ANC
THE ASSOCIATION OF
NOISE CONSULTANTS

# ANC GOOD PRACTICE GUIDE

## Acoustic Testing of Schools

**This document sets out the technical guidance for acoustic measurements in accordance with Building Bulletin 93 (BB 93). There is currently no ANC scheme in place to assess testers for compliance with these guidelines.**

**The purpose of these guidelines is to enable consistency in interpretation of the methods described in BB 93, Approved Document E (ADE), and relevant ISO standards so that acoustic measurements in school buildings may be made consistently between organisations.**

**This guidance is not intended to be more restrictive than the standards, but to provide guidance for the application of those standards for testing in schools.**

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# Acoustic Testing of Schools

# 1. Foreword

### 1.1. Introduction

This document sets out the technical guidance for acoustic measurements in accordance with Building Bulletin 93 (BB 93). There is currently no ANC scheme in place to assess testers for compliance with these guidelines.

The purpose of these guidelines is to enable consistency in interpretation of the methods described in BB 93, Approved Document E (ADE), and relevant ISO standards so that acoustic measurements in school buildings may be made consistently between organisations.

This guidance is not intended to be more restrictive than the standards, but to provide guidance for the application of those standards for testing in schools.

### 1.2. Competence required

The organisation carrying out the testing should be UKAS-accredited for sound insulation testing, or a member of the Association of Noise Consultants Registration Scheme. Competence to carry out sound insulation testing does not necessarily imply competence for speech transmission index (STI) testing.

### 1.3. Schedule of testing

BB 93 recommends that at least one in four rooms intended for teaching and study purposes should be tested for sound insulation, reverberation time and ambient noise levels and that at least one in ten student positions in open plan spaces should be tested for speech intelligibility. BB 93 recommends that at least one in four teaching / study rooms below a separating floor should be tested.

A representative sample of each different construction type and acoustic performance requirement should be tested.

Notes on this section

i) The statement “one in four rooms” can be interpreted in a number of ways. It is suggested that the total number of rooms or spaces for teaching and learning is determined, and divided by four (rounding up) to calculate the number of wall (and floor, where appropriate) airborne sound insulation, reverberation time and ambient noise level tests required.

ii) Breakout areas that are used for teaching / study may also be counted as “rooms”, and may be tested if appropriate.

iii) A representative sample of each construction type and acoustic performance requirement would typically include tests of different room types, i.e. including assembly and sports halls as well as room types that occur with greater frequency.

### 1.4. Performance standards

The acoustic performance standards are described in section 1 of BB 93. The room type should be derived from the descriptions in Table 1.1, 1.4 and 1.5 of BB 93. In addition, the performance standards for ambient noise in naturally ventilated rooms are modified by the subsequent guidance of BB 101.

Where there are alternative performance standards, specified in accordance with section 1.2.1 of BB 93, these should be should be stated.

### 1.5. Permitted use of this Guide

This Guide is Copyright of the Association of Noise Consultants Ltd. Its purpose is to advise ANC members, other consultants and other interested parties.

It may be quoted or referenced in other documents but such references do not imply that the ANC endorse those documents. Use of this Guide does not mean that a company is member of the Association.

### 1.6. Association of Noise Consultants

The ANC (Association of Noise Consultants) is the representative body for consultancy practices providing advice on acoustics, noise and vibration issues. ANC represents well over 100 companies who employ approximately 800 professionally qualified acousticians.

For further details of ANC and contact information please go to www.theanc.co.uk or email info@theanc.co.uk

### 1.7. Format and updating of this Guide

This guide is made available electronically via the ANC website. It is intended to be a dynamic document that will be amended and updated as necessary. Users are invited to send comments, queries and suggestions for changes to the Chairman of the ANC Schools Committee.

In general, text in black sets out guidance and, where appropriate, sections are followed by notes in smaller text in blue. These notes do not form part of the formal guidance, but are to provide explanation or discussion of the guidance in each section.

# 2. Abbreviations and references

## 2.1. Abbreviations

*Abbreviations and acronyms used in this guide are explained below.*

| | |
|---|---|
| ANC | Association of Noise Consultants, the UK's professional body for acoustic consultancies. |
| ADE | Approved Document E of the Building Regulations "Resistance to the passage of sound" which refers to BB 93 for acoustic performance standards for school buildings. |
| UKAS | United Kingdom Accreditation Service. |
| BB 93 | Building Bulletin 93 Acoustic Design of Schools, A Design Guide, 2003, DfES |

## 2.2. References

*All standards are subject to revision, and parties to agreements should apply the most recent editions of the standards indicated below.*

Approved Document E of the Building Regulations "Resistance to the passage of sound" 2003 edition, incorporating 2004 amendments.

Building Bulletin 93 - Acoustic Design of Schools, A Design Guide, 2003.

Building Bulletin 101 – Ventilation of school buildings, 2006.

BS EN ISO 140-4: 1998 "Acoustics – Measurement of sound insulation in buildings and of building elements. Part 4 – Field measurements of airborne sound insulation between rooms"

BS EN ISO 140-7: 1998 "Acoustics – Measurement of sound insulation in buildings and of building elements. Part 4 – Field measurements of impact sound insulation of floors"

BS EN ISO 140-14: 2004 "Acoustics – Measurement of sound insulation in buildings and of building elements. Part 14 – Guidelines for special situations in the field".

BS EN ISO 717-1: 1997 (incorporating amendment A1: 2006) "Acoustics – Rating of sound insulation in buildings and of building elements. Part 1: Airborne sound insulation"

BS EN ISO 717-2: 1997 (incorporating amendment A1: 2006) "Acoustics – Rating of sound insulation in buildings and of building elements. Part 2: Impact sound insulation"

ISO 3382: 2000 "Measurement of reverberation time of rooms with reference to other acoustical parameters"

BS EN ISO 3382-2: 2008 "Acoustics - Measurement of room acoustic parameters - Part 2: Reverberation time in ordinary rooms"

BS EN 60268-16: 2003 Sound system equipment – Part 16: Objective rating of speech intelligibility by speech transmission index.

ANC Guidelines – Noise Measurement in Buildings ANC-9701, August 1997, Association of Noise Consultants. Noise from Building Services.

ANC Guidelines – Noise Measurement in Buildings ANC-9801, October 1998, Association of Noise Consultants. Noise from External Sources.

[1] An empirical study of the effects of occupied test rooms and a moving microphone when measuring Airborne Sound Insulation. A joint research project by the Association of Noise Consultants (ANC), Robust Details Ltd (RDL) and the Building Research Establishment (BRE). Authors: Iain Critchley MIOA MInstSCE for Peninsular Acoustics (ANC); Philip Dunbavin MSc, FIOA, MIOSH, MSEE, MInstSCE for RDL. IOA Spring Conference, Reading University 2008.

[2] The effectiveness of manual scanning measurements to determine the spatial average sound pressure level in rooms, Internoise 2010, Lisbon, Portugal. C. Hopkins, Acoustic Research Unit, School of Architecture, University of Liverpool.

# 3. General Principles

## 3.1. Standards and references

Sound insulation should be tested in accordance with ISO 140-4 and ISO 140-7, and rated in accordance with ISO 717-1 and ISO 717-2 with the additional requirements and clarifications as set out in section 1.3.4 of Building Bulletin 93.

Attention is also drawn to ISO 140-14. Appendices A and B of this standard supplement the guidance in ISO 140-4 and ISO 140-7 respectively. These appendices are described as informative rather than normative but offer valuable clarification, which is taken into account in this Guide.

$T_{mf}$ should be derived from reverberation time testing carried out in accordance with ISO 3382-2, ISO 140-4, or ISO 140-7 in octave bands.

Indoor ambient noise measurements should be made in accordance with the guidance in BB 93. Additional information on noise measurements in buildings is available in the Association of Noise Consultants' Guidelines on Noise Measurement in Buildings, Part 1: Noise from Building Services and Part 2: Noise from External Sources.

Speech intelligibility measurements should be made in accordance with EN 60268-16, with the additional guidance set out in BB 93.

All testers should have access to, and be familiar with, all of the above standards and documents.

Notes on this section

i) Compliance with the standards and guidance described in BB 93 and ADE is necessary. ADE requires compliance with ISO 140 Parts 4 and 7, and ISO 717 Parts 1 and 2. The ANC is working to assist with and influence the revision of international standards and is represented on the appropriate national and international standards committees.

ii) In some respects the standards are believed to be unnecessarily prescriptive, often for historical reasons. Nonetheless, until either the standards or ADE is changed, this guidance should be consistent with the standards.

iii) In some cases where the standards are particularly unclear, Annex B of ADE imposes a specific interpretation. For example, ADE specifies arithmetic averaging of level differences derived from measurements using individual loudspeaker positions, as discussed later in this Guide. It follows that energy averaging of source and receiving room levels from more than one loudspeaker position measured sequentially does not comply with ADE.

iv) In places where the standards are incomplete or ambiguous, and are not clarified in ADE, guidance on the interpretation of the standards is provided. The argument ".but surely this is what the Standards Committee meant" is considered inadmissible in the context of a national or international standard. Where the standards allow several methodologies, this guidance should not impose one of these methodologies at the expense of others. Neither should this guidance try to impose a "Gold standard" in excess of the requirements of the ISO requirements, e.g. by requiring averaging of a larger number of measurements than are required under the standards.

# 4. Requirements for equipment

## 4.1. Sound level meters, pre-amps and calibration

In this section the terms “instrument” and “instrumentation” shall be taken to include the sound level meter, pre-amplifier and microphone. The sound level meter should be used with the microphone and pre-amplifier with which the relevant calibration and / or conformance checks were applied. If it is necessary to use a different microphone or pre-amplifier (e.g. due to a failed or damaged microphone), the tester should ensure that these are compatible with the meter and, if necessary, should have the meter re-calibrated with the replacement microphone and/or preamplifier.

The measurement instrumentation and calibrator used on site should comply with the requirements set out in ISO 140-4 and ISO 140-7. In general, this requires sound level meters or real-time analysers to comply with accuracy Class 0 or 1, as defined in IEC 60651 and IEC 60804, and on-site calibrators to comply with accuracy Class 1, as defined in IEC 60942. It is the responsibility of the tester to ensure that the equipment used complies with this requirement and testers should make reasonable efforts to verify claims made by the manufacturers and suppliers of their equipment.

The instrument and calibrator should have a valid, traceable certificate of calibration, and should have been calibrated by an independent calibration organisation within the past two years. In the case of equipment less than two years old, a certificate of conformance from the equipment manufacturer is acceptable in lieu of a calibration certificate.

Instrumentation (including calibrators) should be cross-checked against other instruments periodically, and at least annually, or after any event such as heavy handling which the tester believes could affect the performance of the instrument. The instrument (and, if appropriate, the calibrator) should be sent for re-calibration in the event of variance or drift outside the limits permitted in the standards.

The calibration of the sound level meter should be checked on site before and after each measurement, or set of measurements, using a microphone calibrator complying with accuracy Class 1 as defined in IEC 60942. Any variation (also known as “calibration drift”) of more than 0.2 dB in calibration level between calibration checks should be recorded, and in reporting the results of the measurements, the consultant should give consideration to the possible effect of this variation.

Notes on this section

i) Where the test organisation owns several instruments and calibrators, cross-checking between instruments is relatively straightforward. Testers owning only one instrument should cross-check with other testers at least annually, e.g. at conferences or at ANC meetings.

ii) In practice, provided that meters and calibrators are given adequate time to stabilise after being switched on, the “calibration drift” for good quality Type 1 instrumentation is generally found to be less than 0.2 dB at 1 kHz. This is substantially better than the instrumentation tolerances derived from IEC 60651, 60804 and 60942. It is suggested that if drift of more than 0.2 dB at 1 kHz occurs, the instrument and calibrator should be checked and if necessary referred to the manufacturer or to an external calibration organisation.

iii) Attention is drawn to the relevant sections of BS 7580-1: 1997 Specification for The Verification of Sound Level Meters Part 1. Comprehensive procedure, which requires sound level meters to be submitted for calibration with a calibrator which itself has been verified and certified within the previous year. The ANC has confirmed that their interpretation of this requirement is that internally self-certified calibration cross checks such as those performed in house using the ANC calibration kit can be used to satisfy this requirement on an annual basis, and that all instrumentation in the chain should be externally calibrated every two years.

## 4.2. Loudspeakers for sound insulation measurements

Either cabinet or polyhedral loudspeakers may be used. Cabinet loudspeakers commonly comprise one or two drive units in a cabinet, operating at different frequencies, with or without a vent port. Polyhedral loudspeakers commonly comprise dodecahedral or semi-dodecahedral units with a number of identical drivers. In both cases the drivers should be driven in phase.

In either case the loudspeaker should be capable of generating the source noise steadily and continuously at a sufficiently high level to be clearly measurable in the receiving room for the test. Typically this will require a free-field sound pressure level in excess of 90 dB $L_{eq}$ at 1 metre from the loudspeaker in all ⅓-octave bands from 100 Hz to 3150 Hz. Where high levels of sound insulation are measured, in situations where the background is not very low, higher sound source levels may be required.

Notes on this section

i) Section A.1.3 of EN ISO 140-4 discusses polyhedral loudspeakers and sets out a procedure for assessing their directivity. The standard does not, however, require polyhedral loudspeakers or preclude the use of other types of loudspeakers. Research [1] has demonstrated that there is no significant difference between results obtained with polyhedral and cabinet loudspeakers, and therefore this Guide permits either type.

ii) Section 6.2 of EN ISO 140-4 states: *"If the sound source enclosure contains more than one loudspeaker operating simultaneously, the loudspeakers shall be driven in phase or it shall be ensured that the radiation is uniform and omnidirectional, as specified in A.1.3".* In practice, no enclosure will be effective for the purpose of sound insulation testing if it comprises loudspeakers driven out of phase, so the radiation uniformity check should not be required. There is no requirement for the source to be omnidirectional for sound insulation measurement.

## 4.3. Hemisphere polyhedron loudspeakers (special case)

Section A.1.3 of ISO 140-4 states "*Omnidirectional radiation into the room is also achievable with a hemisphere polyhedron loudspeaker (mounted directly on the floor). Carry out vertical measurements in this case in the direction from the lower room to the upper room*".

This appears to conflict with the requirements stated in A2 of ISO140-4 as follows:

1. Distance between room boundaries and source centre shall be not less than 0.5 m.
2. Different loudspeaker positions shall not be located within the same planes parallel to the room surfaces.

However, A2 goes on to say that *"Deviating from the above mentioned requirements concerning the distance between the room boundaries and the source, especially in small rooms, it is often of advantage for the practical execution of the measurements to use loudspeaker positions in the corners of the source room. Take special care with regard to possible influence on the flanking transmission and with regard to unwanted increase of level fluctuations in the source room."*

ISO 140-4 therefore makes provision for carefully considered deviation from the normal requirements (1 and 2 above), especially in the case of small rooms. Annex D of the Standard suggests that 'small rooms' are defined as rooms with volumes of 50 $m^3$ or less.

It can therefore be safely concluded that the use of hemisphere polyhedron loudspeakers is permitted under ISO 140-4, and that they give omnidirectional radiation when mounted on a hard, reflective surface. Research [1] also concluded that there is no measurable difference between the three types of sound source (Infinite baffle, stand-mounted dodecahedron and floor-mounted hemi-dodecahedron).

### 4.4. Noise input – pink noise, graphic equalisers etc

The noise source should be non-time varying random noise at a constant level over the frequency range being measured. Although it is permitted to test separate ⅓-octave bands sequentially, in practice tests are normally carried out using broadband noise and measuring all ⅓-octave bands simultaneously. If broad-band noise is used, the spectrum may be shaped to ensure an adequate signal-to-noise ratio in the receiving room.

If two loudspeaker sources are used simultaneously they should be driven by similar, but uncorrelated, signals. In practice this means that they should be driven by separate random noise generators.

Notes on this section

i) ISO 140-4 recommends white noise. Depending on the sound insulation characteristics of the rooms tested and the background noise environment in the receiving room, higher signal to noise ratios may be achieved in different parts of the frequency range of interest with other spectral shapes, such as shaped broadband noise.

ii) The measurement procedure depends on the source room signal being constant. The tester should check periodically under controlled conditions that the source level measured over two 30 second periods does not vary by more than 1 dB in any ⅓-octave band in the measured frequency range when neither microphone or loudspeaker are moved. If the equipment is found not to comply, the test results which have been taken since the previous check will be thrown into doubt; therefore a suitable period should be chosen to minimise this risk.

iii) If more than one sound source is used simultaneously, the output power of each source should be similar in each relevant frequency band.

### 4.5. Tapping machines

In the absence of any other standard, the requirements for the tapping machine are set out in Annex A of ISO 140-7. It is the responsibility of the tester to ensure that the equipment used complies with this requirement, and testers should make reasonable efforts to verify claims made by the manufacturers and suppliers of their equipment.

As impact sound insulation is measured in terms of level, rather than level difference, any differences between tapping machines and variations in the output of individual tapping machines over time will have a direct effect on the result of the measurement.

Some aspects of a tapping machine are considered vulnerable to change during the life of the machine and ISO 140-7 states that the following parameters should be verified regularly:

- velocity of hammers
- diameter and curvature of hammer heads
- falling direction of hammers
- time between hammer impacts.

Some parameters need only be measured during the conformance checks unless the tapping machine has been modified. These are:

- distance between hammers
- supports of the tapping machine
- diameter of the hammers
- mass of the hammers (unless the hammer heads have been refinished)
- time between impact and lift and maximum possible falling height of the hammers.

In the absence of a national standard for calibration of tapping machines, the Registration Scheme Handbook includes detailed recommendations for conformance checks by the owner.

This guidance also requires a conformance check by a third party (normally a laboratory or the tapping machine manufacturer) at least every two years, to confirm that the tapping machine is within the tolerances set out in Annex A of ISO 140-7. These parameters should be checked by the tapping machine manufacturer; however, testers should make reasonable effort to verify that these parameters meet the values given in Annex A of ISO 140-7 (e.g. a conformance sheet should be included with the tapping machine).

Notes on this section

i) The measurement procedure depends on the tapping machine output being constant. The tester should check periodically under test conditions that the received room level measured over two 30 second periods with no change in the tapping machine position does not vary by more than 1 dB in any ⅓-octave band in the measured frequency range.

ii) Where measurements are carried out on bonded soft floor coverings, such as carpet, the hammer drop height should be set up on a flat hard surface initially.

iii) It is noted that there is an error in ISO 140-7, which may be traced as follows:

a) The specification for the standard impact source (the tapping machine) is given in Appendix A of both ISO 140-6 and ISO 140-7. Unfortunately Appendix A of ISO140-7 contains an error; the velocity of the tapping machine hammer at impact is given as 0.033 m/s.

b) Appendix A of ISO140-6 states: “the mass of each hammer shall be 500 g from which it follows that the velocity at impact must be (0.886± 0.022) m/s. The tolerance limits of the velocity may be increased to ± 0.033 m/s if it is ensured that the hammer mass lies within accordingly reduced limits of (500± 0.6) g”.

c) The impact velocity is derived using the principal of conservation of energy.

d) $\frac{1}{2}mv^2 = mgh$; rearranging gives $v = \sqrt{2gh}\ \mathrm{m/s}$.

e) $g = 9.81\ \mathrm{m/s^2}$, h = 40 mm; hence v = 0.886 m/s

### 4.6. Loudspeaker for STI measurements

As described in EN 60268-16: 2003, for the highest accuracy, the sound source used for STI measurements of unamplified talkers should either be an artificial mouth or suitable test loudspeaker having similar directivity characteristics to those of the human mouth or head (see ITU-T Recommendation P.51: 1996).

# 5. Measurement procedures - airborne sound insulation

## 5.1. General requirements and options

The airborne sound insulation should be measured in accordance with ISO 140-4, ADE and BB 93. All measurements and calculations should be carried out using ⅓ octave frequency bands. Performance should be rated in terms of the weighted standardized level difference, $D_{nT(Tmf,max),W}$, where $T_{mf,max}$ is the reference reverberation time used in accordance with BB 93.

There are different options for the airborne measurement procedure:

i. Using one or two source loudspeakers
ii. Using static or moving microphones
iii. Measuring sequentially or simultaneously in source and receiving rooms
iv. Reverberation times – using continuous or impulsive sources

The standards also allow for measurement of ⅓-octave bands sequentially or simultaneously, but this guide assumes that testers will measure all ⅓-octave bands simultaneously using real-time analysers, as the sequential process would be extremely time-consuming.

## 5.2. Room types, sizes and conditions

### Room types

Rooms to be tested will normally be teaching and learning spaces. Where appropriate, however, tests may be carried out in ancillary spaces, but not usually corridors, stairwells or hallways. Tests should be conducted between completed rooms.

Changes in teaching methods mean that circulation spaces may also be used for teaching purposes. However, there may be no standard method for testing sound insulation to adjacent spaces. See section iv) below.

Measurements may be made in furnished or unfurnished rooms.

### Room volumes and test direction

The sound insulation requirement may determine the direction of the test, so that the test may be carried out from the smaller to the larger room. Section 6.2 of ISO 140-4 indicates that the test should be carried out from the larger room to the smaller room except where a contradictory procedure is agreed upon.

When measuring airborne sound insulation between a pair of rooms and the sound insulation requirement is the same in both directions, the sound source should be in the larger room.

Notes on this section

i) Where the room volumes are significantly unequal (e.g. where one is at least twice as large as the other) and the performance requirement differs in different directions, it may be appropriate to test in both directions.

ii) It is noted that the sound insulation requirement between different rooms changes in steps of 5 dB. The variation in level difference in each direction is a function of the receiving room volume and reference reverberation time. The level difference measured in each direction would be expected to differ by:

a) $10 \cdot \text{Log}(V_1 \cdot T_{mf,max2} / V_2 \cdot T_{mf,max1})$ dB

iii) Where $V_1$ is the volume of room 1, and $T_{mfmax2}$ the reference reverberation time of room 2, etc. Therefore unless reference reverberation times are significantly different, the room volumes need to be a multiple of one another for the level difference to be significantly different in each direction

iv) It is common, but incorrect, practice when measuring airborne sound insulation across a floor to locate the source room downstairs so as to eliminate the possible effect of floor vibrations caused by vibration from the speaker mounted on the floor. This is a not a requirement of the Standards, and, as the loudspeaker is generally mounted off the floor (see Section 5.4); this is generally not a problem. The requirement for measuring in the appropriate direction therefore takes precedence. If the source is located in the upper room a loudspeaker stand should be used so that the minimum distances are complied with.

### Use of guidance in ISO 140-14

ISO 140-14 is the result of a comprehensive Danish report, which was formally published in full as ISO 140-13.

The apparent sound reduction index of a partition, *R'*, may be most reliably measured by considering diffuse sound fields on either side of a partition. Hence where rooms are large, or contain significant dimensions perpendicular to the separating partition, consideration is given in ISO 140-14 to a “virtual room” in proximity to the separating partition.

However, the level difference, *D*, between rooms may be considered as relating to not only the level difference between “virtual rooms” adjacent to the separating partition, but as between the whole of the spaces of the rooms. ISO 140-4 makes no distinction between these different situations, as it assumes that the sound field is diffuse throughout both spaces.

ISO 140-14 points out that the energy-averaged level in a sound field that decays significantly with distance has no physical meaning. If, however, the sound insulation performance is being measured against a design parameter that is based on the sound level in the whole of either space, consideration should be given as to the applicability of ISO 140-14. The performance parameter *D* may be most appropriately assessed when the whole of the available spaces are used to measure the level of the sound fields.

### Openings

Doors should be closed; ventilators and windows should be open as required to provide adequate ventilation in both the source and receiving rooms.

Units, cupboards, etc., on all walls should have their doors open and be unfilled.

Notes on this section

i) Where there is a natural ventilation strategy using opening windows, the extent to which windows will need to be opened to provide “adequate ventilation” will depend on the physical arrangement, environmental conditions, and the number of room occupants. The mechanical engineers should be able to advise the maximum design requirement for openings to provide “adequate ventilation” under the most onerous conditions.

### 5.3. Room modes and use of diffusers

This Guide recommends that diffusers should be located in the source and receiving rooms where these are unfurnished and it is thought that room modes may affect the test result.

Notes on this section

i) ISO 140-4 states that measurements between empty rooms with identical shape and equal dimensions should preferably be made with diffusers (e.g. furniture or building boards) in each room, and that three or four objects of 1.0 $m^2$ should be sufficient. Use of the word "preferably" in the standard makes this a recommendation rather than an absolute requirement.

ii) ANC testers have found that room modes can have significant effects even in rooms of different shapes and volumes, particularly when these are empty and unfurnished. For rooms of typical dimensions, the effect of modes tends to be greatest in the 100 Hz and 125 Hz ⅓-octave bands.

iii) The guide therefore recommends the use of diffusers in all cases where the tester considers that room modes may be significant. In occupation, rooms will generally contain enough absorption and diffusion to attenuate low-frequency room modes. It should be remembered that the calculation procedure in ISO 140 assumes normal reverberant fields and diffuse conditions in accordance with Sabine's law, and the addition of diffusers makes this assumption more realistic.

iv) See also the discussion of source room noise spectrum in section 5.5

### 5.4. Loudspeaker positions

For loudspeaker types, see Section 4.2.

One or more loudspeakers may be used to create the source noise field. If more than one loudspeaker is used simultaneously, all inputs should be from separate random noise sources.

In either case the following requirements for loudspeaker positions apply:

- The loudspeaker(s) should be not less than 0.5 m from any room boundary. Hence loudspeakers should be raised off the floor.
- Different loudspeaker positions shall not be located within same planes parallel to room boundaries. (Section A2 of ISO 140-4) This means that different loudspeaker positions should not be at the same height.

Notes on this section

i) There is additional guidance on loudspeaker positions in Appendix A of ISO 140-4.

ii) The Standard does not state by how much the planes of loudspeaker positions should differ. In the absence of guidance in the standards, this Guide suggests that the difference in height should be at least 100 mm.

iii) For tests using cabinet loudspeakers the following positions are often used:

a) For tests on separating walls, the loudspeaker positions are between 0.5 m and 1.0 m from the room corners furthest from the separating wall, and between 0.5 m and 1.5 m from the floor. This maximises the area of the source room available for spatial averaging of sound levels, and minimises direct sound incidence on the separating wall.

b) For tests on separating floors where the source room is below the receiving room, the loudspeakers are between 0.5 m and 1.0 m from any two corners of the room and at least 0.5 m from the floor.

c) For tests on separating floors where the source room is above the receiving room, the positions are between 0.5 m and 1.0 m from any two corners of the room, and at least

0.5 m from the floor and suitably mounted to avoid direct radiation affecting the separating element.

iv) Note on using hemisphere polyhedron loudspeakers.

a) Testing Separating Walls.

As with a stand-mounted polyhedron, or a stand-mounted, infinite baffle (IB) or cabinet loudspeaker, the sound source should be positioned in the corners of the room, furthest away from the test partition. To ensure that the radiation pattern complies with ISO140-4 Annex A, the speaker should be mounted on a hard reflective surface, i.e. the floor. It can be placed quite close to the walls of the room while still maintaining a distance of 0.5 metres between the walls and the centre of the sound source.

When using a hemisphere polyhedron sound source in this way, the normal requirement for the sound source to be 0.5 metres from the floor and for the sound source positions to be on different planes relative to the floor (but not to other surfaces) can be disregarded, following the advice in A.2 paragraph 6.

If the tester is concerned about the possible transmission of vibration into the floor, then the sound source can be placed on a well-damped vibration isolation pad. A folded blanket or a folded hi-viz jacket is well-suited to this purpose.

An alternative test arrangement is to mount the sound source on a stand or chair so that it is raised off the floor. In this case, the sound source is no longer omnidirectional and can therefore be treated in the same way as any Infinite Baffle sound source; but note that there will be a significant loss of energy in the lower frequencies, which could cause difficulties in creating a uniform spectrum to meet the 6 dB rule.

b) Testing 'top down'.

If the sound source is required to be in the upper room, there is no option but to place the hemisphere polyhedron sound source on a dedicated stand or a stool so that the floor is not in the direct field of the sound source. A height of at least 1.0 metre is recommended. The sound source should be placed close to the corners of the room but taking special care with regard to possible influence on the flanking transmission.

c) 6 dB Rule.

Achieving a uniform frequency response can be difficult with both polyhedron and hemisphere polyhedron sound sources as most designs have a small volume compared to a conventional rectangular cabinet loudspeaker. In the case of the hemisphere polyhedron, placing the unit flat on the floor, as required for omnidirectional radiation, enhances the low frequency output. Some manufacturers e.g. Norsonic, produce a matching power amplifier with a switchable 'equalisation' circuit, which helps to 'flatten' the response at low frequencies. Research [1] has proved that reliable measurements are possible down to 50 Hz using a floor-mounted hemisphere polyhedron sound source.

A floor-mounted hemisphere polyhedron sound source is normally less sensitive to small changes in room position than a conventional sound source so it can take some time to get a sound field in the room which is within 6 dB at the lower third-octave bands of 100 Hz, 125 Hz and 160 Hz. The tester should have a graphic equaliser available as a stand-by.

## 5.5. Source noise spectrum

For the source room measurements, the difference between the average sound pressure levels in adjacent ⅓-octave bands should be no more than 6 dB. If this condition is not met, the source loudspeaker position should be adjusted in the first instance and, if necessary, diffusers should be installed in the source room. The source room measurement should then be repeated until the condition is met. If this is not achievable solely by these means, the source spectrum may be adjusted using a graphic equaliser or loudspeaker / amplifier tone controls until the condition is met.

Notes on this section

i) ADE Annex B2.4 clarifies the statement in ISO 140-4, Section 6.2, which does not use the word "average". Whether using a moving microphone or fixed microphone positions, therefore, this requirement applies to the time- and space-averaged source room level over 30 seconds or more.

ii) Research [1] has shown this to be an unnecessary requirement. It is, however, a requirement of the standard and so at present remains a requirement of this guide.

iii) The modal excitation is strongly affected by loudspeaker position, and, in some cases, moving the loudspeaker by as little as 100 mm can change the average SPL in the source room by as much as 10 dB at low frequencies. It follows that, in rooms with strong modal responses, the result of a test can depend substantially on loudspeaker position. Room modes tend to be reduced or eliminated by furnishings and are comparatively rare in normally furnished rooms. Hence, room modes occurring during testing can result in a failure to meet the specification which is not representative of conditions when the rooms are in use.

iv) Adjusting the source noise spectrum does not eliminate the room modes, whereas changing the loudspeaker location does. With a cabinet loudspeaker having a reasonably flat response, it is very unusual to encounter a room where the 6 dB requirement cannot be met by moving the loudspeaker and / or installing diffusers. When using a polyhedron loudspeaker, the problem is often more difficult to solve and diffusers and / or a graphic equaliser are more likely to be required.

## 5.6. Sound level measurements

### Overview

The average sound pressure level ($L_{eq}$) in the source and receiving rooms is measured in ⅓-octave bands using either fixed microphone positions or a moving microphone. The number of measurements required depends on whether one or more loudspeaker is being used simultaneously.

The measurements made in the source and receiving rooms to determine a level difference for a specific loudspeaker position should be made without moving the sound source or changing the output level of the sound source.

### Using fixed microphone positions

If using fixed microphone positions, the sound level in each room should be measured using at least five microphone positions, with a measurement of at least six seconds at each position. These measurements should be averaged logarithmically, i.e. on an energy basis. This can usually be done within the instrument, using the "pause" function on the meter to measure, effectively, a single Leq of 30 seconds or more. Alternatively 5 separate measurements can be stored for subsequent processing in software. The latter option allows later analysis of the sound level at each measurement location, which can be useful in post-measurement analysis, particularly to determine whether a failure might be due to strong room modes. In this case an assessment of the compliance of the test with this Guide and Standards can be made.

ISO 140-4 requires a minimum of five positions equally distributed within the space permitted for measurement in the room. They should be at least 0.7 m apart, at least 0.5 m from any room surface, at least 1 m from loudspeakers and should be at different heights. ISO 140-4 also states that "Greater separating distances should be used whenever possible" and that "Microphone positions…shall be evenly distributed within the space permitted for measurement in the room". Where possible, therefore, the distances between microphone positions should be increased to sample the permitted area of the room equally.

The use of the guidance in ISO 140-14 may also be considered as outlined in section iv).

Notes on this section

i) In small rooms it may be difficult to achieve the minimum distances especially if two loudspeakers are used simultaneously. In that case it is better to revert to the single loudspeaker technique. If necessary, in very small rooms, reduce the space between microphone locations – see guidance in ISO 140-14. On no account should you measure less than 0.5 m from room surfaces as this has a significant effect on the measured level.

### Using a moving microphone

Both ISO 140-4 and ADE allow use of a moving microphone instead of fixed microphone positions. The traverse of a moving microphone is defined as having… *“a sweep radius of at least 0.7 m, with a traverse period of at least 15 s and a traverse plane inclined at more than 10 degrees from any plane of the room”.*

As with fixed microphone locations, these are minimum dimensions and the traverse “*shall be inclined in order to cover a large proportion of the space intended for measurement*”. ISO 140-4 does not, however, state that this traverse should be achieved by a mechanical rotating boom, and the majority of testers do this manually.

Notes on this section

i) Fixed and moving microphone techniques have been compared in joint ANC/ RDL/ BRE research project [1]; no significant difference has been found, even where the moving microphone does not follow a single inclined plane but is swept through other paths not achievable by a mechanical rotating boom in order to sample more of the available space.

ii) Research [2] provides further evidence on the use of alternative traverse paths.

### Number of measurements using fixed microphone positions

If one loudspeaker is used, a minimum of five fixed measurements is required in each room for each loudspeaker position; a minimum of two loudspeaker positions is required.

If more than one loudspeaker is used simultaneously a minimum of ten fixed measurements in each room is required.

### Number of measurements using a moving microphone

If one loudspeaker is used, a minimum of one moving microphone measurement is required in each room for each loudspeaker position; a minimum of two loudspeaker positions is required.

If more than loudspeaker is used simultaneously with a moving microphone, a minimum of one measurement is required in each room.

### Additional guidance

The minimum numbers of measurements described in sections 0 and 0 are required to comply with ISO 140-4. ISO 140-14 offers additional guidance for minimum numbers of speaker positions, fixed microphone positions and moving microphone positions based on the floor area of the rooms tested. It is suggested that these be adopted unless there are good reasons not to do so. These are:

| Measurement set up | Floor area of the room / $m^2$ | Number of loudspeaker and microphone positions | | |
|---|---|---|---|---|
| | | Loudspeakers (source room only) | Fixed microphones | Moving microphones |
| A | < 50 | 2 | 5 (10) | 1 (2) |
| B | 50 to 100 | 2 | 10 (10) | 2 (2) |
| C | > 100 | 3 | 15 (15) | 3 (3) |
| NOTE: The numbers in parentheses are the total numbers of sound pressure level measurements to be carried out in the room | | | | |

**Number of microphone and loudspeaker positions determined from the floor area of the source and receiving room**

If a single loudspeaker is used, at least two sets of source and receiving room measurements are required, with the loudspeaker moved between sets of measurements. This gives at least two level differences, which are then averaged arithmetically.

Notes on this section

i) When a single source is used, a typical procedure could be as follows:

   a) Set up the loudspeaker in the first position
   b) Measure the source room level
   c) Measure the receiving room level
   d) Move the loudspeaker to the second position
   e) Measure the source room level
   f) Measure the receiving room level

ii) The tester should not move the loudspeaker between steps b and c, or between steps e and f.

## 5.7. Effect of the tester in the source room

The Scheme does not require additional absorption or substitution techniques to compensate for the effect of the tester in the source room.

Notes on this section

i) Research [1] has confirmed that this effect is not significant.

## 5.8. Background noise measurement

The standards do not describe the methodology required for background noise measurements. As the purpose of the background noise measurement is to evaluate the effect of extraneous noise sources on the receiving room measurement, it follows that the procedure should be the same as for the receiving room measurement, i.e.

- If using fixed microphone positions, measure at the same positions and for the same measurement duration as used for the receiving room measurement and average in the same way to obtain the background room measurement.

- If using a moving microphone, use the same microphone trajectory and measurement period as used for each source room measurement.
- In either case the total duration of the background noise measurements should be at least 30 seconds.

Measure as far as possible with the same background noise as occurred during the receiving room measurement, e.g. if extraneous noise exists during the receiving room measurement the background noise measurement should take account of this. If this is not possible the receiving room measurements should be repeated. For this reason it is good practice to measure the background noise immediately before or immediately after the receiving room measurement.

### 5.9. Measurement of reverberation time

ISO 140-4 and ISO 140-7 refer to the ISO 354 (BS EN 20354:1993) method for measuring reverberation time. However, ISO 3382-2: 2008 indicates in paragraph 4.3.3 that ISO 3382-2 should be used with all parts of ISO 140. The requirements in ISO 3382-2 regarding number of measurements are no more onerous than those in ISO 140-4 or -7 when measuring reverberation time to correct an engineering measurement of sound insulation.

ISO 3382-2 also notes that in rooms with a complicated geometry, more measurement positions should be used. A distribution of microphone positions shall be chosen which anticipates the major influences likely to cause differences in reverberation time throughout the room.

Reverberation times in the receiving room may be measured using either interrupted or impulsive noise sources. If using an impulsive source the reverberation time should be calculated using the Schroeder reverse-integration method. This method is standard in nearly all modern sound level meters.

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), as indicated in section 5 of ISO 140-4.

In rooms with floor areas less than 50 $m^2$, at least one source position and three microphone positions are required, with two measurements at each of the three microphone positions, i.e. a total of at least six measurements.

In rooms where the floor area exceeds 50 $m^2$, the guidance in ISO 140-14 is that at least two speaker positions with six microphone positions for each are used, i.e. a total of at least 12 measurements. However, ISO 3382-2 indicates that, where the reverberation time is used to correct other engineering-level measurements, a minimum of one source position and three microphone positions is adequate, with two decays recorded at each microphone position to give a total of six measurements.

The standards allow the use of either T20 or T30, but ISO 140-14 and ISO 3382-2 recommend the use of T20. Reasons for the preference of T20 are described in ISO 3382-2.

# 6. Impact sound transmission of a separating floor

## 6.1. General requirements and options

The impact sound transmission of a separating floor should be measured in accordance with ISO 140-7, with the impact sound in the source room generated by a tapping machine as described in section 4.5. The average impact sound pressure level ($L_i$) is measured in the receiving room only, using either fixed microphone positions or a moving microphone. All measurements and calculations should be carried out using ⅓-octave frequency bands. The performance should be rated in terms of the weighted standardised impact sound pressure level, $L'_{nT(Tmfmax),w}$, in accordance with BB 93 and ISO 717-2.

There are different options for the impact measurement procedure:

i. Using static or moving microphones
ii. Using different configurations of microphone / tapping machine positions
iii. Reverberation times – using continuous or impulsive sources

The standards also allow for measurement of ⅓-octave bands sequentially or simultaneously, but this guide assumes that testers will measure all ⅓-octave band simultaneously using real-time analysers as the sequential process would be extremely time-consuming.

## 6.2. Tests between rooms

The test has to be conducted from an upper room to a teaching or learning room below (but not to corridors, stairwells or hallways).

## 6.3. Tapping machine hammer height check

The height of the hammer heads above the floor surface should be checked before the test. The tapping machine should be placed on a flat, hard and even surface. The maximum height that the hammer heads achieve just before falling should be 40 mm ± 5%. This can be checked using a dedicated 40 mm high block made out of a hard material. Such a block will generally be supplied by the tapping machine manufacturer. The tapping machine should have adjustable supports so that the hammer head height can be adjusted accordingly. All other parameters as described in section 4.4 should be checked regularly and then need not be checked directly before the test.

## 6.4. Tapping machine locations and set-up

The minimum number of tapping machine positions according to ISO 140-7 is four. ISO 140-14 describes how the reproducibility of results in larger rooms may be increased with increased numbers of tapping machine positions.

The tapping machine should be on a flat, level, clean section of floor, free from dust and debris, such that the force exerted by each hammer is as nearly as possible the same.

More positions may be required for uneven surfaces, e.g. with beams or ribs. The minimum tapping machine distance from the floor perimeter is 0.5 m. The line connecting the hammers should be orientated at 45° to the floor joists, beams or ribs. ISO 140-7 does not state the minimum distance between tapping machine positions, only that they should be randomly distributed on the floor under test, while maintaining a minimum of 0.5m from the edge of the floor.

The tester should make sure that the sound field in the receiving room is dominated by the structure-borne sound travelling through the floor and the flanking surfaces and that airborne sound from the tapping machine via other paths (e.g. down stairwells, through doors and windows) is not significant.

The measurements should not begin until the tapping machine has reached its steady speed. For most tapping machines this can take several seconds. Any unsteadiness or variation in the tapping noise when heard in the receiving room will tend to indicate that the above conditions have not been reached and this should be remedied before measurements are taken.

Notes on this section

i) If airborne sound transmission from the tapping machine is noted to be significant during an impact test, this significance can be quantified. The airborne noise level in the source room from the tapping machine can be measured, and the results of the airborne level difference measurement (adjusted if necessary for the direction of that test and reverberation time measurements in the lower room) used to calculate the airborne level in the receiving room. These values can be compared with the measured sound impact pressure levels recorded, to determine the extent of influence of the airborne sound. If the impact sound pressure levels, $L_i$, are not more than 6 dB above the calculated levels from airborne transmission, it may be considered that the results are at the limit of measurement, and this should be noted in the test report.

ii) It is considered bad practice to move the tapping machine while it is running and some manufacturers state that this may cause excessive wear or damage to the machine. It is recommended that the machine should be switched off before moving it.

## 6.5. Measurements using moving microphones

At least four measurements are required when using a moving microphone, e.g. one measurement for each tapping machine position. The traverse of a moving microphone should have a sweep radius of at least 0.7 m, with a traverse period of at least 15 s and a traverse plane inclined at more than 10 degrees from any plane of the room.

These are minimum dimensions and the traverse “shall be inclined in order to cover a large proportion of the space intended for measurement”. The microphone positions should be at least 1.0 m from the upper floor being excited by the tapping machine and 0.5 m from any other room boundaries or diffusers. If it is not possible to comply with all of the above conditions in very small rooms reduce the sweep radius; do not allow the microphone to pass closer to the room boundaries than stated.

The measurements should be averaged logarithmically to give an overall averaged receiving room level.

## 6.6. Measurements using fixed microphone positions

ISO 140-7 requires at least six measurements, using at least four microphone positions and four tapping machine locations. If the number of tapping machine positions is increased to six or more, only a single microphone position is required for each tapping machine position.

Each measurement of $L_i$ should be of at least 6 seconds' duration. The measurements should be averaged logarithmically to give an overall receiving room level value for $L_i$.

The fixed microphone positions should be at least:

- 1.0 m from the upper floor being excited by the tapping machine
- 0.5 m from any other room boundaries or diffusers
- 0.7 m apart

Within these constraints, microphone positions should be evenly distributed about the receiving room. If it is not possible to comply with all of the above conditions in very small rooms, reduce the spacing between microphone positions; do not measure closer to the room boundaries than stated.

Notes on this section

i) It is noted that the minimum measurement requirements permit two measurements for each of two tapping machine positions, and one measurement for the other two tapping machine positions; this will bias the overall results. It is therefore suggested that an equal number of measurements is made for each tapping machine position.

## 6.7. Floor coverings

The floor covering in schools is generally an integral part of the floor, and testing on the floor finish is generally appropriate.

Notes on this section

i) Where a room has more than one floor finish, ISO 140-14 indicates that measurements should be taken and reported for each floor type separately. The floor covering should be noted in the test report.

## 6.8. Background noise and reverberation time measurement

The procedures are the same as those for airborne tests and are described in sections 5.8 and 5.95.9 of this Guide.

# 7. Sound insulation calculation procedures and precision

## 7.1. Calculation procedures

The main calculation procedures are clearly set out in the standards and are not reproduced here.

If using proprietary software, whether built into sound level meters or for subsequent analysis it is the tester's responsibility to ensure that the software complies with the standards and in particular with the requirement in ADE for arithmetic averaging of level differences.

Testers using spreadsheets to process the measurements and calculate the results should ensure that these spreadsheets comply with all of the requirements of the Standards.

Notes on this section

i) Common errors arise in averaging, in rounding procedures, and in the correction for background noise. Spreadsheets should be written in such a way as to allow each stage to be checked for quality control purposes.

## 7.2. Rounding and precision

Sound pressure levels should be recorded to a precision of 0.1 dB and reverberation times to 0.01 seconds.

When calculating sound insulation test results, no rounding should occur in any calculation until specified by the Standards.

## 7.3. Calculation of DnT(Tmf,max),w

The reference reverberation time ($T_{mf\ max}$) of the receiving room is selected from Table 1.5 of BB 93, depending on the room type description. This value should be used in all ⅓-octave frequency bands to calculate the $D_{nT(T mf\ max),w}$ parameter required by BB 93.

# 8. Indoor ambient noise level measurements

## 8.1. General requirements

Rooms should be finished and unoccupied, but may be either furnished or unfurnished. There should be no more than one person present in the room.

Measurements should be made when external noise levels are representative of conditions during normal school operation.

Indoor ambient noise levels are measured in the manner described in Section 1 of Building Bulletin 93, supplemented by the Association of Noise Consultants Guidelines.

Measurements should be made in at least three positions that are normally occupied during teaching or study periods.

The microphone should be located between 1.2 and 1.5 metres above floor level, and at least 1 metre from any other room surfaces.

Where there is negligible change in noise level over a teaching period, measurements of $L_{\mathrm{Aeq},T}$ over a time period much shorter than 30 minutes (eg $L_{\mathrm{Aeq,5\ min}}$) can give a good indication of whether the performance standard in terms of $L_{\mathrm{Aeq,30\ min}}$ is likely to be met. However, if there are significant variations in noise level, for example due to intermittent noise events such as aircraft or railways, measurements should be taken over a typical 30 minute period in the school day.

## 8.2. Naturally ventilated rooms

The windows or vents should be open as required to provide adequate ventilation.

The extent to which windows or vents will need to be opened to provide "adequate ventilation" will depend on the physical arrangement, environmental conditions, and the number of room occupants.

If the design relies on a 5 dB tolerance when ventilating naturally at 8 l/s/person, separate measurements should be made under these ventilation conditions and the minimum design ventilation rate, which should not be less than 3 l/s/person. The mechanical engineers may be able to advise the maximum design requirement for openings to provide ventilation at the different rates.

In the absence of such guidance, it may be appropriate to open all the windows to their full extent, and report the conditions under which the measurements were made.

It may also be appropriate to determine the maximum openings possible to achieve the indoor ambient noise levels required, and to report the conditions under which the measurements were made.

An external measurement may be recorded to correlate with the design stage information.

### 8.3. Mechanically ventilated rooms

Where there is mechanical ventilation (including mixed mode), any windows should be closed, unless they are required to be open as part of the mechanical ventilation strategy.

The mechanical systems should be in use and running at their maximum design duty.

Measurements should be made in locations that would normally be occupied during teaching or study periods, which are also at the closest proximity to any mechanical ventilation terminations. These locations should, however, be at least 1.5 metres from any specific noise source, in accordance with the Association of Noise Consultants Guidelines, Noise from Building Services.

The minimum record length for continuous steady noise from building services is 10 seconds. A longer sample period may be required if external noise sources are dominant.

If there are extraneous noises that are not typical of the noise environment, the $L_{90}$ parameter may be used to evaluate building services noise, as described in the Association of Noise Consultants Guidelines.

### 8.4. Precision

Measured or calculated noise levels should be recorded to one decimal place.

The value of $L_{Aeq,\,T}$ should be reported to the nearest integer.

# 9. Mid-frequency reverberation time measurements

## 9.1. General requirements

There should be no more than one person present in the room during the measurements.

The performance standards for mid-frequency reverberation times relate to finished, unoccupied, and unfurnished rooms. Any deviation from these room conditions during the testing should be recorded in the test report.

Assembly halls, multi-purpose halls, lecture rooms and music performance/recital rooms may be considered as unfurnished when they contain permanent fixed seating. Where retractable (bleacher) seating is fitted, measurements should be made with the seating retracted.

In BB 93, two measurement methods are described for the measurement of reverberation time, as outlined below. However, as the standards to which BB 93 refers have been updated, both methods are now referenced to the same standard, ISO 3382-2.

## 9.2. Measurement method 1:

BB 93 indicates that measurements should be made in accordance with either low coverage or normal coverage measurements described in ISO 3382: 2000. This version has been superseded by ISO 3382-2: 2008, as described below.

## 9.3. Measurement method 2:

BB 93 indicates that reverberation time measurements should be made in accordance with ISO 140-4 (airborne sound insulation) or ISO 140-7 (impact sound insulation), in octave bands. However, as described in section 5.9 on reverberation time measurements for sound insulation tests, ISO 3382-2 indicates that it should be used with all parts of ISO 140 for measurement of reverberation time.

ISO 3382-2 indicates that when evaluating the reverberation time for comparison with reverberation time specifications the following minimum numbers of measurements should be observed:

| | |
|---|---|
| Source – microphone combinations | 6 |
| Source positions | ≥ 2 |
| Microphone positions | ≥ 2 |
| No. decays in each position (interrupted noise method) | 2 |

**Minimum number of positions and measurements for the engineering method**

Hence for interrupted noise measurements, a minimum of 12 measurements is required; for impulse response measurements, a minimum of 6 measurements is required.

In rooms with a complicated geometry, more measurement positions should be used. A distribution of microphone positions shall be chosen which anticipates the major influences likely to cause differences in reverberation time throughout the room.

Notes on this section:

i) BB 93 suggests that it may be possible to use measurements of reverberation time made for the purposes of sound insulation tests to evaluate the mid-frequency reverberation time. However, this is not possible, as sound insulation measurements are made in third octave bands (as sound insulation testing is required in third octave bands as described in AD-E), and the mid-frequency reverberation time should be calculated from measurements in octave bands. Measurements of reverberation time in third octave bands are not comparable with measurements in octave bands. Therefore separate measurements are required of reverberation time in third octave bands for sound insulation measurements, and in octave bands to evaluate the mid-frequency reverberation time.

ii) The minimum number of measurements required for evaluation of reverberation time is different to the number of measurements required when the reverberation time is measured to correct measurements of sound insulation.

iii) Measurements should utilise microphone positions that are representative of occupied positions within the space.

## 9.4. Precision

Reverberation times should be measured to two decimal places. The mid-frequency reverberation time should also be calculated and reported to two decimal places.

# 10. Speech Transmission Index in open plan spaces

In the normal Speech Transmission Index (STI) measurement set-up for room acoustic assessments, a sound source is used to generate the STI test signal. The test signal is calibrated and corresponds to the nominal speech level. A situation dependant, representative talking distance should be employed. A calibrated STI measuring device is used at the receiver location to determine the STI of the transmission channel.

Measurements should be made in accordance with EN 60268-16. This requires measurements to be made several times and an estimate of the standard deviation to be included.

Measurements of the STI should be taken in at least one in ten typical student listening positions in the open-plan spaces.

Notes on this section:

i) STIPA is a simplified form of STI which is considered to be equally appropriate for assessing the suitability of room acoustics for speech communication as the full STI method. However, if performance is to be measured in terms of STIPA rather than STI, this should be considered as an alternative performance standard and subject to the normal procedures of section 1.2.1 of BB 93.

ii) The RASTI method is now considered obsolete due to serious limitations of the method.

Set the source (artificial mouth or suitable test loudspeaker) on the axis of the appropriate microphone at the normal speaking position and direct it in the normal speaking direction.

Measurements should be made using the following heights for listening or speaking:

- to represent seated students, a head height of 0.8 m for nursery schools, 1.0 m for primary schools and 1.2 m for secondary schools
- to represent standing students, a head height of 1.0 m for nursery schools, 1.2 m for primary schools and 1.65 m for secondary schools
- to represent seated teachers, a head height of 1.2 m
- to represent standing teachers, a head height of 1.65 m.

Set the test signal level at the microphone position to equal that of the speech level under normal operating conditions. The sound pressure level should be set using A-weighting. For source positions representing the teacher’s speaking position, the level should be 66.5 dB at 1 m (ie ‘raised’ vocal effort) in front of the artificial mouth or test loudspeaker. For source positions representing the student’s speaking position, the level should be 60 dB at 1 m (i.e. normal vocal effort) in front of the artificial mouth or test loudspeaker.

Notes on this section:

i) If it is not possible to obtain a sufficiently clean speech-to-noise ratio, when using maximum length sequence (MLS) analysis equipment, it may be possible to use a higher test signal level, and adjust for the actual speech signal spectrum at the microphone position by manually entering speech level data into the speech data table used by the measuring equipment.

Check that the test signal spectrum at the input microphone position is correct to within ±1 dB over the range 88 Hz to 11.3 kHz (the limits of the 125 Hz and 8 kHz octave bands) – refer to ANSI 3.5 for target BB 93 test signal spectra for 'raised' and 'normal' vocal effort as appropriate. Adjust the equalisation (if any) of the artificial mouth or test loudspeaker, as necessary, to satisfy this requirement, or alternatively adjust by manually entering into the speech data table used by the measuring equipment.

Simulation of the estimated occupancy noise may be carried out in the STI measurement, or by manually entering noise data into the noise data table used by the measuring equipment. This noise level will have been established at the design stage (see BB 93 Section 1.1.7) and is defined as the noise level due to the combination of the indoor ambient noise level, all activities in the open-plan space (including teaching and study) and transmitted noise from adjacent spaces.

# 11. Reporting

### 11.1. Administrative information required

The report should include the following information:

- Address of building
- Dates of testing
- The name and address of the organisation carrying out the testing
- The report number
- The name of the person in charge of the test
- The name and signature of the person who has checked the report
- The name and address of the client
- A description of the test methodology and equipment used
- A statement that the test procedures in BB 93 have been followed. Where the procedure could not be followed exactly then the exceptions should be described and reasons given

### 11.2. Signature and verification

The report should be checked by the member of staff who carried out the tests where this is not the report author. It should also be checked and signed by another competent person. Where an organisation comprises only one individual both signatures may be by that person. That person should sign that they have checked the report.

### 11.3. Information required for each test

For each test covered by the report, the following information should be reported:

- identification of the rooms used for each test within the set of tests
- room types interpreted from BB 93 Tables 1.1, 1.4 and 1.5
- the acoustic performance requirement as stated in BB 93, or as amended by BB 101
- any amended acoustic performance requirement accepted as an alternative performance standard
- the measured single-number quantities for each test
- pass or fail for each BB 93 compliance test
- description and identification of the construction of the separating wall or floor tested
- room volumes (including a statement on which rooms were used as source and which as receiving rooms)

### 11.4. Graphical reporting of sound insulation results

The results of each test should be shown in tabular and graphical form in ⅓-octave bands, according to the relevant part of the ISO 140 series and ISO 717 series, including:

- single-number quantities
- reference reverberation time used in the calculation
- $D_{nT}$ and $L'_{nT}$ data from which the single-number quantities are calculated
- indications of results which are to be taken as limits of measurement

### 11.5. Reverberation time test results

The measurement method used should be reported.

Optionally, for each reverberation time test the reverberation time in each octave band may be shown in tabular form, with the $T_{mf}$ calculated.

### 11.6. Indoor ambient noise level test results

The ventilation system in the rooms tested should be reported, with the ventilating conditions at the time of the test.

Optionally, the value in each octave band may be shown in tabular form for each indoor ambient noise level test.

### 11.7. STI test results

For each STI test, the result should be reported with the simulated occupancy noise level used in the measurements or calculations. The location of the source and receiving position for each test should be indicated on a plan, and their respective heights noted.

### 11.8. Optional Reporting

Although not required, it may be useful to have a description of the building including:-

- sketches showing the layout and dimensions of rooms tested;
- description of separating walls, external walls, separating floors, and internal walls and floors including details of material used for their construction, and finishes;
- mass per unit area in kg/m² of separating walls, external walls, separating floors, and internal walls and floors;
- dimensions of any step and/or stagger between rooms tested;
- dimensions and position of any windows or doors in external walls;
- details of penetrating elements and sealing (e.g. services passing through a separating floor).