENT OF AVERAGE SOUND PRESSURE LEVEL

Measurement procedures such as microphone positions or microphone traverse paths, averaging time and spatial averaging procedures are the same with those specified in 6.3 of the standard. www.nordtest.info
B.4 FREQUENCY RANGE OF INTEREST

The sound pressure level shall be measured using octave band filters having at least the following center frequencies in Hz:

125 250 500 1000 2000.

It is recommended to enlarge the frequency range of the measurements by the octave filter band of 4000 Hz in order to obtain additional informations and to get results comparable to that of laboratory measurements according to ISO 140-3. If additional information in the low frequency range is required, then an octave band filter with the center frequency of 63 Hz should be used. When such additional measurements in the low frequency band are performed, the guidance given in Annex C should be followed.

B.5 MEASUREMENT OF REVERBERATION TIME AND EVALUATION OF THE EQUIVALENT SOUND ABSORPTION AREA

As given in 6.5 of the standard.

B.6 CORRECTION FOR BACKGROUND NOISE

As given in 6.6 of the standard.

B.7 PRECISION

As given in 7. of the standard.

B.8 EXPRESSION OF RESULTS

For the statement of the airborne sound insulation of the test walls, the standardized level difference $D_n$ or the sound reduction index $R'$ shall be given at all frequencies of measurement to one decimal place in tabular form and/or in the form of a curve. For graphs with the level in decibels plotted against frequency on a logarithmic scale, the following dimensions shall be used:

- 15 mm for an octave,
- 20 mm for 10 dB.

NOTE

If the test procedure is repeated either in the same or in the opposite measurement direction, the arithmetic mean of all measurement results at each frequency band shall be calculated.
MEASUREMENT OF FLANKING TRANSMISSION

The sound power transmitted into the receiving room can be assumed to consist of the sum of the following components:

- $W_{0d}$ which has entered the partition directly and is radiated from it directly;
- $W_{0f}$ which has entered the partition directly but is radiated from flanking constructions;
- $W_{f4}$ which has entered flanking constructions and is radiated from the partition directly;
- $W_{f5}$ which has entered flanking constructions and is radiated from flanking constructions;
- $W_{1**}$ which has been transmitted (as airborne sound) through leaks, ventilation ducts, etc.

If the flanking transmission has to be investigated, this may be done in either of the following ways:

-1- By covering the specimen on both sides with additional flexible layers, for example 13 mm gypsum board on a separate frame at a distance which gives a resonance frequency of the system of layer and airspace well below the frequency range of interest. The airspace shall contain sound absorbing material. With this measurement $W_{0d}$, $W_{0f}$ and $W_{f4}$ are suppressed, and the measured apparent reduction index is determined by $W_{f5}$. $W_{1**}$ is assumed to be negligible under laboratory conditions. Additional flexible layers, covering particular flanking surfaces may permit identification of the major flanking paths.

-2- By measuring the average surface velocity levels of the specimen and the flanking surfaces in the receiving room. The average surface velocity level $L_v$ of the specimen is given by:

$$L_v = 10 \log \frac{v_1^2 + v_2^2 + \ldots + v_n^2}{n \cdot v_o^2} \text{ dB,}$$  \hspace{1cm} (C.1)

where

- $v_1, v_2, \ldots, v_n$ are the r.m.s. normal surface velocities at $n$ different positions on the specimen;
- $v_o = 10^{-9}$ m/s is the reference velocity.

NOTE - In building acoustics the reference velocity of $5 \cdot 10^{-9}$ m/s also is in use. Therefore, the reference velocity used in equation (C.1) must always be stated.

* See ISO 1683, Acoustics- Preferred reference quantities for acoustic levels.
The vibration transducer used should be well attached to the surface and its mass impedance should be sufficiently low compared with the point impedance of the surface.

If the critical frequency of the specimen or of the flanking objects is low compared with the frequency range of interest, the power $W_k$ radiated from a particular element $k$ with area $S_k$ into the receiving room may be estimated by:

$$W_k = \rho c S_k \overline{v_n^2} \sigma_k,$$

(C.2)

where

$\overline{v_n^2}$ is the spatial average of the mean square of the normal surface velocity;

$\sigma_k$ is the radiation efficiency, a figure of about 1 above the critical frequency;

$\rho c$ is the characteristic impedance of air.

If, for instance, the power radiated from the flanking constructions is determined in this way, the measurement can be used for the calculation:

$$R'_{det} = 10 \log \frac{W_1}{W_{det} + W_{ref}} \text{ dB.}$$

(C.3)

-3- The flanking transmission may be measured directly using the intensity measuring method if the different special conditions to get reliable results with this method are fulfilled.
ANNEX D (informative)

GUIDANCE FOR MEASUREMENTS IN THE LOW FREQUENCY BANDS

D.1. GENERAL

In low frequency bands, lower than about 400 Hz in general and especially lower than 100 Hz, no diffuse field conditions in the test rooms can be expected especially when room volumes of only 50 m\(^3\) or even less are taken into account. The general requirement that the room dimensions should be at least of one wavelength cannot be fulfilled for the lowest bands. The small number of room modes in the bands are the cause of standing wave structures that are found in the whole room space.

The excitation of the room resonance frequencies and therefore the sound reduction index measured is highly dependent from the source locations. Even if the repeatability is often found not to go bad at low frequencies the reproducibility may be very poor.

In order to reduce the unfavourable effects additional effort is necessary in regard to the excitation and sampling of the sound field in the rooms.

It must be regarded that in rooms with very small volumes and unfavourable dimensions it is not possible to get reliable results of low frequency measurements. At least one room dimension should be of one wavelength and another of half a wavelength of the lowest band center frequency and there must be the space to position the source and the microphone according to the requirements. If this cannot be fulfilled a strong increase of the uncertainty of the measurement has to be taken into account and to be stated in the test report.

D.2. MINIMUM DISTANCES

A strong sound pressure level increase is measured towards the room boundaries from a distance of about a quarter of a wavelength. The minimum separating distances (see 6.2.2. of the Standard) have to be increased linearly, being doubled for measurements in the 50 Hz-band. This is also valid for the distances between microphone positions and the surface of the test specimen.

D.3. SAMPLING OF THE SOUND FIELD

In order to get a reliable average of the sound pressure levels in the room space the number of microphone positions must be increased, the use of a continuously moving microphone is highly recommended. At least two circular paths should be used with a sweep radius preferably not less than 1,0 m. It must be regarded that at very low frequencies where the room dimensions tend to be in the range of half a wavelength extremely low sound pressure values are found in the center part of the room. Therefore it must be tried to find suited microphone positions also outside this area.
4. LOUDSPEAKER POSITIONS

The lack of diffusivity in small rooms at low frequency measurements can partly be compensated by exciting different sound field one after the other and averaging the results. Therefore the number of loudspeaker positions must be increased, the minimum number should be three. The sound field excitation in the room corners being only advantageous in theory under ideal conditions should be avoided. Symmetry of the positions must be avoided to an extend as much as possible, the height of the source must be varied too at the different positions.

5. AVERAGING TIME

Due to the smaller filter bandwidth but also to stronger variations in time of the sound field due to interfering waves the averaging times should be increased to not less than 15 s for measurements in the 50 Hz-band. When using a moving microphone the averaging time should not be less than 60 s.

6. REVERBERATION TIME

At very low frequencies test rooms tend to show large reverberation times. This must be avoided as to reduce dominance of single room resonances and to improve the modal overlap. The sound absorption in the rooms should be increased (e.g. by pieces of furniture) but the absorption in the room should be well distributed.

ANNEX E (informative)

FORM FOR THE EXPRESSION OF RESULTS

See the next two pages.

NOTE - The curve of reference values shown in the form is to be taken from ISO 717. It must be ensured that the actual version of that Standard becomes applied.
Apparent sound reduction index according to ISO 140 / 4

**Field measurements of airborne sound insulation between rooms**

**Client:**

**Date of test:**

**Description of the building construction and test arrangement:**

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<th>Frequency (Hz)</th>
<th>Mass per unit area (kg/m²)</th>
<th>A' (1/3oct dB)</th>
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ISO 717/1: \[ R'_w = \] dB

Max dev. dB at \( f \) Hz

---

Frequency range according to the curve of reference values (ISO 717/1)

Source room volume: \( V_s = \) m³

Receiving room volume: \( V_r = \) m³

---

**No. of test report:**

**Name of test institute:**

**Date:**

**Signature:**

www.nordtest.info
Standardized level difference according to ISO 140 / 4
Field measurements of airborne sound insulation between rooms

Client:  
Date of test:  

Description of the building construction and test arrangement, direction of measurement:

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<th>Standardized level difference $D_{nt}$ dB</th>
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</table>

ISO 717/1: $D_{nt} = \pm \text{Max dev.}$ dB

Source room volume: $v_s = \text{m}^3$
Receiving room volume: $v_r = \text{m}^3$

No. of test report:  
Date:  
Name of test institute:  
Signature:  

www.nordtest.info
Building Acoustics:
Field measurements of airborne and impact sound insulation and of sound pressure level from equipment - Survey method

Changes:
1.) Editorial comments from the discussion in Juan-les-Pins
2.) New wording of 5.2.5.3 and 5.2.5.7 by Mr. Servant
3.) Reverberation can optionally be measured
4.) Reverberation time table changed
   four volume classes instead of three,
   differences between adjacent classes ≤ 0,5 dB,
   furnished kitchens and bathrooms separately
Content

0. Introduction
1. Scope
2. Normative references
3. Definitions
   3.1 Average sound pressure level in a room
   3.2 Level difference
   3.3 Reverberation term
   3.4 Standardized level difference
   3.5 Normalized level difference
   3.6 Apparent sound reduction index
   3.7 Reverberation term
   3.8 Impact sound pressure level
   3.9 Standardized impact sound pressure level
   3.10 Normalized impact sound pressure level
   3.11 Facade level difference
   3.12 Standardized facade level difference
   3.13 Normalized facade level difference
   3.14 Equipment average sound pressure level
   3.15 Standardized equipment sound pressure level
4. Measuring equipment
5. Test procedure and evaluation
   5.1 General
   5.2 Generation of sound field
      5.2.1 General
      5.2.2 Airborne sound insulation between rooms
      5.2.3 Impact sound insulation between rooms
      5.2.4 Airborne sound insulation of facades
      5.2.3.1 Loudspeaker method
      5.2.3.2 Traffic noise method
      5.2.5 Equipment noise
      5.2.5.1 Water installation
      5.2.5.2 Common mechanical ventilation
      5.2.5.3 Lifts and motor driven car park doors
      5.2.5.4 Rubbish chutes
      5.2.5.5 Boiler, blower and auxiliary equipment
      5.2.5.6 Individual heating and ventilation equipment
   5.3 Measurement of sound pressure levels
      5.3.1 Airborne and impact sound insulation between rooms
      5.3.2 Airborne sound insulation of facades
      5.3.3 Equipment sound pressure levels
   5.4 Frequency range of measurements
   5.5 Reverberation term data
      5.5.1 Furnished rooms
      5.5.2 Unfurnished rooms
   5.6 Precision
6. Expression of results
   6.1 Airborne sound insulation
   6.2 Impact sound insulation
   6.3 Equipment sound pressure level
7. Test report
   Annex A - Short survey test method
   Annex B - Forms for expression of results (airborne sound insulation)
   Annex C - Forms for expression of results (impact sound insulation)
0. INTRODUCTION

This International Standard describes survey test methods which provide estimates of the airborne sound insulation, impact sound insulation and of the sound pressure levels from equipment installed. The methods may be used for screening tests of the acoustical properties of buildings. The methods are not intended to be applied for measuring acoustical properties of building elements. The main difference to the corresponding methods on engineering precision level is having less time to be spent but less precision has to be taken into account.

The approach of the survey methods is to simplify the measurement of sound pressure levels in rooms by using a hand-held sound level instrument and by manually sweeping the microphone in the room space. The reverberation time measurement used in the engineering method is, for general cases, replaced by usage of tabular values. The reverberation time can optionally be measured. The measurement of airborne and impact sound insulation is carried out in octave bands. For measuring noise from housing equipment A-weighted sound pressure levels are recorded. Measurements using the survey method can be performed markedly faster than those applying the engineering method if the instruments used (source and sound level meter) are both portable and battery supported.

A short survey test method for measuring airborne and impact sound insulation based on A-weighted sound pressure levels and tables for the transition into single numbers of sound insulation is given in Annex A.

1. SCOPE

This International Standard specifies field survey methods for measuring
a) the airborne sound insulation between rooms,
b) the impact sound insulation of floors,
c) the airborne sound insulation of facades, and
d) the sound pressure levels in rooms from equipment.

The methods described in this International Standard are applicable for measurements in rooms of dwellings or in rooms of comparable size with a maximum of 150 m².

For airborne sound insulation, impact sound insulation and facade sound insulation the method gives values which are frequency dependent. They can be converted into a single number characterizing the acoustical performances by application of ISO 717-1 and 2. For equipment noise the results are given in A-weighted sound pressure levels.

The measurement uncertainty of the results obtained using the survey method is larger than the uncertainty inherent in the corresponding test methods on engineering level.

The results obtained can be used to compare sound insulation between rooms or sound pressure levels in rooms and to compare actual sound insulation or sound pressure levels with specified requirements or regulations.
NOTE 1
Engineering methods for field measurements of airborne and impact sound insulation are dealt with in ISO 140-4 and -7. Engineering methods for field measurements of airborne sound insulation of facade elements and facades are dealt with in ISO 140-5. An engineering method for measurement of equipment noise is dealt with in EN xxxxx.

2. NORMATIVE REFERENCES

The following Standards contain provisions which, through reference in this text, constitute provisions of this International Standard. At the time of publication, the editions indicated were valid. All Standards are subject to revision, and parties to agreements based on the International Standards are encouraged to investigate the possibility of applying the most recent editions of the Standards listed below. Members of IEC and ISO maintain registers of currently valid International Standards.


ISO 140-7: , Measurements of sound insulation in buildings and of building elements - Part 7: Field measurements of impact sound insutation of floors.


EN xxxxx: , Measurement of sound levels from equipment in buildings.

IEC Publication 225: 1985, Octave, half-octave and third-octave band filters intended for the analysis of sounds and vibrations.

IEC Publication 651:1979, Sound level meters.


OIML* R 58: 1984, Sound level meters.

OIML* R 88: 1989, Integrating-averaging sound level meters

*: Organisation International de Metrologie Legale - 11 rue Turgot, 75009 Paris (France).
3. DEFINITIONS

For the purpose of this International Standard, the following definitions apply:

3.1 Average sound pressure level in a room

Ten 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. This quantity is denoted by \( L \):

\[
L = 10 \log \left( \frac{1}{T} \int_0^T \frac{p^2(t)}{p_0^2} \, dt \right) \quad \text{dB}, \quad (1)
\]

\( p \) is the sound pressure in Pa and may be 'A' weighted or given in octave bandwidth unweighted, \( p_0 = 20 \mu Pa \) is the reference sound pressure, \( T \) is the integration time in s.

3.2 Level difference

The difference in the space and time average sound pressure levels produced in two rooms by one sound source in one of them. This quantity is denoted by \( D \):

\[
D = L_1 - L_2 \quad \text{dB}, \quad (2)
\]

where

\( L_1 \) is the average sound pressure level in the source room,
\( L_2 \) is the average sound pressure level in the receiving room.

3.3 Reverberation term

Ten times the common logarithm of the ratio of the actual reverberation time \( T \) of the receiving room to the reference reverberation time \( T_0 \) (\( T_0 = 0.5 \) s). This quantity is denoted by

\[
k = 10 \log \frac{T}{T_0} \quad \text{dB}, \quad (3)
\]

The reverberation term \( k \) is taken from a table as an estimation (see clause 5.5).
3.4 Standardized level difference:

The level difference corresponding to a reference value of the reverberation time in the receiving room. This quantity is denoted by \( D_{st} \):

\[
D_{st} = D \cdot k \quad \text{dB} ,
\]

where

\( D \) is the level difference (see eq. (2)),

\( k \) is the reverberation term (see eq. (3)).

3.5 Normalized level difference:

The level difference \( D \) corresponding to the reference absorption area in the receiving room. This quantity is denoted by \( D_n \):

\[
D_n = D \cdot k \cdot 10\log\left(\frac{A_0 \cdot T_0}{0.16V}\right) \quad \text{dB} ,
\]

where

\( k \) is the reverberation term,

\( T_0 \) is the reference reverberation time in s (for rooms in dwellings or rooms of comparable size \( T_0 = 0.5 \) s),

\( V \) is the volume of the receiving room in m\(^3\),

\( A_0 \) is the reference absorption area in m\(^2\) (for rooms in dwellings or rooms of comparable size \( A_0 = 10 \) m\(^2\)).

3.6 Apparent sound reduction index:

Ten times the common logarithm of the ratio of the sound power \( W_1 \) which incidents on a partition under test to the total sound power transmitted into the receiving room, when in addition to the sound power \( W_2 \) radiated by the partition, sound power \( W_3 \), radiated by flanking elements or by other components, has to be regarded.

This quantity is denoted by \( R' \):

\[
R' = 10\log\left(\frac{W_1}{W_2 \cdot W_3}\right) \quad \text{dB} ,
\]

NOTE 2

Being equivalent to apparent sound reduction index the expression apparent transmission loss also is in use.

Under the assumption of diffuse sound fields in the two rooms, the apparent sound reduction index in this International Standard is evaluated from:

\[
R' \cdot D \cdot k \cdot 10\log\left(\frac{S \cdot T_0}{0.16V}\right) \quad \text{dB} ,
\]
where
D is the level difference,
k is the reverberation term,
S is the area of the partition in m²,
V is the volume of the receiving room in m³,
T₀ is the reference reverberation time in s (for rooms in dwellings or rooms of comparable size T₀ = 0.5 s).

In the case of staggered or stepped rooms, S is that part of the area of the partition common to both rooms. If the common area between the stepped or staggered rooms is less than 10 m², this shall be indicated in the test report. S is then calculated by V/7.5 where V is the volume in m³ of the receiving room which shall be the smaller room.

In the case that no common area exists S shall be taken as 10 m².

NOTE 3
In the apparent sound reduction index, the sound power transmitted into the receiving room is related to the sound power incident on the common partition irrespective of actual conditions of transmission. The apparent sound reduction index is independent of the measuring direction between the rooms if the sound fields are diffuse in both rooms.

3.7 Impact sound pressure level:

The average sound pressure level in the receiving room when the floor under test is excited by the standardized impact sound source. This quantity is denoted by L_i. If more than one position of the tapping machine is used, calculate the impact sound pressure level by averaging the sound pressure levels L_i,n at N positions according to

\[ L_i = 10 \log \left( \frac{1}{N} \sum_{n=1}^{N} 10^{L_i,n/10} \right) \]  \[ \text{dB} \quad (8) \]

3.8 Standardized impact sound pressure level:

The impact sound pressure level L_i reduced by the reverberation term k. This quantity is denoted by L'_i,\text{ST}.

\[ L'_i,\text{ST} = L_i - k \] \[ \text{dB} \quad (9) \]

3.9 Normalized impact sound pressure level:

The impact sound pressure level L_i increased by a correction term which is given in decibels, being ten times the common logarithm of the ratio between the actual equivalent absorption area of the receiving room and the reference equivalent absorption area. The actual equivalent absorption area is calculated from the reverberation term, the reference reverberation time and the room volume. The normalized impact sound pressure level is denoted by L'_i :

\[ L'_i = L_i + k + 10 \log \frac{A_\text{a}}{0.16V} \] \[ \text{dB} \quad (10) \]
where

\( V \) is the volume of the receiving room in m³;
\( k \) is the reverberation term,
\( T_0 \) is the reference reverberation time in s (for rooms in dwellings or rooms of comparable size \( T_0 = 0.5 \) s),
\( A_0 \) is the reference equivalent absorption area in m² (for rooms in dwellings or rooms of comparable size \( A_0 = 10 \) m²).

### 3.10 Facade level difference:

The difference between the outdoor sound pressure level 2 m in front of the facade, \( L_{1,2m} \), and the space and time average sound pressure level, \( L_2 \), in the receiving room. This quantity is denoted by \( D_{2m} \).

\[
D_{2m} = L_{1,2m} - L_2 \quad \text{dB} \quad , \quad (11) \]

If road traffic noise has been used as sound source the notation is \( D_{n,2m} \) and if a loudspeaker has been used it is \( D_{l,2m} \).

### 3.11 Standardized facade level difference:

The facade level difference \( D_{2m} \) corresponding to a reference value of the reverberation time in the receiving room. This quantity is denoted by \( D_{2m,nT} \).

\[
D_{2m,nT} = D_{2m} \cdot k \quad \text{dB} \quad , \quad (12) \]

where

\( k \) is the reverberation term.

### 3.12 Normalized facade level difference:

The facade level difference \( D_{2m} \) corresponding to the reference equivalent absorption area in the receiving room. This quantity is denoted by \( D_{2m,n} \).

\[
D_{2m,n} = D_{2m} \cdot k \cdot \frac{10 \log A_0 T_0}{0.16V} \quad \text{dB} \quad , \quad (13) \]

where

\( V \) is the volume of the receiving room in m³;
\( k \) is the reverberation term,
\( T_0 \) is the reference reverberation time in s (for rooms in dwellings or rooms of comparable size \( T_0 = 0.5 \) s),
\( A_0 \) is the reference equivalent absorption area in m² (for rooms in dwellings or rooms of comparable size \( A_0 = 10 \) m²).
3.13 Equipment A-weighted sound pressure level

The equipment A-weighted sound pressure level $L_A$ of equipment noise is the average of the maximum A-weighted sound pressure levels measured with time weighting "S" at three positions in the room:

$$L_A = 10 \log \left( \frac{1}{3} \sum_{i=1}^{3} 10^{\frac{L_{Ai}}{10}} \right) \text{dB} , \quad (14)$$

where

- $L_{Ai}$ is the maximum A-weighted sound pressure level measured at position $i$ ($i = 1, 2, 3$).

**NOTE 4**

Alternatively, C-weighted sound pressure levels and equipment sound pressure levels and/or time weightings "F" can be used, provided, this is clearly indicated in the results (for instance in the way $L_{AP}$, $L_{CS}$ or similar). The detailed prescription for using frequency and time weighting is given in the method on engineering level in EN xxxxx.

3.14 Standardized equipment A-weighted sound pressure level:

The standardized equipment A-weighted sound pressure level $L_{A,ST}$ is

$$L_{A,ST} = L_A - k \text{ dB} . \quad (15)$$

where

- $L_A$ is the equipment average A-weighted sound pressure level,
- $k$ is the reverberation term.

4. MEASURING EQUIPMENT

The measuring equipment shall comply with the requirements of clause 5.

The loudspeaker for measuring sound insulation between rooms shall comply with the requirements given in ISO 140-4, Annex A.

The loudspeaker for measuring sound insulation of facades shall comply with the following requirements: The directivity of the loudspeaker in a free field shall be such that the local differences in the sound pressure level in each frequency band of interest are less than 5 dB measured on a surface of the same size and orientation as the test specimen. The directivity of the loudspeaker can be tested according to the method given in ISO 140-5, Annex B.

If the loudspeaker method is adapted to large facades, that is facades where one dimension exceeds 5 m, differences up to 10 dB can be accepted. This shall be reported in the measurement report.

The tapping machine shall comply with the requirements given in ISO 140-7, Annex A.
The accuracy of the sound level measurement equipment shall comply with the requirements of accuracy class 0 or 1 formulated in IEC 651/IEC 804. The complete measuring system including the microphone shall be adjusted before each measurement to enable absolute values of sound pressure levels to be obtained. If not otherwise stated by the equipment manufacturer a sound calibrator which meets the requirements of IEC 942 for sound calibrators class 0 or 1 shall be used.

Diffuse field calibration of the measurement equipment is required. For sound level meters calibrated for measurements in sound fields of progressive plane waves corrections for the diffuse sound field must be applied.

Filters shall comply with the requirements defined in IEC 225.

NOTE 5
It is recommended to use simple and battery supported sound level meters and sound sources.

NOTE 6
For pattern evaluation (type testing) and regular verification tests requirements are given in OIML R58 and R88, for the tapping machine requirements are given in ISO 140-7, Annex A.

5. TEST PROCEDURE AND EVALUATION

5.1 General

The measurements of airborne sound insulation and of impact sound insulation are made in octave bands. The measurement of equipment sound pressure levels are made in A-weighted sound pressure level. The measurements shall be performed with doors and windows closed and shutters open.

5.2 Generation of sound field

5.2.1 General

For measurements of the airborne sound insulation between rooms and the airborne sound insulation of facades using the loudspeaker method, the sound power of the source should be adjusted so that the sound pressure level in the receiving room (in each frequency band) is at least 6 dB higher than the background noise level. This shall be checked by switching the source on and off before starting the measurement.

If the difference between the signal level and the background noise level is less than 6 dB, the measured signal level shall be recorded in the report. A note shall be added to say that the measured receiving room level was affected by background noise and the corresponding level difference has been underestimated by an unknown amount.

No correction for background noise shall be applied.

When measuring the airborne sound insulation of facades by the traffic noise method, the
background noise level in the receiving room cannot easily be assessed. Because of this, steps should be taken to ensure that the noise level in the receiving room due to sources within the building is as low as possible. Excessive background noise from internal sources will lead to an underestimate of the facade insulation. A comment shall be made in the report if this is thought to have occurred.

5.2.2 Airborne sound insulation between rooms

The sound generated in the source room should be steady and have a continuous spectrum in the frequency range considered. Filters with a bandwidth of one octave may be used. White noise as source signal is recommended. When using broad-band noise, the spectrum of the noise source may be modified to ensure an adequate signal to noise ratio at high frequencies in the receiving room. The sound spectrum in the source room should not have level differences larger than 6 dB between adjacent octave bands.

If the sound source enclosure contains more than one loudspeaker operating simultaneously, the loudspeakers shall be driven in phase. Multiple sound sources may be used simultaneously providing they are of the same type and are driven at the same level by similar, but uncorrelated signals.

Place the sound source on the floor on the side of the room opposite the partition. It shall face a junction of two walls and its front face shall be 1 m from the junction.

When testing rooms in a vertical direction, use the lower room as the source room. When testing rooms of unequal size in a horizontal direction, unless otherwise specified use the larger room as the source room.

5.2.3 Impact sound insulation between rooms

The impact sound shall be generated by the standardized tapping machine (see ISO 140-7). The tapping machine shall be placed in the source room on the diagonal near the centre of the floor. This single position is sufficient if the floor is isotropic.

In the case of anisotropic floor construction (with ribs, beams, etc.) add two positions so that the three positions are randomly distributed over the floor area. The hammer connecting line should be orientated at 45° to the direction of the beams or ribs. In these cases, the distance of the tapping machine from the edges of the floor shall be at least 0,5 m.

5.2.4 Airborne sound insulation of facades

The airborne sound insulation of facades is measured by using an outside loudspeaker or road traffic noise. The room behind the facade serves as receiving room.

5.2.4.1 Loudspeaker method

Place the loudspeaker outside the building at a distance d from the facade with the angle of sound incidence as close as possible to 45° (see figure 1). Choose the position of the
loudspeaker and the distance d to the facade so that the variation of the sound pressure level on the test specimen is minimized. This implies that the sound source is preferably placed on the ground. Alternatively place the sound source as high above the ground as practically possible. The distance r from the sound source to the centre of the test specimen shall be at least 7 m (d > 5 m) from the facade being tested.

![Diagram of loudspeaker method](image)

Figure 1. Geometry of the loudspeaker method.

The sound generated shall be steady and have a continuous spectrum in the frequency range considered. Filters with a bandwidth of a one octave may be used. White noise as source signal is recommended. When using broad-band noise the spectrum of the noise source may be modified to ensure an adequate signal to noise ratio at high frequencies in the receiving room. The sound spectrum in front of the facade should not have level differences larger than 6 dB between adjacent octave bands.

The sound power shall be sufficiently high for the sound pressure level in the receiving room to be at least 6 dB higher than the level of the background noise in any frequency band.

5.2.4.2 Traffic noise method

The traffic noise method with road traffic as noise source can be used if the sound pressure level is high enough in relation to the background noise in the receiving room. If the sound is incident on the facade from different directions and with varying intensity, as road traffic noise in busy streets, the facade level difference is obtained from the average sound pressure levels measured simultaneously on both sides of the facade.

NOTE 7
Due to background noise the traffic noise method is normally limited to measure $D_{ntw} < 40$ dB.

5.2.5 Equipment noise

For the measurements each appliance shall be operated as far as possible separately from others. All equipment shall be used in normal operating conditions and, if relevant, operate in such a way that other requirements are fulfilled. The value expressed by the standardized
equipment sound pressure level relates to the noisiest operating conditions of the appliance concerned.

For each type of equipment the relevant condition and operating cycle for the measurements is defined in the following sections.

The maximum noise produced by the equipment under test is not under the control of the operator. For reliable measurements the equipment noise level should be at least 6 dB(A) higher than the background noise level. Where possible this shall be checked before starting each measurement. If this condition cannot be fulfilled or checked, the measured level shall be recorded in the report and a note shall be added to say that the measured equipment noise level was affected by background noise and the actual equipment noise level has been overestimated by an unknown amount.

5.2.5.1 Water installation

Before any measurement the shut-off valves and check valves shall be set to their maximum opening position.

a) Conditions
Normal water pressure; if it varies during a day - choose the period with the highest pressure.
b) Operating cycle
Single taps: slowly open completely - then close.
mixing taps: slowly open the hot tap completely, then the cold tap - close the hot tap, then the cold tap.
thermostatic taps: slowly open completely at average temperature setting - slowly decrease temperature - slowly increase temperature - close.
bath, sinks, wash basins, showers and bidets: operate taps as above with opened water outlet.
toilet: complete flush-fill cycle.
geyser, pressure increase equipment, dirt water pumps: start - operate at full load - stop.

5.2.5.2 Mechanical ventilation

a) Conditions
set air flow to the highest rate specified in the ventilation regulations If there are no ventilation regulations, set air flow to the highest rate available.
b) Operating cycle
continuous operation

5.2.5.3 Lifts

a) Conditions
for passenger lifts, service lifts or car lifts the receiving room shall be the habitable room nearest to the engine room. If it is necessary to make measurements at an intermediate level choose the habitable room nearest to the hoistway.
b) Operating cycle
start lift from the level closest to the engine room - stop at intermediate level - open and close door (if by hand without force). When the lift has arrived at the end of its way, call it back directly to the engine room, open and close the door.

5.2.5.4 Rubbish chutes

a) Conditions
the chute shall be clear of waste.
b) Operating cycle
dispatch simultaneously two standard objects from the top storey.
c) Standard object
unplasticized polyvinyl chloride with open ends,
nominal external diameter 50 mm,
nominal thickness 3 mm,
weight per meter length 0,7 kg/m,
length 0,1 m.

5.2.5.5 Boiler, blower and auxiliary equipment

a) Conditions
continuous operating under normal (loaded) conditions
b) Operating cycle
for electrical controlled appliances: start-up - operate - stop

5.2.5.6 Heating and ventilation equipment

a) Conditions
maximum normal waterflow and pressure; maximum normal air flow.
b) Operating cycle
start-up from cold conditions - operate at full load - open and close slowly each appliance
(taps for heating elements; regulators of air devices - stop.

5.2.5.7 Motor driven car park door

a) Conditions
Choose the habitable room directly above or beside the motor driven car park door as receiving room
b) Operating cycle
Three cycles of opening and closing the door.
5.3 Measurement of sound pressure levels

5.3.1 Airborne and impact sound insulation between rooms

Measure the average sound pressure level in the room directly using an integrating sound level meter. The measurement time interval shall be approximately 30 s. Stand as near to the centre of the room as possible facing away from the loudspeaker in the source room or from the separating element in the receiving room. Hold the sound level meter out at arm's length. Move the microphone four times horizontally through 180°, moving the arm up and down in a gentle movement during the traverse. Complete the four rotations in a total time of approximately 30 s. Read the average sound pressure level \(L_a\) from the meter to give the value for the average sound pressure level in the room.

The following separating distances are minimum values and should be exceeded where possible:
- 0.5 m between any microphone position and room boundaries,
- 1.0 m between any microphone position and the sound source.

**NOTE 8**
Hearing protectors should be worn by the operator when measuring in the source room.

5.3.2 Airborne sound insulation of facades

Place the outdoor microphone at a distance of \((2.0 \pm 0.2)\) m from the plane of the facade or at such a larger distance that the distance to the part of the facade nearest to the road - for instance the balustrade - is at least 1 m. Position the microphone in the receiving room at a height of \((1.5 \pm 0.1)\) m above the floor level, opposite the middle of the width of the facade.

If the sound source is a loudspeaker measure the outdoor sound pressure level with an integration time of 30 s and the level in the receiving room according to clause 5.3.1.

If the sound source is the prevailing road traffic, measure the outdoor level and the indoor level simultaneously. The integration time shall be 60 s and the indoor level is obtained by repeating the procedure of clause 5.3.1 twice during this period. During this measurement period at least 15 vehicles shall have passed.

5.3.3 Equipment A-weighted sound pressure level

Measure the equipment average A-weighted sound pressure level \(L_A\) in the room directly using a sound level meter. Three positions are used. In each position the measurement time interval shall be at least 30 s and shall be chosen in accordance with at least one cycle of the equipment working under normal conditions. The measurement shall be made in two
positions in the central part of the room at least 2 m away from each other and in one position standing approximately 1 m from a corner and facing the corner. Use three cycles of the equipment working under normal conditions. The average sound pressure level in the room shall then be calculated by averaging the levels according to eq. (12).

The following separating distances are minimum values and should be exceeded where possible:
- \( d > 0.5 \) m between any microphone position and room boundaries,
- \( 1.0 \) m between any microphone position and the sound source. under test (e.g., ventilation outlets).

5.4 Frequency range of measurements

The sound pressure level measured using octave band filters shall have at least the following centre frequencies in Hz:

- 125
- 250
- 500
- 1000
- 2000.

Noise from equipment is measured in A- (or C-) weighted sound pressure level.

5.5 Reverberation term data

In the survey method described in this International Standard the reverberation time is estimated from a table. The table contains the reverberation term \( k \) for average typical construction of rooms in dwellings or in rooms of comparable size, depending on their state of furnishing and, if unfurnished, on the type of walls, floor and ceiling and on the volume \( V \) of the receiving room. It is based on a statistical evaluation of reverberation times obtained in dwellings in several European countries. The standard deviation of the reverberation terms \( k \) derived from the tables is approximately 1 dB.

Alternatively, the reverberation time may be measured according to the method described in ISO 140-4 in octave bands and the reverberation term may be calculated by using the measured reverberation times. However, the total measurement time is then approximately equal to the time required for the engineering method and the measuring equipment must be appropriate for reverberation time measurements. Measurement of reverberation time can be advantageous if performed only once in a typical room of a building under test which has a large number of identical rooms.

The tabular values of the reverberation terms are listed in Table 2. Table 2 is valid for a reference reverberation time \( T_0 = 0.5 \) s and for room sizes of up to 150 m\(^2\). Furnished rooms like living rooms, sleeping rooms and rooms of similar volume and furniture are considered in one group. Furnished kitchens and bathrooms are considered separately. Concerning unfurnished rooms the reverberation term depends on the type of construction as listed in Table 1.
Table 1. List of symbols representing the type of construction.

<table>
<thead>
<tr>
<th>UNFURNISHED</th>
<th>soft floor</th>
<th>covering</th>
<th>hard floor</th>
<th>covering</th>
</tr>
</thead>
<tbody>
<tr>
<td>Floor type</td>
<td>light</td>
<td>heavy</td>
<td>light</td>
<td>heavy</td>
</tr>
<tr>
<td>Light walls/ceiling</td>
<td>a</td>
<td>b</td>
<td>c</td>
<td>d</td>
</tr>
<tr>
<td>Heavy walls/ceiling</td>
<td>e</td>
<td>f</td>
<td>g</td>
<td>h</td>
</tr>
</tbody>
</table>

"Light wall" is typically a plaster board or wooden wall mounted on studs. Heavy walls covered with plaster board linings must be considered as light walls.

"Heavy wall" is typically a masonry or concrete block wall without lining.

"Light floor" is typically a floor of wooden planks or boards on timber beams.

"Heavy floor" is typically a concrete slab with or without floating concrete covering.

"Floor covering" is typically carpet (soft), tiles or timber flooring (hard).

If the type of construction is not the same throughout the room, but the areas of different construction are approximately equal, use the average of the values given for the different construction types. For example: if a room has a heavy floor with a carpet, three heavy walls, one light wall and a light ceiling, use the average of b and f. If the areas of different construction are not approximately equal, use the value for the type of construction having the largest area.
Table 2. Reverberation terms in dB in octave bands and corresponding to A- or C-weighted sound pressure levels.

<table>
<thead>
<tr>
<th>Volume V in m³</th>
<th>&lt;15</th>
<th>15...35</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>125 250 500</td>
<td>125 250 500</td>
</tr>
<tr>
<td>Octave bands in Hz</td>
<td>1000 2000 A. C</td>
<td>1000 2000 A. C</td>
</tr>
<tr>
<td>Furnished rooms:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kitchens</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Others</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unfurnished rooms:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Type:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mixed type:</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Volume V in m³</th>
<th>35...60</th>
<th>&gt;60</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>125 250 500</td>
<td>125 250 500</td>
</tr>
<tr>
<td>Octave bands in Hz</td>
<td>1000 2000 A. C</td>
<td>1000 2000 A. C</td>
</tr>
<tr>
<td>Furnished rooms:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(except bathrooms) and kitchens</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unfurnished rooms:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Type:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mixed type:</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: The table provides reverberation terms in dB for different volume categories and octave bands, corresponding to A- or C-weighted sound pressure levels.
If other reference reverberation times $T_{\text{ref}}$ are to be used the resulting reverberation term $k_{\text{ref}}$ shall be calculated from the tabular values of $k$ using:

$$k_{\text{ref}} = k \cdot 10 \log_{10} \frac{0.5s}{T_{\text{ref}}} \db,$$  (16)

or directly from the measured reverberation times $T$ using

$$k_{\text{ref}} = 10 \log_{10} \frac{T}{T_{\text{ref}}} \db.$$  (17)

In these cases $k_{\text{ref}}$ shall replace $k$ in equations (4) to (15).

5.6 Precision

It is required that the measurement procedure should give satisfactory reproducibility. This can be determined in accordance with the method shown in ISO 140-2 and should be checked from time to time, particularly when a change is made in procedure or instrumentation.

NOTE 9

Numerical requirements for reproducibility of the engineering methods are given in ISO 140-2. The reproducibility limit of the survey method is estimated to exceed the reproducibility limit of the engineering methods by 2 dB.

### 6. EXPRESSION OF RESULTS

#### 6.1 Airborne sound insulation

For the statement of the airborne sound insulation, the standardized level difference $D_{nT}$, the normalized level difference $D_n$ or the sound reduction index $R'$ shall be given at all frequencies of measurement to one decimal place in tabular form and/or in the form of a curve. For graphs with the level in decibels plotted against frequency on a logarithm scale, the following dimensions shall be used:

- 15 mm for one octave,
- 20 mm for 10 dB.

The use of a form in accordance with Annex B is requested. Being a short version of the test report all information of importance regarding the test object, the test procedure and the test results shall be stated.

#### 6.2 Impact sound insulation

For the statement of the impact noise insulation, the standardized impact sound pressure level $L'_{\text{int}}$ or the normalized impact sound pressure level $L'_n$ shall be given at all frequencies of measurement to one decimal place in tabular form and/or in the form of a curve. For graphs with the level in decibels plotted against frequency on a logarithm scale, the following dimensions shall be used:
15 mm for one octave,
20 mm for 10 dB.

The use of a form in accordance with Annex B is requested. Being a short version of the test report all information of importance regarding the test object, the test procedure and the test results shall be stated.

6.3 Equipment sound pressure level

For the statement of the noise level from housing equipment the standardized equipment sound pressure level shall be given in A- or C-weighted sound pressure level rounded to one dB.

7. TEST REPORT

With reference to this International Standard, the test report shall state :

a) Name of organization that has performed the measurements.

b) Name of client.

c) Date of test.

d) Identification (location of the building, identification of the rooms, description of the test arrangement).

e) Description of the building construction.

f) Volumes of the rooms tested.

g) The reverberation terms k which were used (the reference reverberation time, if different from 0.5s).

h) The area of the separating element tested (where appropriate)

i) The relevant quantity describing the acoustical property of the building :

   i) the standardized or the normalized level difference or the apparent sound reduction index as a function of frequency,

   ii) the normalized or the standardized impact sound pressure level as a function of frequency,

   iii) the standardized equipment sound pressure level.

j) Brief description of procedure and measuring equipment and, if necessary, a note on the check of background noise.

For the evaluation of single-number rating from the octave-band results, see ISO 717-1 and -2. It should be clearly stated that the evaluation has been based on a result obtained by a field survey method.
Annex A (informative) = dB(A) method of ISO/TC43/SC2/WG10
Annex B
(informative)

Forms for the expression of results

This annex gives examples for the expression of results for the field measurements of airborne and impact sound insulation in buildings using the survey method.

NOTE 10
The curve of reference values shown in the form is taken from ISO 717-1 and ISO 717-2.
Apparent sound reduction index according to EN ..... 
Field measurements of airborne sound insulation - Survey method

Client: 
Date of test: 

Description of the building construction and test arrangement:

Identification and

<table>
<thead>
<tr>
<th>Frequency</th>
<th>$R'$ oct dB</th>
</tr>
</thead>
<tbody>
<tr>
<td>125</td>
<td></td>
</tr>
<tr>
<td>250</td>
<td></td>
</tr>
<tr>
<td>500</td>
<td></td>
</tr>
<tr>
<td>1000</td>
<td></td>
</tr>
<tr>
<td>2000</td>
<td></td>
</tr>
</tbody>
</table>

Area $S$ of test-specimen: $m^2$ 
Source room volume: $m^3$ 
Receiving room volume: $m^3$ 

Room type: 

frequency range according to the curve of reference values (ISO 717-1)

Rating according to ISO 717-1:

$R'_{w}(C;C_{tr}) = ( ; ) dB$

Evaluation based on field measurement results obtained by a survey method

No. of test report: 
Name of test institute: 
Date: 
Signature:
Normalized level difference according to EN ..... Field measurements of airborne sound insulation - Survey method

Client: 
Date of test: 
Description of the building construction and test arrangement, direction of measurement:

Identification and 

Source room volume: m³
Receiving room volume: m³
Room type:

<table>
<thead>
<tr>
<th>Frequency (Hz)</th>
<th>Dn,oct (dB)</th>
</tr>
</thead>
<tbody>
<tr>
<td>125</td>
<td></td>
</tr>
<tr>
<td>250</td>
<td></td>
</tr>
<tr>
<td>500</td>
<td></td>
</tr>
<tr>
<td>1000</td>
<td></td>
</tr>
<tr>
<td>2000</td>
<td></td>
</tr>
</tbody>
</table>

70
60
50
40
30
20

Normalized level difference Dn

717-1

frequency range according to the curve of reference values (ISO 717-1)

Rating according to ISO 717-1:

\[ D_{n,w}(C; C_{tr}) = \text{( ; ) dB} \]

Evaluation based on field measurement results obtained by a survey method

No. of test report: 
Name of test institute: www.nordtest.info
Date: 
Signature: 
Standardized level difference according to EN ......
Field measurements of airborne sound insulation - Survey method

Client:  
Date of test:  
Description of the building construction and test arrangement, direction of measurement:

<table>
<thead>
<tr>
<th>Frequency</th>
<th>D_{nt}</th>
<th>D_{nt}</th>
<th>dB</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hz</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>125</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>250</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>500</td>
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<td></td>
</tr>
<tr>
<td>1000</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2000</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Source room volume: m³  
Receiving room volume: m³  
Room type:  

Frequency range according to the curve of reference values (ISO 717-1)

Rating according to ISO 717-1:

\[ D_{nt,w(C;C_{tr})} = \left( \ ; \right) \text{dB} \]

Evaluation based on field measurement results obtained by a survey method

No. of test report:  
Name of test institute:  
www.nordtest.info  
Date:  
Signature:
Normalized impact sound pressure levels according to EN ..... 
Field measurements of impact sound insulation of floors - Survey method

Client: 
Date of Test: 

Description of the building construction and test arrangement:

Receiving room volume: 
Room type: 
m³ 

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\[ l_n, L'n,_{w} = 60 \text{ dB} \]

Frequency range according to the curve of reference values (ISO 717-2)

Rating according to ISO 717-2:

\[ L'n,_{w}(C_t) = ( ) \text{ dB} \]

Evaluation based on field measurement results obtained by a survey method

No. of test report: 
Name of test institute: 
Date: 
Signature: 

www.nordtest.info
Standardized impact sound pressure levels according to EN ..... Field measurements of impact sound insulation of floors - Survey method

Client: [Client Information]

Date of Test: [Date]

Description of the building construction and test arrangement:

Identification and:

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Room type:

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Frequency range according to the curve of reference values (ISO 717-2)

\[ L'_{wT} = 60 \text{ dB} \]

Rating according to ISO 717-2:

\[ L'_{nT,w}(C_i) = \quad (\quad) \text{ dB} \]

Evaluation based on field measurement results obtained by a survey method

No. of test report: [Report Number]

Name of test institute: [Institute Name]

Date: [Date]

Signature: [Signature]
Proposal for NORDTEST Method

Final Draft

Building elements:
Sound insulation measurements with an intensity scanning method in situ

Introduction

The ISO 140 set of standards specify methods to determine the sound reduction index of building elements in the laboratory and in situ. This NORDTEST method is primarily aimed at being an alternative to ISO 140/4. It is for use when determining apparent sound reduction indices using intensity measurements in situ. These measurements may also be used to rank component contributions to the total sound reduction index.

Measurements carried out according to ISO 140/4, based upon sound pressure measurements, produce sound reduction indices that are the sum of all transmission paths between the source room and receiving room. The intensity based measurements determine the sound reduction indices for each chosen exit area on the path from source to receiving room. Hence the component parts of a construction can be evaluated. There is a fundamental difference between sound reduction indices based on sound pressure measurements as compared to sound intensity measurements. In the receiving room the sound pressure method gives an estimate of the total sound energy from all boundary surfaces where as the intensity method gives an estimate of the net transmitted sound energy through the test specimen. The results obtained by the two methods are therefore not expected to agree.
1 SCOPE

This NORDTEST method specifies a sound intensity method to determine the sound reduction index and rank partial contributions to the index for building elements/constructions in situ.

2 FIELD OF APPLICATION

2.1 General

This NORDTEST method is intended to be used in situ where information is required about the partial sound transmission through building elements. This information may be required when the standard ISO 140 measurements indicate that a building element has not fulfilled its specification and improvement measures need to be specified. The method may be used instead of ISO 140/4, when the sound field in the receiving room is not sufficiently diffuse. ISO 140/4 is to be used in preference to the method, when the sound field in the receiving room is diffuse and absorption cannot be added to the receiving room.

2.2 Grade of Accuracy

Engineering

3 REFERENCES

ISO 140/4 ACOUSTICS - Measurements of Sound Insulation in Buildings and of Building Elements - Part IV: Field Measurements of Airborne Sound Insulation Between Rooms. (under revision)

NS/INSTA 121. Akustikk - Bestemmelse av Lydeffektnivå for lydkilder ved hjelp av Lydintensitetsmålinger. Sveipemetoden.

ISO 717 ACOUSTICS - Rating of Sound Insulation in Buildings and of Building Elements.


IEC 942 Sound Calibrators.

IEC 1043 Instruments for the measurement of sound intensity.
4 DEFINITIONS

4.1 Sound pressure level, $L_p$:
10 times the common logarithm of the ratio of the space and time average of the sound pressure squared, to the reference sound pressure $p_o$ as given by:

$$L_p = 10 \log \left( \frac{p}{p_o} \right)^2$$

where:

- $p_o$ is 20 $\mu$Pa the reference pressure.

4.2 Sound intensity, $\tilde{I}$:
Time averaged rate of sound energy flow per unit area oriented normal to the local particle velocity. This is a vector quantity which is equal to:

$$\tilde{I} = \lim_{T \to \infty} \frac{1}{T} \int_0^T p(t) \dot{u}(t) \, dt \quad \text{W/m}^2 \quad (4.1)$$

where:

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

4.3 Normal sound intensity, $I_n$:
Sound intensity component in the direction normal to the measurement surface.

4.4 Intensity direction indicator, $K$:
$K$ is defined here as $K = +1$ for intensity flowing out of the measurement surface, into the receiving room and $-1$ for intensity flowing from the receiving room, into the measurement surface. The indicator $K$ appears in front of the absolute intensity value. For intensity level, the direction is indicated by (3 spaces) for intensity flowing out of the measurement surface, into the receiving room and (-) for intensity flowing from the receiving room, into the measurement surface. The indicator sign appears in front of the intensity level.
4.5 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:

$$L_{In} = 10 \log |I_n/I_0| \quad \text{dB} \quad (4.2)$$

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

4.6 Field indicator, $F$:

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

$$F = L_p - L_{In} \quad \text{dB} \quad (4.3)$$

For assessing the total field indicator from many sub-areas, the intensity and pressure levels for each sub-area are converted to linear values and multiplied by the surface area of each sub-area. These values are calculated using equation (4.3) to form the total field indicator.

$$F_{\Sigma} = 10 \log \left[ \Sigma S_i L_{p_i} / 10 \right] - 10 \log \left[ \Sigma K_i S_i L_{In_i} / 10 \right] \quad \text{dB} \quad (4.4)$$

Note - the field indicator, $F$ used in this method, is the same as the $F_2$ indicator used in ISO 9614-1.

4.7 Residual pressure-intensity index, $\delta_{p10}$:

The difference between indicated sound pressure level and unsigned indicated sound intensity level when the intensity probe is placed in a sound field such that the sound pressure is uniform over the volume containing all the probe sensors.

4.8 Apparent sound reduction index, $R'$:

Ten times the common logarithm of the ratio of the sound power $W_1$ incident on the test specimen, to the total sound power transmitted into the receiving room; where in addition to the sound power $W_2$ radiated by the test specimen, sound power $W_3$, radiated by flanking elements or by other components, is included.
This quantity is denoted \( R' \):

\[
R' = 10 \log \left( \frac{W_1}{W_2 + W_3} \right) \quad [\text{dB}] \tag{4.5}
\]

For the purpose of ISO 140/4 the sound reduction index is evaluated from:

\[
R' = L_{p1} - L_{p2} + 10 \log \left( \frac{S}{A} \right) \quad [\text{dB}] \tag{4.6}
\]

where:
- \( L_{p1} \) is the average sound pressure level in the source room
- \( L_{p2} \) is the average sound pressure level in the receiving 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 equation (4.5) to (4.6) assumes that the sound fields are perfectly diffuse including a diffuse incident sound and the volumes and surfaces are equal in the source and receiving rooms.

### 4.9 Sub-area

The measurement surface is often divided into a number of smaller areas known here as sub-areas. The subscript \( i \) denotes a variable ascribed to a sub-area.

### 4.10 Apparent intensity sound reduction index, \( R'_I \):

When the sound reduction index is evaluated using sound intensity, the definition in equation (4.5) is altered in that the flanking transmission defined as \( W_3 \) can be excluded:

\[
R'_I = 10 \log \left( \frac{W_1}{W_2} \right) \quad [\text{dB}] \tag{4.7}
\]

\( W_1 \), the incident power is evaluated in the same way as for the ISO 140/4 pressure determination and \( W_2 \) is evaluated using sound intensity averaged over the test specimen.

\[
R'_I = L_{p1} - 6 - 10 \log \Sigma K_i S_i 10^{L_{fn}/10} + 10 \log (S) + 10 \log \left( 1 + S_{b1} c / 8f_0 V_1 \right)
\]

\( \tag{4.8} \)
where:

- \( L_{p1} \) is the average sound pressure level in the source room.
- \( L_{i1} \) is the sound intensity level averaged over the sub-area \( i \).
- \( S_{b1} \) is the area of all the boundary surfaces of the source room.
- \( c \) is the speed of sound in air.
- \( f_0 \) is the centre frequency of the 1/1 or 1/3 octave band in which the reduction index is being evaluated.
- \( V_1 \) is the volume of the source room.

Where \( K_i = -1 \) then the reduction index is undefined for that sub-area and frequency band.

All values of intensity level shall be used when calculating the total reduction index, even those that have \( K = -1 \). If the sum, \( R'_{i1} \), is evaluated showing sound power flow from the receiving room to the source room, the sound reduction index is undefined for that frequency band.

The last term of equation (4.8) is the Waterhouse correction, see Appendix 4.

The sound intensity method allows evaluation of partial sound reduction indices for sub-areas of a test specimen.

\[
R'_{i1} = L_{p1} - 6 - L_{i1} - 10 \log \left( 1 + \frac{S_{b1}c}{8f_0^2V_1} \right) \quad \text{dB} \quad (4.9)
\]

These sub-area sound reduction indices may be combined to give the total sound reduction index of a test specimen.

\[
R'_1 = 10 \log (S) - 10 \log \left[ \sum K_i S_i / 10^{R'_{i1}/10} \right] \quad \text{dB} \quad (4.10)
\]

All values for \( R'_{i1} \) shall be used when calculating the total reduction index \( R'_1 \), even those that are undefined i.e. \( K = -1 \) or fail the field indicator test, \( F < 10 \) dB. If the sum, \( R'_1 \), is calculated with sound power directed from the receiving room towards the measurement surface, the total reduction index is undefined for that frequency band.

4.11 Sub-area ranking, \( Q_i \)

\( Q \) is defined as:

\[
Q_i = R'_{i1} - 10 \log S_i \quad (4.11)
\]

This is used to compare the apparent sound reduction indices of the sub-areas that make up the transmission path into the receiving room. They shall be arranged in order of the sound power that they emit into the receiving room. The rank \( Q_i \) is smallest for the worst sub-areas.
This ranking can be performed in one-third octave bands or as a single number rating as described in ISO 717.

4.12 Measurement surface

This is a hypothetical surface on which intensity measurements are made. The measurement surface shall form a closed surface over/in front of the test specimen.

4.13 Physical surface/test specimen

This is the surface of the area that exits into the receiving room and is covered by the measurement surface. With intensity measurements the test specimen is defined by the area scanned over by the intensity probe. Small objects that protrude from the surface, even though they may penetrate the measurement surface are not part of the physical surface if they do not contribute significantly to the power transmitted into the receiving room.
5 INSTRUMENTATION

5.1 General

The intensity measuring instrumentation shall be able to measure intensity levels in decibels in one-third octave bands. It is preferred that sound intensity is measured in real time. The sound pressure level measuring instrumentation shall be able to measure pressure levels in decibels in one-third octave bands.

The residual pressure-intensity indicator $\delta_{p10}$ of the intensity probe and analyser shall be higher than $F+7$ dB.

5.2 Calibration and field check

The instrument, including the probe, shall comply with IEC publication 1043.

To check the instrumentation for correct operation prior to each series of measurements, the field check procedure specified by the manufacturer shall be applied.

If no field check is specified, the following procedure, to indicate anomalies within the measuring system that may have occurred during transportation, etc., shall be applied:

i) Sound pressure level.
   Check each pressure microphone of the intensity probe for sound pressure level using a class 0 or 1 calibrator in accordance with IEC Publication 942.

ii) Intensity.
   Place the intensity probe 1 m from the sound source, this should place the probe in the direct field from the source, in the source room, with the probe axis oriented towards the source. Measure the normal sound intensity level. Rotate the intensity probe through $180^\circ$ about an axis normal to the measurement axis and place it with its acoustic centre in the same position as for the first measurement. Measure the intensity again. For the highest intensity level measured in one octave or one-third octave bands, the two sound intensity levels $L_{1n}$ shall differ by less than 1.5 dB and direction indicated for the intensity shall differ, for the measuring equipment to be acceptable.
6 TEST ARRANGEMENT

6.1 Rooms

For the test method to be used in the field, it is not possible to standardise the size of the test specimen and the volume and shape of the rooms.

To test the suitability of the receiving room for carrying out intensity measurements, the sound source in the source room should be switched on, the intensity probe should be scanned diagonally across the test specimen and the field indicator F calculated for all frequency bands of interest. If F is larger than 10 dB in a majority of the bands of interest, extra absorption material shall be added to the receiving room. With extra absorption in place a new diagonal scan should be carried out. The F indicator should be checked against the 10 dB requirement in a majority of the bands of interest.

If/when there is sufficient absorption material within the receiving room the intrusion of background noise shall be checked for. This is carried out by measuring the sound intensity over a diagonal scan with the source level reduced by 10 dB, the F indicators shall be unchanged (+1 dB) between the two scans for the frequency bands of interest. If this condition is not met, the source level should be raised to 10 dB above the original level and another diagonal intensity scan carried out.

These methods for checking the suitability of the source and receiver rooms are suggested so that the intensity levels are correctly estimated and background noise does not invalidate the measurements.

6.2 Mounting conditions

The measurements are carried out in situ with the test specimen mounted in its normal manner.
7 TEST PROCEDURE

7.1 General

Often the standard measurements according to ISO 140/4 will be carried out before the intensity measurements described here are carried out. Using the same source level obtained by the procedure in 6.1, the sound intensity averaged over the test specimen sub-areas shall be measured.

7.2 Generation of sound field in source room

The sound source, its spectrum, its steadyness and position(s) shall meet the requirements in ISO 140/4. That is: “The sound generated in the source room should be steady and of continuous spectrum in the frequency range considered. Filters with a bandwidth of at least one-third octave may be used.

"If the sound source contains more than one loudspeaker operating simultaneously, the loudspeakers should be contained in one enclosure, the maximum dimension of which should not exceed 0.7m. The loudspeakers should be driven in phase.

"The loudspeaker enclosure should be placed to give a sound field as diffuse as possible and at such a distance from the test specimen that the direct radiation upon it is not dominant.”

It is recommended that the loudspeaker is placed in accordance to ISO 140/4, 0.5 m from the boundaries. An alternative to using a single source is to use two sources fed with uncorrelated noise and positioned in different corners away from the test specimen. This alternative may be used to reduce the number of scans required for a measurement.

7.3 Measurement of average sound pressure level in the source room

The same measurement procedure as used in ISO 140/4 shall be used to determine the average sound pressure level in the source room. That is: "The average sound pressure level may be obtained by using a number of fixed microphone positions or a continuously moving microphone with an integration of $p^2$."
7.4 Measurements on the intensity measurement surface in the receiving room

7.4.1 Measurement surface

The measurement surface shall consist of flat sub-areas, that form a closed surface over/in front of the test specimen. The sub-areas shall be defined so that they take account of the test specimen's construction and its natural boundaries. Extra sub-areas may also be defined to account for individual flanking "sources" into the receiving room.

The measurement surfaces shall be parallel to the physical surface and between 0.1 and 0.3m from the physical surface.

7.4.2 Scanning procedure

The intensity 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 test specimen.

The measurement surface shall be divided into one or more sub-areas. The scan shall be made with a steady speed between 0.1 to 0.3 m/s. When measurements are interrupted when going from one sub-area to another, the measured values should be stored and a new measurement started for the next sub-area.

Each sub-area shall be scanned using parallel lines turning at each edge as shown in figure 1. The scanning line density depends on how irregular the sound radiation is. A large amount of irregularity such as leakages requires a higher line density. Normally the line density is chosen to be equal to the measurement distance. The normal range is between 0.05 and 0.2 m.

If the measurement surface is box shaped, as shown in figure 2, particular care should be given to the intersection between the box surface and the physical surface. The measurement surface must be closed properly, it is essential to scan as close as possible to the physical surface when closing the box.

7.4.3 Sound intensity, one sub-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. If the sound pressure is not measured simultaneously, it should be measured with a new scan following the intensity scan. Two complete scans (of intensity and pressure) shall be carried out and their results compared. The scanning path should be rotated 90 degrees between the two scans, if possible. For frequency bands with acceptable F indicator the difference in $L_{in}$ between the two scans shall be 1dB or less for the measurement to be acceptable. If the two scans are not within 1dB then either a third scan can be carried out or the remedial measures described in 6.1 may be used to improve the situation.
Figure 1. Scanning patterns for two scans

Figure 2. Box shaped measurement surface
The arithmetic average of the two scanned intensity results shall then be used to calculate the partial intensity sound reduction indices using the formula in equation (4.9). If all sub-areas of the test specimen comprise a complete side of the receiving room, the measured partial indices can then be summed to form the total sound reduction index, using equation (4.8 or 4.10).

It is likely that some sub-areas will have negative or very low intensity in some frequency bands, hence the reduction index will be very high in these bands and the F indicator will fail the 10dB limit. These high R' values shall be included when calculating the total R' value for the test specimen.

7.5 Frequency range of measurements

The sound pressure level and sound intensity level shall be measured using one-third octave band filters in the frequency range covered by the filters with centre frequencies from 100 to 5000 Hz.

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

50 63 80
8 EXPRESSION OF RESULTS

For the statement of the apparent airborne sound insulation of the test specimen, the apparent (in situ) 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 graph. In addition a graph of the field indicator shall always be given in the graph. For graphs with the level in decibels plotted against frequency on logarithmic scale, the following dimensions shall be used:

5mm for one-third octave
20mm for 10 dB.
9 TEST REPORT

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

a) name of the organization that has performed the measurements
b) date of the tests
c) manufacturer's name and product specification
d) description of test specimen and rest of the source and receiving rooms
e) air temperature in the measuring rooms
f) apparent intensity sound reduction index, field indicator and the ranking order for
   the sub-areas and the whole test specimen, as a function of frequency
g) brief description of the test procedure and equipment
h) limit of the measurement in the case of background noise
i) if the whole test specimen reduction index is calculated, the single number rating
   according to ISO 717
APPENDIX 1
Ranking of partial transmission areas
(Informative)

In section 4.9 the sub-area ranking variable Q is defined. The Q values can be for individual one-third octave bands or for the single number rating. When reduction index is defined, the Q value is high for a high transmission loss part of the path between source and receiving rooms, and low if the part of the path emits a large proportion of the sound energy from the source room. The Q values should be presented on graphs with the same format as for sound reduction indices.

The direction indication K for the intensity is negative when the sound energy, at the measuring surface, travels from the receiving room towards the source room. In general some sub-areas will have a negative sign for some one-third octave bands but if the requirements for background noise and F indicator are met, then the total sound power radiated into the receiving room should be positively directed into the room.
APPENDIX 2

Recommendations for defining measuring surfaces and scanning of these surfaces.

(Informative)

The description of the scanning procedure in section 7.4.2 should be followed, this section is just an amplification of section 7.4.2. It has been found to be very important to close the measurement surface fully onto the physical plane, for example NORDTEST project 746-88 SP report 1991:23 for obtaining sound intensity derived sound reduction indices in the laboratory. For individual building elements that are mounted in a niche, it has been found that accurate measurements can be made with the measurement surface in the same plane as the outer plane of the niche.

For measuring surfaces that are divided into several sub-areas, these do not need to be closed onto the physical surface at the joins between two sub-areas as long as there is no gap between them. Around the outer edge of the measuring surface it should be closed onto the physical surface. Sub-areas can be used to investigate flanking transmission routes into the receiving room, these should also be properly closed onto the physical surface.

The recommended minimum distance of 0.1m between the measuring surface and the physical surface should be taken as an absolute minimum. This is due to the complexity of the acoustic field, the direction of the intensity vector varies greatly and high local F indicator values are indicated close to the physical surface.

The scan speed range is recommended from experience and some tests [Pettersen & Newman Proc. InterNoise '89 pp.979-984]. When the conditions are difficult the lowest scan speed should be used but the scan speed must be steady to hinder biasing the result.

Section 7.4.3 states that the scan should be carried out twice with the scan line set at 90 degrees to each other. If a sub-area is long and thin then there will be a bias towards the edges of the sub-area. In this case the second scan should also be scanned with the long scan lines along the length of the sub-area.
APPENDIX 3
Field indicators; explanation and calculation
(Informative)

Within the method two indicators are defined $F$ and $\delta_{p10}$. $\delta_{p10}$ is a property of the measuring equipment and is either measured in a calibrator or an anechoic chamber with the sound field such that the particle velocity, in the direction of the probe measurement axis, is zero.

The $F$ indicator is only defined once but can be applied to a multitude of conditions ie one sub-area, all sub-areas. When the $F$ indicators for several sub-areas are added together, the intensity and pressure have to be weighed with the sub-area area so that a small sub-area with a high $F$ indicator does not over emphasize the measurement difficulty.
APPENDIX 4
Waterhouse correction
(Informative)

In equation (4.8) the last term is the Waterhouse correction. This correction is applied to compensate for the higher sound energy densities close to a boundary than in the centre of the room, where the sound pressure is measured.

For this method the Waterhouse correction is applied to the source room, as it is the source room where pressure measurements are carried out, to evaluate incident sound power on the test specimen.

The Waterhouse correction is in this method applied to the source room and in the Nordtest method “Building elements: Sound insulation measurements with an intensity scanning method under laboratory conditions” it is applied in the receiving room. In the laboratory method the receiving room was chosen to most closely approximate pressure based ISO standard measurements. In this method the definition of Sound Reduction Index \( R = 10\log (W_1/W_2) \) has been used to define the choice of room to apply the Waterhouse correction to.
APPENDIX 5
Selection of source room noise excitation
(Informative)

To gain the best quality results from the measurements, it is advantageous to have as high a sound level as possible in the source room and a reasonably flat spectrum in the receiving room.

The most effective method of achieving this aim is to use an equaliser(s) on the noise signal(s) fed to the power amplifier(s) for the source(s). This shall then be adjusted to flatten the spectrum in the receiving room.

If an equaliser is not available, some benefit may be gained by using white rather than pink noise, for situations with high sound reduction indices at high frequencies.
Building site for ISO 140-4 measurements
Building site for ISO 140-4 measurements
Rooms for intensity measurements
Measurement of airborne sound insulation according to ISO 140-4 (CD N491)

Measuring object: Room

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Measurement of airborne sound insulation according to ISO 140-4 (CD N491)

Measuring object: Living room

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www.nordtest.info
Measurement of airborne sound insulation acc. to survey meth., 8th draft 1995-03

Measuring object: Room

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\[
R'W = 56 58 56 56 54
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Calculation of 1/1-octave values from the 1/3-octave measurement according to ISO 140

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Measurement of airborne sound insulation acc. to survey meth., 8th draft 1995-03

Measuring object: Living room

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Calculation of 1/1-octave values from the 1/3-octave measurement according to ISO 140

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www.nordtest.info
Measurement of airborne sound insulation acc. to survey meth., 8th draft 1995-03

Measuring object: Bathroom

<table>
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<tr>
<th>Frequency (Hz)</th>
<th>Results from laboratory:</th>
<th>Mean dB</th>
<th>St. dev. dB</th>
<th>Reproducibility dB</th>
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Reproducibility dB = 4,1 5,2 2,0 1,6 1,9

Calculation of 1/1-octave values from the 1/3-octave measurement according to ISO 140.

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Survey method measurements for VTT

**Room**

- Survey method
- Calculated from 1/3-oct.

**Living room**

- Survey method
- Calculated from 1/3-oct.

**Bathroom**

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Survey method measurements for SP

Room

Living room

Bathroom

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Survey method measurements for SINTEF

Room

Living room

Bathroom

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Survey method measurements for IBRI

Room

Living room

Bathroom

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Survey method measurements for DELTA

Room

Living room

Bathroom
Measurement of airborne sound insulation by intensity method

Measuring object: Door

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Source room level

| Frequency Hz | Results from laboratory: |          |            |                |
|--------------|---------------------------|---------|-------------|                |
|              | VTT dB | SP dB | SINTEF dB | IBRI dB | DELTA dB |          |            |                |
| 50           | 87,2   | 82,8  | 84,1       | 86,1     |          |          |            |                |
| 63           | 88,0   | 81,0  | 84,3       | 82,1     |          |          |            |                |
| 80           | 87,5   | 81,4  | 84,0       | 81,7     |          |          |            |                |
| 100          | 83,8   | 76,4  | 87,9       | 87,0     |          |          |            |                |
| 125          | 81,9   | 80,8  | 91,2       | 91,5     |          |          |            |                |
| 160          | 89,0   | 82,9  | 92,8       | 94,4     |          |          |            |                |
| 200          | 89,0   | 83,2  | 93,1       | 99,2     |          |          |            |                |
| 250          | 91,1   | 84,1  | 94,0       | 100,2    |          |          |            |                |
| 315          | 91,2   | 91,0  | 94,5       | 97,5     |          |          |            |                |
| 400          | 92,1   | 91,6  | 92,0       | 99,3     |          |          |            |                |
| 500          | 93,4   | 95,2  | 92,7       | 100,7    |          |          |            |                |
| 630          | 93,0   | 97,5  | 90,2       | 100,6    |          |          |            |                |
| 800          | 92,0   | 97,7  | 91,2       | 100,0    |          |          |            |                |
| 1000         | 90,4   | 97,6  | 90,2       | 97,8     |          |          |            |                |
| 1250         | 91,0   | 98,3  | 92,4       | 97,8     |          |          |            |                |
| 1600         | 92,8   | 100,2 | 93,6       | 98,9     |          |          |            |                |
| 2000         | 94,7   | 102,2 | 94,4       | 100,0    |          |          |            |                |
| 2500         | 96,3   | 101,7 | 93,9       | 98,2     |          |          |            |                |
| 3150         | 91,9   | 99,5  | 93,2       | 95,4     |          |          |            |                |
| 4000         | 89,3   | 96,6  | 91,1       | 91,8     |          |          |            |                |
| 5000         | 83,6   | 90,3  | 85,4       | 85,0     |          |          |            |                |

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# Measurement of airborne sound insulation by intensity method

**Measuring object:** Window

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<th>Frequency (Hz)</th>
<th>VTT dB</th>
<th>SP dB</th>
<th>SINTEF dB</th>
<th>IBRI dB</th>
<th>DELTA dB</th>
<th>Mean dB</th>
<th>St. dev. dB</th>
<th>Reproducibility dB</th>
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**Results from laboratory: Window**

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<th>SINTEF dB</th>
<th>IBRI dB</th>
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**Source room level**

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### Measurement of airborne sound insulation by intensity method

**Field indicators**

**Measuring object:** Door

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<th>Residual intensity dB</th>
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**Measuring object:** Window

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[www.nordtest.info](http://www.nordtest.info)
Measurement of airborne sound insulation by intensity method
Comparison between ISO 140 method and intensity method

Measuring object: Door and window

| Frequency (Hz) | Mean of 5 laboratories
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R'\text{W (dec.)} 24.6 22.4
R'W 24 22