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## **Acoustic criteria and specification**

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**BBC Research and Development White Paper No. WHP 021**

## **Acoustic criteria and specification.**

Author : R. Walker

### **Abstract**

*This document comprises a collection of earlier BBC internal papers relating to the specification of acoustic criteria for building projects. Those papers were originally produced by the BBC's Acoustics Committee. They were intended to form guidance notes for use by project managers and other people with responsibilities for designing, commissioning or specifying acoustic aspects of new and refurbished areas. This collection has been re-issued to provide a convenient point of reference for project teams working on new developments.*

**Key words:** acoustics, building, noise, insulation, reverberation time

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## Acoustic criteria and specification.

Author : R. Walker

### Introduction.

This white paper is a collection of notes and recommendations for acoustics in new and refurbished buildings.

They were originally produced by the BBC Acoustics Committee to aid project managers and other people with responsibilities for designing, commissioning or specifying acoustic aspects of new and refurbished areas.

The criteria relate almost as much to non-programme areas as they do to the technical areas used for making programmes because of the potential for serious disruption of the programme-making activities from those other areas.

In the current financial and technical climate, there is seen to be less need for acoustic specifications. Certainly, the standards that were once thought to be necessary for all kinds of programme production are not now seen to be so important. However, the truth is that acoustic standards still need to be applied. The differences are in the numerical values of those standards, and the perceived lack of cost-effectiveness of more stringent requirements.

Most of that change is in the altered acceptability of technical defects in programmes amongst managers, production staff and audience alike. The original criteria were based on physical characteristics of programme production and properties of human aural perception. The physics of programme production have changed little and those of physical human hearing process not at all. Any ‘relaxations’ in the acoustic criteria which are now thought to be appropriate will manifest themselves either in more difficult programme production or in audible defects in the programme sound.

It is still true that “appropriate” acoustic standards have to be applied. It is inconceivable that

programmes could be made efficiently and effectively in spaces that were clearly inappropriate. The question of what is appropriate, taking into account the costs implicit in creating and maintaining the facilities, the difficulties in programme production and the reduced audience appreciation, can only be answered in each case by the design team. It is no longer the case that acoustic specialists have any place in judging what is right or wrong. The most that they can do is to advise on the probable outcomes of different courses of action.

The principal reason for producing this collection was the increasing frequency with which project teams were now finding themselves with no satisfactory references to acoustic requirements.

The original documents were last updated in the period 1987-1992. No effort has been made to update these documents, other than to correct a number of grammatical errors and internal cross-references. In particular, the references to, for example, British Standards, are now out of date. It is certain that many of them have been updated since the original documents were written. It is left for the reader to obtain the most recent versions, if required. Furthermore, BBC papers referred to and not included in this collection should be considered to be ‘out of print’ and therefore no longer available – unless they have also been published in electronic form as White Papers on the R&D web site. However, it is hoped that sufficient information has been included here to make this collection reasonably self-contained.

The specifications referred to are now attached at the end of this collection as a set of three single-page documents that can be used as model specifications.



# Acoustics Committee Note No. 1990/1

## Guidance on the use of acoustic criteria.

The Acoustics Committee has produced a number of notes on acoustic criteria and their application. This note is intended to be an overview and a guide to how the individual criteria are inter-related.

### Summary.

The achievement of good acoustic standards is essential if the areas are to provide satisfactory environments, both initially and throughout their working lifetime. Unlike technical equipment, modifications and improvements to buildings cannot be simply achieved by replacement after a few years. A building has to be designed for a working period of at least twenty to thirty years, during which time it will contain three or more new generations of technical equipment. Accordingly, the acoustic standards that are incorporated into the original design have to support the use of the technical equipment in the building for a period during which the changes may be unforeseeable.

In comparison with the cost of even one generation of the installed equipment, the costs of reasonable acoustic standards are small. In comparison with five or six generations of equipment they are minuscule.

With these factors in mind, the Acoustics Committee has produced a set of acoustic standards and tolerances to which the majority of projects ought to conform. Acknowledging the other pressures on the design of a new facility, the Committee has also taken account of the need to be cost-effective and has advised that certain relaxations from the formal standards may be acceptable in many cases. These relaxations must be considered as a whole throughout the duration of a project and will always lead to audible interference. Whether this interference will be significant depends on the design relaxations and the eventual operational use of the area. Those factors can only be decided through consultations between the project design team, the acoustics specialists and the users.

### Background noise.

The main source for the background noise criteria is still RD Report Number 1980/8. This specifies three criteria levels, i, ii and iii, for different critical applications. These are mainly studios and their control rooms and other, ancillary, areas where critical assessment and control of programme sound takes place. To these three basic criteria have been added three others. One is for vehicles, where the control of noise levels is so difficult that higher levels than in comparable studios have to be accepted. Two are for areas, such as VT machine rooms and offices, where there is a need to provide reasonable working conditions but in which no critical assessments are carried out.

Acoustics Committee Note Number 1992/1 contains a fuller description of the derivation of the criteria and the actual levels of the criteria as functions of frequency. It also contains descriptions of measurement techniques, instrumentation requirements and some examples of appropriate tolerances, in the form of a model specification which may be used or modified for use in contract documents.

### Sound Insulation.

The main source for the airborne sound insulation criteria is a Research Department Report currently in preparation [now RD 1990/10]. This is an updated version of RD 1981/1 and contains mostly the same data, although some of the categories have been revised. In principle, the required sound insulation is set by the difference between the highest sound levels in the source area and the necessary continuous background noise in the receive area. Because sporadic sounds are much more disturbing than steady, anonymous noise, ventilation system noise in the receive area is relied on to mask the potential interference from external sources. Thus, there is a very close relationship between the background noise and sound insulation criteria.

The Report includes a chart giving the airborne sound insulation requirements between many different types of areas, including ancillary areas and building exteriors. About 400 combinations are given explicitly, together with a description of the method to enable others to be calculated if necessary.

Acoustics Committee Note Number 1988/1 contains a fuller description of the derivation of the criteria and some examples of the criteria as functions of frequency. It also contains descriptions of measurement techniques, instrumentation requirements and some examples of suitable tolerances, in the form of a model specification which may be used or modified for use in contract documents.

### **Internal acoustics.**

The specifications for the necessary internal acoustic conditions in rooms of different types have never been formalised to the same extent as those for background noise and sound insulation. There are a number of reasons for this. The most important one is that, apart from some common cases such as 'Talks' studios and sound control rooms, each case has to be considered individually. Acoustics Committee Note 1989/2 gives some guidance on the normal values for the mid-frequency reverberation time as a function of room size and usage, but the allowable ranges given there are very wide and that document alone would not be sufficient for the design of any individual area. The reverberation time is usually also a function of frequency. Some examples of these variations are also given in Acoustics Committee Note 1989/2.

The internal acoustic design of an area depends on many other factors besides the reverberation time. These are, at the present time, not quantifiable although a number of International Committees and many research workers are studying the problem (and have been for some years). Foremost amongst these other factors are the state of acoustic diffusion and control of strong, discrete reflections.

Acoustics Committee Note 1989/2 also contains descriptions of measurement techniques, instrumentation requirements and some examples of suitable tolerances, in the form of a model specification which may be used or modified for use in contract documents.

### **Inter-relationships and relaxations.**

Because the required sound insulation depends directly on the level of background noise in the receiving area, these two criteria are inextricably linked. In principle, this means that the necessary sound insulation depends on the achieved background noise level. This is not a practicable basis for planning because neither ventilation system nor sound insulation design are precise. Some latitude has, therefore, to be allowed. At the present time, the tolerances for ventilation system noise are +0/-10 dB. The sound insulation criteria are based on the +0 dB limit. Thus, there is already a 10 dB potential shortfall in the effective, achieved insulation.

In these days of financial stringency, in many (if not most) cases, there is an expressed requirement to "reduce the cost [standards]". This is usually interpreted as reducing the sound insulation. The formal insulation criteria are based on the Users' previously stated requirement that interference from external sources should always be "inaudible". In fact, because of the way in which the criteria were derived, based on the psycho-acoustic 'masking effect', they are actually for the "just perceptible" limit rather than the "just imperceptible" one. A rigorous study carried out by Radio Projects determined that many of the areas studied were actually functioning satisfactorily with sound insulations about 5 dB less than the formal limit. By extrapolation, this relaxation has subsequently been allowed for all cases, on the understanding that it will sometimes permit definite and audible interference between areas.

Whether or not this 5 dB allowance may be additional to the allowable 10 dB shortfall in ventilation system achieved levels will depend on the circumstances of the individual project. It may also not be generally allowable for other, non-programme noise sources such as traffic, aircraft, workshops, offices, etc.

In considering the potential relaxations it is important that the tolerances are appropriately distributed. It is unwise to allow the overall acoustic design, implicitly or by default, to inflict all of the tolerances on the one part of the system – the sound insulation – that it is practically impossible to change retrospectively.

## **Conclusions**

The importance of careful consideration of the acoustic factors in any building project has been outlined. A number of Acoustics Committee Notes relating to aspects of acoustics have been referred to and the inter-relationships between the three principal aspects of acoustic design have been emphasised. To achieve adequate acoustic standards at the least cost requires that all of the relevant factors are given sufficient deliberation.

RW, 11th May 1990



## ACOUSTICS COMMITTEE NOTE NUMBER 1989/2

### Specification for reverberation time and recommendations for internal acoustic design.

The attached document is a proposed model specification for Reverberation Time and set of recommendations for internal acoustic design.

#### **A. Reverberation time specification.**

The need for such a specification has arisen because of the changes in the BBC's approach to building projects. Using external consultants we can no longer expect to control projects by informal discussions.

It is intended that this specification document be issued to or incorporated into the other documents issued to a consultant, either within (ie. ACED) or outside the BBC, as the expected and contracted performance of the subject of the contract.

In each individual case it is for the users, that is Radio, Television, World Service, News and Current Affairs or Regions, to define the detail contents of the specification. This proposal is intended to form the basis of such a specification. It attempts to cover all aspects of the measurement of reverberation time.

Inevitably, this approach has resulted in the inclusion of some aspects that we have not hitherto considered to any significant extent. It may also have resulted in the inclusion of seemingly quite arbitrary performance details that are, nevertheless, open to serious abuse if not specified at all.

Likewise, there may be parts of the specification which are of no direct interest to the users but which must be included for completeness in the event of legal proceedings for an alleged failure to complete a contract.

We may not assume any specialist knowledge on the part of the consultant that does not fall within his domain.

The format is based on the style of British (and incidentally ISO, etc.) Standards, giving only the briefest background explanation. Such standards

should be familiar to consultants. Likewise, all material that is not absolutely necessary should be omitted. The specification is neither a design guide nor a 'statement of case'.

This model does not represent any significant intentional changes to the reverberation time criteria. It merely formalises the situation already existing. Design specifications for reverberation time are given here as examples only. Individual cases may be specified to be different to these examples.

#### **B. Internal acoustic design.**

The second part of the document is in the form of design guidelines. Because many of the parameters which are important in the design of a satisfactory room are not quantifiable, these can only be given as general guidelines. Objectively, they can be neither specified nor assessed.

## **A. SPECIFICATION FOR REVERBERATION TIME.**

### **1 Scope.**

#### **1.1 General.**

This specification describes the criteria, the method of measurement and the tolerances for reverberation time in BBC premises.

#### **1.2 Application.**

The most critical areas are those in which programmes are to be made. Other areas may also require the same criteria because of the critical assessment of programme material that occurs in them.

The least critical areas are those without any direct programme connection, such as offices and other ancillary rooms. Criteria are not often specified for these and, where they are, are usually less stringent but are nevertheless applicable.

Although this specification gives the normal ranges of criteria values for programme areas, the actual numerical values to be applied will be specified individually.

#### **1.3 Tolerances.**

The tolerances which are to be applied to the criteria reflect the different sensitivities of the types of rooms. Programme areas usually have more stringent tolerance limits than non-programme areas.

#### **1.4 Parameters specified.**

This specification covers the following aspects of reverberation time :

- a) The typical ranges of values for the reverberation time criteria
- b) The distribution of the reverberation time values with frequency.
- c) The tolerances to be applied.
- d) The equipment to be used for measurement.

### **1.5 Test Specification.**

This specification also covers the method of carrying out the measurement of the reverberation time in practical situations.

## **2 Object and general requirements.**

### **2.1 Object.**

The reverberation time in any enclosed space is a function of the size and material contents of the space. In many cases, material will have been included in the design with the specific purpose of modifying the acoustic environment, but almost all of the material, including the structure of the room boundaries will have some acoustic effect. In rooms that are to be use for the production or assessment of programme material, where the internal acoustic environment is specified in detail, it is important that the intended conditions are achieved within close limits. In non-critical rooms, such as offices and especially newsrooms and similar potentially noisy environments, it is occasionally desirable to include acoustic treatment for reasons of the occupants' comfort. In such cases, the tolerances are wider.

The object of this specification is to ensure that the appropriate criteria and tolerances are interpreted in a consistent manner and that the measurements are carried out in accordance with a unified method.

### **2.2 Requirements.**

Throughout this document the directives "shall" or "must" refer to mandatory specifications. Other directives refer to optional specifications.

## **3 Definitions.**

The definitions of terms used in this specification can be found in the International Electrotechnical Vocabulary (I.E.V.), Chapter 801, Acoustics and Electroacoustics. For convenience, some of the terms are also defined (less formally) here.

### **3.1 Background noise**

The inevitable acoustic noise within a room which results from sources both external to and within the room, by virtue of its location and associated services.

### **3.2 Decay curve**

The path followed by a plot of sound pressure level in decibels as a function of time, after an excitation source has ceased.

### **3.3 Decay rate**

The gradient of the decay curve, in  $\text{dB}\cdot\text{s}^{-1}$ .

### **3.4 Dynamic range**

The difference in decibels between a higher and a lower sound pressure level.

### **3.5 Ensemble average.**

The aggregate decay curve which would be obtained by linearly averaging an infinite number of individual decay curves at one microphone position.

### **3.6 Frequency.**

The number of cycles per second of a sound. Measured in units of 'Hertz' (Hz)

### **3.7 Integration, exponential.**

A means of adding whereby an exponential weighting function is applied, such that earlier values are assigned relatively less weight

### **3.8 Integration, linear.**

A means of adding whereby each contribution to the sum is weighted equally.

### **3.9 Noise.**

Any unwanted acoustic energy.

### **3.10 Reverberation time.**

The time taken for sound energy to decay to a level which is 60dB below its initial level. Equal to 60 times the reciprocal of the decay rate.

### **3.11 Steady-state sound field.**

The final state of the sound level distribution in space and time generated by a source of acoustic energy.

### **3.12 Sound level.**

Common contraction of "sound pressure level". 20 times the logarithm of the rms sound pressure relative to  $20\mu\text{Pa}$ .

## **4 General Parameters.**

### **4.1 Frequency characteristics.**

The reverberation time requirement is usually quoted as a single figure, nominally independent of frequency. Because some tolerances are allowed and because these tolerances are different in different frequency ranges, the complete specification has some frequency dependent aspects. The general form of the reverberation time criterion as a function of frequency is as shown in Fig. 1. This is essentially an adaptation of the control room and listening room criterion from EBU Technical Recommendation R 22-1985(E).

The permitted tolerances implicit in a specification such as given in Fig. 1 will normally be detailed individually in each case. As examples only, Table 1 gives some typical values for the features of Fig. 1 for different types of areas.

The reverberation time must be measured in one-third octave frequency bands.

### **4.2 Measurement.**

The reverberation time in a room is assessed by generating an appropriate acoustic test signal and analysing the way the resulting sound pressure level declines as a function of time after the end of the excitation. The measuring device(s) must be fitted with a filter or set of filters to split the frequency range into one-third octave intervals, in accordance with BS 3593 (ISO 266) and BS 2475 (ISO 225). This is usually, but not necessarily, effected by limiting the frequency range of the excitation source.

### **4.3 Microphone positions.**

The reverberation time in any one frequency band is theoretically defined and practically specified as an average value throughout the whole volume of the room. Each average value is obtained by repeating the measurement at a number of places in the room and carrying out an averaging process, as defined in Section 6.4, on the resulting

numbers. In some cases, usually in very large rooms or where there is otherwise a specific requirement, the areas to which the criterion relates will be specified.

## 5 General Criteria.

The formal criteria and tolerances are limited to the frequency range including the International Standard one-third octave band centred on 50 Hz to that centred on 10000 Hz.

Reverberation time criteria are currently defined in terms of typical values for rooms of different types. As a guide, Figure 2 shows these recommended ranges, but each case will have an individual specification, depending on the detail requirements, which will also include permitted tolerances of the type shown in Fig. 1.

## 6 Measurement.

### 6.1 Method.

The measurement of the reverberation time shall be carried out in general accordance with the methods of BS 5363:1975 (ISO 3382-1975) and BS 3638:1987 (ISO 354-1985), the essential principles of which are repeated here for convenience.

### 6.2 Instrumentation, 1.

#### 6.2.1 *Generation of the sound field*

The sound field should be generated by any convenient means which ensures that the steady-state sound field is fully established before the excitation is terminated. This will require a duration of not less than  $0.2T$ , where  $T$  is the reverberation time which is to be measured. The test signal shall preferably consist of band-limited noise, with a bandwidth of one-third octave, using filters conforming to BS 2475:1968 (IEC 225:1966) or the equivalent. The sound level shall exceed the continuous steady background noise level by an amount sufficient to allow accurate evaluation of the rate of decay over an adequate range of sound levels.

When using a one-third octave band source, the termination of the excitation shall be neither so abrupt that excessive additional frequency components are generated nor so slow that the measurement of the decay is compromised. An

equivalent reverberation time for the instrumentation of  $0.5 T$  is the absolute maximum that can be regarded as meaningful and, corrections should be applied if it exceeds  $0.1 T$  (see Appendix).

Alternatively, the source may consist of wide-band noise, with the frequency analysis carried out by a one-third octave, real-time analyser. In this case, it is necessary to ensure that the room response to the excitation signal is uniform such that the difference in level between any two adjacent bands is less than 6dB.

The sound output device is most conveniently one or more loudspeakers, which should be nominally omni-directional and arranged to produce as diffuse a sound field as possible so that the direct field is not dominant at any microphone position.

#### 6.2.2 *Recording the sound decay.*

The receiving instrumentation shall consist of one or more microphones, which should be nominally omni-directional, amplifiers, filters and a recording system. The recording system shall be either a pen-and-paper or electronic means for displaying the time-function of the sound pressure level decay in decibels against a linear time-scale, adequate to permit the determination of the decay-rate. In rectifying and averaging the sound signal to derive the sound pressure level, the recording system will involve some kind of integration. If this integration is exponential then the time-constant shall be less than, but as close as possible, to  $T/20$ . If the integration is linear then the averaging time shall be less than  $T/7$ .

The measurement techniques employed must be such as to allow adequate discrimination of the short reverberation times encountered in many areas. An overall inherent instrumentation decay-rate of at least  $600 \text{ dBs}^{-1}$  will be required in many cases.

The overall signal-noise ratio must be adequate to resolve the reverberation time with a reasonable degree of accuracy. In practice, this means that in each frequency band the excitation signal level must exceed the background noise level by a minimum of 25 dB and preferably by more than 35 dB.

### **6.2.3 Measurement of the average sound fields.**

Because of the statistical irregularities inherent in the measurement, it will usually be necessary to obtain for each frequency band and microphone position an estimate of the ensemble average decay line. This may be obtained by averaging several individual decays.

To obtain the room average value for the reverberation time, measurements of the reverberation time in each frequency band shall be taken at several different microphone positions and the average value (see Section 6.4) of the results obtained for each frequency band. The number of these microphone positions shall be not fewer than five in rooms of less than 400 m<sup>3</sup> and at least ten in larger rooms. None of these positions shall be within 1 m of a wall, floor or ceiling surface. They should be distributed reasonably evenly throughout the volume of the room and should not be closer together than 2 m.

In very small rooms, that is of less than 50 m<sup>3</sup>, these requirements will not be realistic. In such circumstances, it will be necessary to use closer spacing of the microphone positions and/or fewer than five different positions.

In very large rooms or if otherwise specified, specific restrictions may be applied as part of the contract to the range of microphone positions.

None of the above shall be taken as excluding continuously moving microphone positions, such as are obtained by use of rotating booms. In such cases, the area swept by the boom may be taken to be equivalent to the number of individual, fixed microphone positions that it could encompass, within the restrictions which apply to individual microphone positions.

### **6.3 Instrumentation, 2.**

An alternative and equivalent method is the Schroeder reverse impulse integration method. This method theoretically obtains ensemble average decays for a single microphone position by using a single impulsive excitation and carrying out a mathematical integration process on the reversed time waveform. Given adequate signal-to-noise ratios, this method is capable of giving equivalent results to Method 1.

Many of requirements of Section 6.2 are also applicable to this method. However, the impulsive excitation may be by any convenient means and the signal recording and analysis must, perforce, be electronic.

The method is subject to some serious errors when applied over a wide dynamic range because of the inherent rounding errors caused by truncation of the infinite timescale. It should only be used to obtain reverberation time values over a sound pressure level range which is significantly less than the actual signal-to-noise ratio.

### **6.4 Processing of results.**

For each frequency band the values obtained at each microphone position for reverberation time must be averaged to obtain the overall value for the area and for that frequency band. The average is defined as the simple arithmetic sum of the individual sample values divided by the number of samples.

### **6.5 Presentation of results.**

The results should be presented in a graphical form as the average reverberation time against frequency band. The recommendations of BS 6397:1983 (ISO 263(1975)) may be followed, see for example BS 4196:Part 0:1981 (ISO 3740-1980), but any reasonable presentation will be acceptable. The presentation must include an indication of the design criterion.

Any frequency bands in which, for reasons of excessive background noise, the measurement could not be made or was limited to an estimate of the initial reverberation time only must be clearly indicated as such in the presentation of the results.

Any frequency bands in which the ensemble average decay curve showed significant curvature shall be indicated as such.

All presentations must include full details of the measurement - the definitions of the area (that is, both the name by which it are known and that of the building), the date and approximate time of the measurement, the equipment used for the measurement, the number of microphone positions and the type of excitation. A dimensioned sketch of the location must also be

included, indicating the size, shape and internal volume of the area.

## 7 Tolerances.

### 7.1 'Programme areas'

Most critical areas will have an individual reverberation time design criterion and set of tolerances. These may include some frequency dependent features. However, there is a large class of areas which usually have the same specification and tolerances, namely relatively small studios used for voice only and many rooms in which sound quality assessments or sound control functions are carried out. The description of this criterion is given here as an example. Other types of areas will be subject to the same general controls and limitations, even though the numerical details will differ.

In setting these tolerances it is recognised that there are difficulties in the design of some rooms and the measurement of reverberation time at low frequencies. Accordingly, the tolerances have been divided into three frequency bands. (All frequency ranges are inclusive).

#### **Control Room criterion:**

**Overall.** – The achieved reverberation time averaged over the frequency range 200 Hz to 3.15 kHz shall lie in the range 0.2 to 0.3 s. Whatever average value is actually achieved, the remaining tolerances are expressed relative to this achieved average,  $T_m$ .

**Mid frequencies.** – In the frequency range 200 Hz to 3.15 kHz every frequency-band average value shall fall within the range  $0.8 T_m$  to  $1.2 T_m$ .

**Low frequencies.** – In the frequency range 50 Hz to 200 Hz every frequency-band average value shall fall within the range bounded by the line  $0.8 T_m$  and a straight line (on a logarithmic scale of reverberation time) drawn from  $1.2 T_m$  at 200 Hz to  $2.5 T_m$  at 50 Hz.

**High frequencies.** – In the frequency range 3.15 kHz to 10kHz every frequency-band average value shall fall between the lines bounded (a) on the higher side between  $1.2 T_m$  at 3.15 kHz and  $T_m$  at 10 kHz and (b) on the lower side between  $0.8 T_m$  at 3.15 kHz and  $0.6 T_m$  at 10 kHz.

Significant secondary (dual-slope) decays are not permitted at any microphone position or in any frequency band. The criterion of significance is if the reverberation time over the range -20 to -35 dB (relative to the steady-state sound pressure level) differs from that over the range -5 to -20 dB by more than a factor of 2:1. The primary result shall be that over the -5/-20 dB range and the preferred means of presentation is by showing a subordinate point on the results. If the ratio is more than 2 then this shall be deemed to be unacceptable.

### 7.2 'Non-programme areas'

Non-critical areas almost never have criteria for reverberation time. However in some cases, usually in order to control the internal environment for the room's occupants, it is desirable to specify an upper limit to the reverberation time. This may also be a function of frequency.

## 8 Appendix - correction for instrumentation response time

The actual reverberation time,  $T_a$ , of a room, when measured with instrumentation with an inherent response time equivalent to a reverberation time of  $T_i$ , is related to the measured reverberation time,  $T_m$  by:

$$T_a = \sqrt{(T_m^2 - T_i^2)}$$

## B. RECOMMENDATIONS FOR INTERNAL ACOUSTIC DESIGN.

The reverberation time is the only objective measure of the internal acoustic conditions within a room that is reasonably well understood, but it is, at best, a poor guide to the subjective acoustic environment. Many proposals for alternative or additional measurements have been made over the years but none can, at present, be interpreted subjectively, at least in small rooms. There is some good evidence that these alternatives are meaningful in concert halls and other large spaces, but such rooms are rare within the BBC.

This problem was recognised by the authors of EBU R22-1985(E) who did, however, give some general guidelines. If followed, these guidelines are likely to lead to satisfactory conditions but

there are no guarantees. They are given here verbatim.

“ ...

***Diffusion of sound and the distribution of the sound absorbing material.***

*In so far as it is practicable, the sound absorbing material should be distributed around the walls and on the ceiling as evenly as possible, with regard to both the physical arrangement and its effect across the frequency spectrum.*

*Particular care should be given to the arrangements of the acoustic treatment between 1 m and 2 m from the floor especially in respect of the lateral symmetry. It is also important to consider the effect of reflections and flutter echoes that would result from the untreated surfaces such as cable trunkings and light fittings as well as the larger surfaces of doors, windows and equipment cabinets. Any resonances in equipment, fittings or acoustic treatment should be damped so that the rate of attenuation of their oscillations is considerably faster than the reverberation time.*

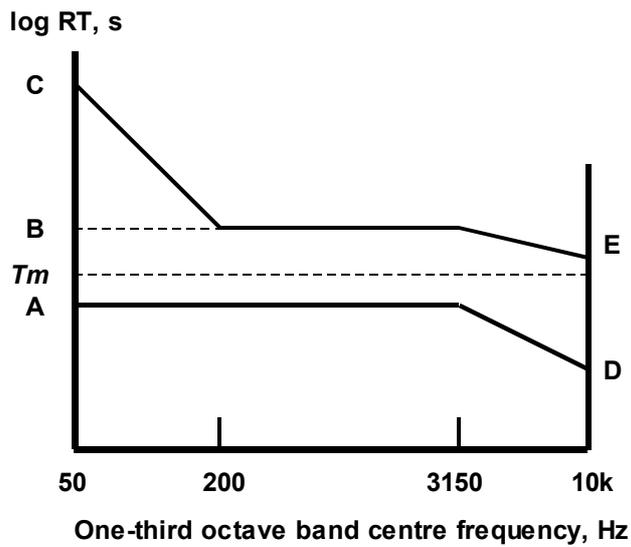
*An approximate guide to the successful application of the above techniques can be obtained from the spread of reverberation times over different measurement positions.*

***Early reflections.***

*If interference (“comb filter”) effects are to be avoided (and these can be especially problematical in the lower frequencies), attention must be paid to the amount of absorption available to attenuate the potential first reflections, especially around loudspeaker positions.*

...”

## Reverberation time specification



The permissible tolerance limits are expressed relative to  $T_m$ , the average of the measured reverberation times for the one-third octave frequency bands 200Hz to 3150 Hz.

Multipliers of  $T_m$  are :-

A =
B =
C =
D =
E =

Fig. 1. Tolerances for reverberation time

Type of area	$T_m, s^{(1)}$	$a^{(2)}$	$b^{(2)}$	$c^{(2)}$	$d^{(2)}$	$e^{(2)}$
<b>Talks studios and their control rooms</b>	0.2	0.8	1.2	2.5	0.6	1.0
<b>Other sound control rooms</b>	0.2	0.8	1.2	1.2	0.6	1.0
<b>Large music studio</b>	1.6	0.9	1.1	1.1	0.8	1.1
<b>Large TV studio</b>	0.8	0.8	1.1	1.2	0.6	1.0

(1) This value is an example only. For typical range of values refer to Fig. 2.

(2) These numbers are multipliers of the average value,  $T_m$ . They are not the reverberation time in seconds.

Table 1. Typical values for reverberation time and tolerances.

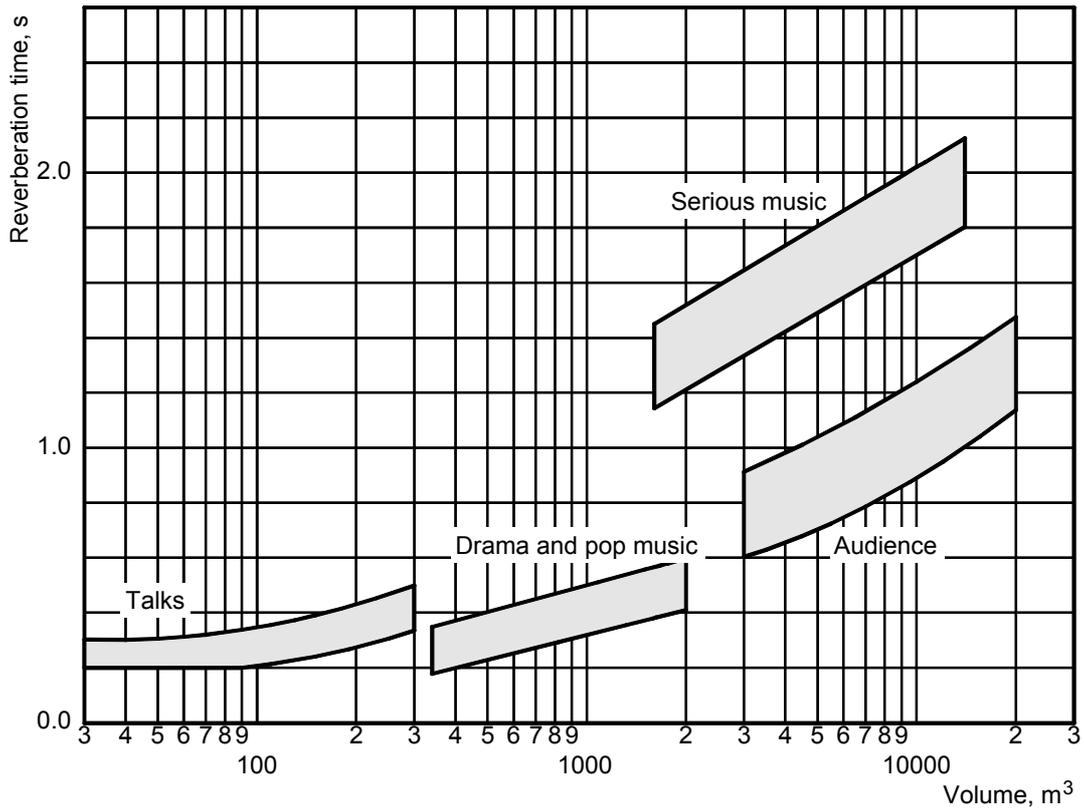


Fig. 2a Typical reverberation time of sound studios

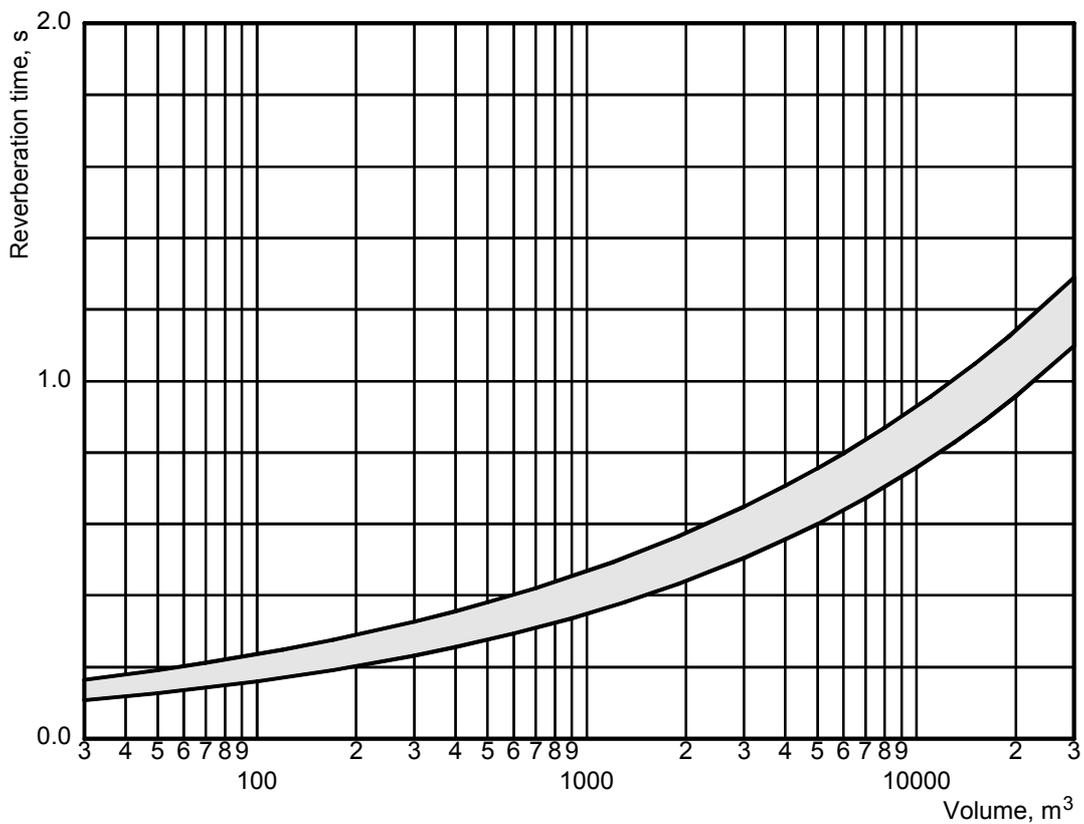


Fig. 2b Typical reverberation time of television studios

(Values represent average reverberation time in the frequency)  
 (range 250-4000 Hz., based on preferred BBC studios)



# ACOUSTICS COMMITTEE NOTE NUMBER 1992/1

## Criteria for background noise levels.

The attached document is a proposed model specification for Background Noise levels.

The need for such a specification has arisen because of the changes in the BBC's approach to building projects. Using external consultants we can no longer expect to control projects by informal discussions.

It is intended that this specification document be issued to or incorporated into the other documents issued to a consultant, either within (ie. BDMS) or outside the BBC, as the expected and contracted acoustic performance.

In each individual case it is for the users to define the detail contents of the specification. This proposal is intended to form the basis of such a specification. It attempts to cover all aspects of the measurement of acoustic noise.

Inevitably, this approach has resulted in the inclusion of some aspects which we have not hitherto considered to any significant extent. It may also have resulted in the inclusion of seemingly quite arbitrary performance details which are, nevertheless, open to serious abuse if not specified at all.

Likewise, there may be parts of the specification which are of no direct interest to the users but which must be included for completeness in the event of legal proceedings for an alleged failure to complete a contract.

We may not assume any specialist knowledge on the part of the consultant that does not fall within his domain.

The format is based on the style of British (and incidentally ISO, etc.) Standards, giving only the briefest background explanation. Such standards should be familiar to consultants. Likewise, all material which is not absolutely necessary should be omitted. The specification is neither a design guide nor a 'statement of case'.

This model does not represent a further increase in the stringency of the noise criteria. It merely

formalises the situation already existing. In any case, the actual specifications in individual cases may be set to be different to those given here. However, it should be noted that there might be consequential effects on other aspects of the design which arise as a result of deviations from these recommended criteria.

## **Acoustics Committee Note No. 1992/1 Criteria for background noise levels.**

### **1. Scope.**

#### **1.1 General.**

This specification describes the criteria, the method of measurement and the tolerances for background noise levels in BBC premises.

#### **1.2 Application.**

The most critical areas are those in which programmes are to be made. Other areas may also require the same criteria because of the critical assessment of programme material which occurs in them.

The least critical areas are those without any direct programme connection, such as offices and other ancillary rooms. The criteria for these are less stringent but are nevertheless applicable.

Although this specification gives the normal criteria values for most circumstances, the actual numerical values to be applied in individual cases may sometimes be specified as being different.

#### **1.3 Tolerances.**

The tolerances which are to be applied to the criteria reflect the different sensitivities of the types of rooms. Programme areas have upper and lower tolerance limits whilst non-programme areas have only upper tolerances.

#### **1.4 Parameters specified.**

This specification covers the following aspects of background noise

- a) The absolute levels of the noise.
- b) The distribution of the noise levels with frequency.
- c) The tolerances to be applied.
- d) The equipment to be used for measurement.

#### **1.5 Test Specification.**

This specification also covers the method of carrying out the measurement of the background noise levels.

## **2. Object and general requirements.**

### **2.1 Object.**

In most rooms there is an inevitable general noise level which is a function of the room's location and the building mechanical services. Most commonly this noise arises as a result of the mechanical ventilation system but it may also arise from airborne or structure-borne interference from sources unconnected with the room. For the purposes of producing or assessing broadcast programmes this noise level must not be excessive.

Even in non-critical rooms, such as offices, there is an upper limit to the level of noise which the occupants can tolerate.

It is less obvious that, at least in critical areas, there is also a minimum level of background noise level which can be tolerated. Because it is not economical to provide very high values of sound insulation between rooms, the background noise level in any room is relied upon to mask any interference which might otherwise be audible.

Thus, for critical areas, there is both an upper and a lower limit to the tolerable background noise level. Ideally, these limits would be the same level but, in practice, they must have sufficient separation to allow for some design and installation margins.

The object of this specification is to ensure that the appropriate criteria and tolerances are interpreted in a consistent manner and that the measurements are carried out in accordance with a unified method.

### **2.2 Requirements.**

Throughout this document the directives "shall" or "must" refer to mandatory specifications. Other directives refer to optional specifications.

## **3. Definitions.**

The definitions of terms used in this specification can be found in the International Electrotechnical Vocabulary (I.E.V.), Chapter 801, Acoustics and Electroacoustics. For convenience, some of the terms are also defined (less formally) here.

### 3.2 Noise.

Any unwanted acoustic energy within a room.

### 3.3 Background noise.

The inevitable acoustic noise within a room that results from sources both external to and within the room, by virtue of its location and associated services.

### 3.4 Sound level.

Common contraction of "sound pressure level". 20 times the logarithm of the rms sound pressure relative to 20 $\mu$ Pa.

### 3.5 Frequency.

The number of cycles per second of the sound. Measured in units of 'Hertz' (Hz)

### 3.6 $L_{eq}$ .

Equivalent level. The steady sound level which would have the same average sound power as a time-varying level.

### 3.7 Mechanical ventilation system.

System for inputting or extracting air by means of a mechanical device.

## 4. General Parameters.

### 4.1 Frequency characteristics.

The general form of a background noise criterion as a function of frequency is as shown in Fig.1. The permitted sound level has high values at low frequencies and lower values at high frequencies. This is generally characteristic of mechanical ventilation systems and of airborne sound interference. It is specified and measured in one-third octave bands for programme areas and octave bands for non-programme areas.

### 4.2 Measurement.

The noise is assessed using some form of sound level measuring device fitted with a filter or set of filters to split the frequency range into one-third octave intervals (programme areas) or octave intervals (non-programme areas). For broadcasting purposes, it is not sufficient to use

some overall measure such as the 'A-weighting' characteristic.

### 4.3 Microphone positions.

The sound level is specified as an average value for the whole of a room. This average value is obtained by repeating the measurement at a number of places in the room and carrying out an averaging process on the resulting numbers.

## 5. Criteria.

### 5.1 Application.

Unless stated to the contrary these criteria shall be taken to be applicable to the noise generated by mechanical ventilation systems alone.

### 5.2 'Programme areas'

The formal criteria and tolerances are limited to the frequency range including the one-third octave band centred on 50 Hz to that centred on 4000 Hz. Outside that frequency range less stringent limits and tolerances are applicable.

Three general background noise criteria are currently defined for rooms in which broadcast programmes are made or are critically assessed. They are shown in Fig. 1 as the curves i, ii and iii and are tabulated in Table 1. They have precisely the same shape as each other and differ only in their level, being spaced by 5dB. In Television, only the studio and the sound and production control areas fall within this category.

Two additional criteria are defined for mobile applications, where the practical difficulties limit the extent to which noise can be controlled. These are, numerically, 10 and 15dB above criterion i respectively.

For areas meeting these criteria, the classifications which have proved successful in the past are -

- iii Criterion for the most demanding areas, for example, Radio Drama studios.
- ii The normal criterion for Radio and Television areas.
- i -Relaxed criterion for any area where a better standard is not warranted.
- $V_s$  Criterion for Radio vehicles and TV vehicle sound control areas .

$V_p$  Criterion for TV vehicle vision production areas.

### 5.3 'Non-programme' areas.

Other areas, in which non-critical activities take place, will usually be specified to either the NR35 (Private Office) or the NR45 (General Office) criteria shown in Fig. 2 and also in Table 2. These include such places as apparatus rooms and canteens/kitchens where there may be a statutory or H.& S.W. requirement to control the noise levels. For Television control areas, all except Sound and Production control fall within this category.

The specifications for such areas are in general accordance with the CIBSE Guide A1 extract.

### 5.4 Noise from other than mechanical ventilation systems.

All noise from other sources that are normally present within a building shall be reduced by sound insulating partitions, building layout, vibration breaks or other noise and vibration control means so that the highest level recorded at any frequency in the controlled room in the absence of the ventilation noise is less than the value of the specified criterion at that frequency.

This Section (5.4) shall not be taken to refer to abnormal noise such as building modifications in the vicinity of the controlled room even if such noises occur frequently.

## 6. Measurement.

### 6.1 Instrumentation.

The measurements of the noise levels shall be carried out using a sound level meter conforming to BS 5969:1981 (IEC 651:1979), Type 1 fitted with appropriate filters conforming to BS 2475:1968 (IEC 225:1966) or the equivalent instrumentation.

The time-weighting response must be set to S (slow) or the equivalent.

Alternatively, a measurement of the  $L_{eq}$  over a 1 second period with instrumentation of equivalent accuracy will be considered to be effectively identical, provided that there are no substantial

variations in the noise level during the 1 second integration period (see Section 7).

### 6.2 Method.

The measurement of the average noise level in a room shall be carried out in general accord with the methods of BS 4142 (ISO R1996), the essential principles of which are repeated here for convenience.

To obtain the average value for the level of the noise within a room measurements of the sound level in each frequency band shall be taken at several different microphone positions and the average value (see Section 6.3) of the results obtained for each frequency band. The number of these microphone positions shall be not fewer than five in rooms of less than 400 m<sup>3</sup> and at least ten in larger rooms. None of these positions shall be within 1 m of a wall, floor or ceiling surface. They should be distributed reasonably evenly throughout the volume of the room and should not be closer together than 2 m. In very small rooms, that is of less than 50 m<sup>3</sup>, these requirements will not be realistic. In such circumstances, it will be necessary to use closer spacing of the microphone positions and/or fewer than five different positions.

To enable the subsequent identification of excessively noisy locations, values recorded at all microphone position and in every frequency band shall be noted separately (see Sections 6.4 and 7.1).

Note should also be made of any intermittent noises or interference from sources other than the room ventilation system. If these noises are measurable in the presence of the noise from the ventilation system then a separate measurement and record of such noises must be made. This requirement does not apply to those abnormal noises exempted in Section 5.4.

At the beginning of the measurement session, at intervals of not more than 30 minutes thereafter and again at the end of the measurement the accuracy of the measurement system shall be checked using an appropriate acoustic calibrator accurate to  $\pm 0.5$ dB.

### 6.3 Processing of results.

For each frequency band the values obtained at each microphone position must be averaged to obtain the overall value for the room. If all of the sample values lie within a total range of 10 dB then the average can, with negligible error, be the simple arithmetic sum of the individual sample values divided by the number of samples.

If a 10 dB range does not contain all of the sample values then the more accurate logarithmic average is necessary. This is a true average of the noise energy in the room (see Appendix A).

The averaging process is repeated for all of the measured frequency bands.

### 6.4 Presentation of results.

The results for the average noise level in the room should be presented in a graphical form as the sound level against frequency band. The recommendations of BS 6397:1983 (ISO 263(1975)) may be followed, see for example BS 4196:Part 0:1981 (ISO 3740-1980), but any reasonable presentation will be acceptable. The presentation must include the design criterion. It must also include the results obtained at any excessively noisy microphone position, as defined in Section 7.1.

The presentation may also include any additional measurements made of noises other than that from the ventilation system. Alternatively, these additional results may be presented on a separate sheet which must repeat the design criterion.

All presentations must include full details of the measurement - the definition of the room (that is, both the name by which it is known and that of the building), the date and approximate time of the measurement, the equipment used for the measurement, the number of microphone positions and the identification of the noise sources.

## 7. Tolerances.

### 7.1 'Programme areas'

The permitted tolerances for areas in which programme making or critical assessment of sound quality are carried out (these include all areas covered by criteria i, ii and iii, by criteria

derived relative to them or other critical area criteria as specified) are as follows:

**Overall.** The average of the measured sound pressure levels in every frequency band shall fall within a range which is +0 to -10 dB relative to the specified criterion.

**Position.** No individual microphone position within the limits specified in Section 6.2 shall give a measured sound level at any frequency more than 5 dB above the average value for the whole room at that frequency .

**Variation.** There shall be no perceptible variation of the noise level over short time periods. This requirement shall be deemed to be satisfied if there is a maximum variation in noise level of less than 5 dB for all normal operating conditions.

**Uniformity.** In the average results there shall be no one-third octave band value which exceeds the average of the two adjacent band values by more than 5 dB.

Although the formal criteria are limited in scope to the frequency range 50 Hz to 4000 Hz, there are mandatory limits for the permissible levels outside that range:

**Low frequencies.** For the one-third octave bands of 40 Hz and below the average noise level in each band should not exceed a level that increases at a rate of 4 dB per band from the specified criterion value at 50 Hz.

**High frequencies.** The average noise level in each one-third octave frequency band should not exceed that specified by the criterion at 4000 Hz for criteria i and ii and 2000 Hz for criterion iii.

### 7.2 'Non-programme areas'

The non-critical areas have no lower limit to the permissible noise levels. The tolerances for these areas are simply that in every frequency band the average sound pressure level shall not exceed the specified criterion.

**TABLE 1: BBC CRITERION VALUES\*  
(in one third octave bands)**

Hz	iii	ii	i	V <sub>s</sub>	V <sub>p</sub>
50	35.2	40.2	45.2	55.2	60.2
63	31.0	36.0	41.0	51.0	56.0
80	27.4	32.4	37.4	47.4	52.4
100	24.1	29.1	34.1	44.1	49.1
125	21.2	26.2	31.2	41.2	46.2
160	18.6	23.6	28.6	38.6	43.6
200	16.1	21.1	26.1	36.1	41.1
250	13.9	18.9	23.9	33.9	38.9
315	11.8	16.8	21.8	31.8	36.8
400	9.9	14.9	19.9	29.9	34.9
500	8.1	13.1	18.1	28.1	33.1
630	6.3	11.3	16.3	26.1	31.1
800	4.7	9.7	14.7	24.7	29.7
1000	3.2	8.2	13.2	23.2	28.2
1250	1.8	6.8	11.8	21.8	26.8
1600	0.4	5.4	10.4	20.4	25.4
2000	-0.9	4.1	9.1	19.1	24.1
2500		2.8	7.8	17.8	22.8
3150		1.6	6.6	16.6	21.6
4000		0.5	5.5	15.5	20.5

**TABLE 2: ISO NR VALUES\*  
(in octave bands)**

Hz		NR35	NR45
31		79.2	86.0
63		63.1	71.0
125		52.4	61.1
250		44.5	53.6
500		38.9	48.6
1000		35.0	45.0
2000		32.0	42.2
4000		29.8	40.0
8000		28.0	38.3

\*NOTE. These values are given to 1 decimal place of accuracy mainly to present a relatively smooth curve when produced electronically. It is neither meaningful nor necessary to use such accuracy for calculations or presentation of the measured results.

## APPENDICES.

### A: ENERGY AVERAGING

The average sound energy in the room is obtained from the individual microphone position

results by averaging the absolute sound energy represented by each result.

If the  $n$ th microphone position from a total of  $N$  has produced a noise level in a particular frequency band of  $L_n$  dB then the average for the room,  $L_r$ , is obtained from:

$$L_r = 10 \log_{10} \frac{1}{N} \sum_{n=1}^N 10^{L_n/10}$$

### B: Numerical values of the criteria.

Computerised methods of report preparation may make it desirable to have the criteria available as algebraic expressions rather than as tables of values. This may make it easier to use non-standard values and, with the availability of higher resolution output devices, also permits smoother reproduction.

The BBC criteria were originally specified in the form of a graph which was hand-drawn and which conforms with no reasonable algebraic expression. However, the following has been found to produce a close fit to criterion i and, by definition, will become the basis of the values in future.

$$c = 188254/b^3 - 26910/b^2 + 2540/b - 47.34$$

where  $c$  is the required criterion value and  $b$  is the ISO standard band number ( $= 10 \log f$ ).

The ISO NR criteria are defined by international agreement in the form of a table of values and are not available as an algebraic expression. However, the following has been found to produce a close fit — to within 0.1dB at most levels and frequency bands.

$$c = (4346.7N - 331858)/b^3 - (676.5N - 56499)/b^2 + (24.328N - 1411.1)/b + 0.7796N - 3.422.$$

where  $b$  is the ISO standard band number and  $N$  is number of the Noise Rating curve.

RW. 3rd November, 1992, Rev. 3

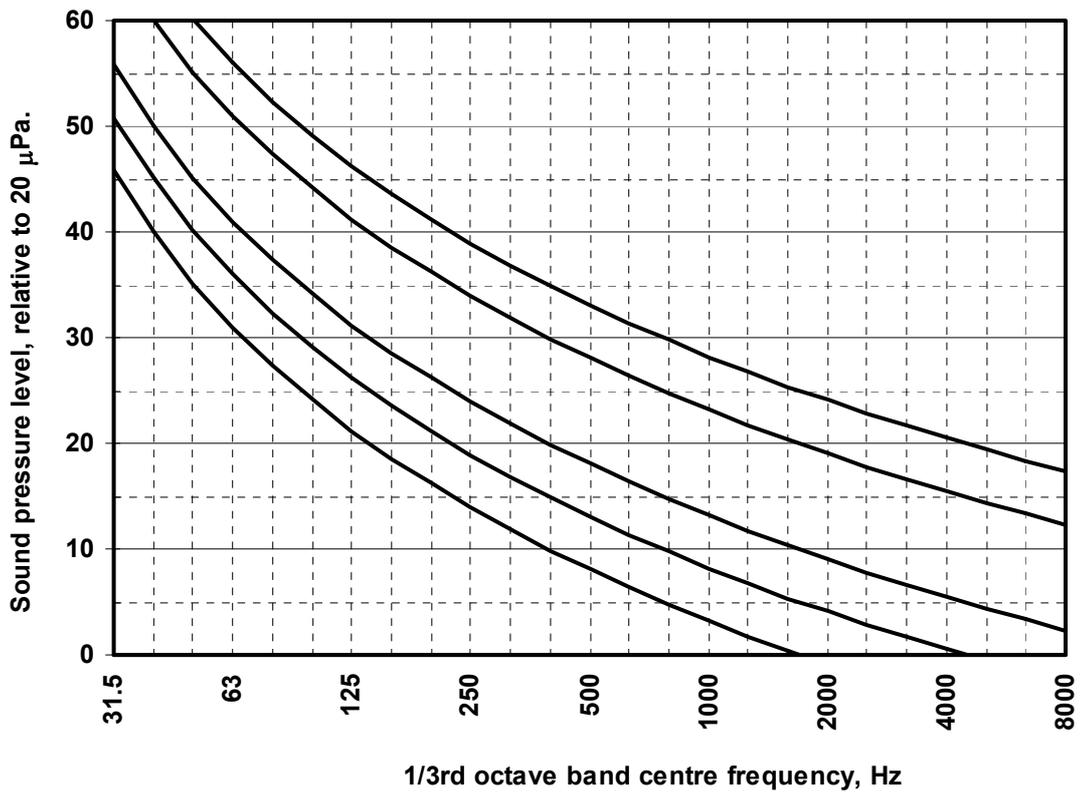


Fig. 1 One third octave band background noise criteria for programme areas.

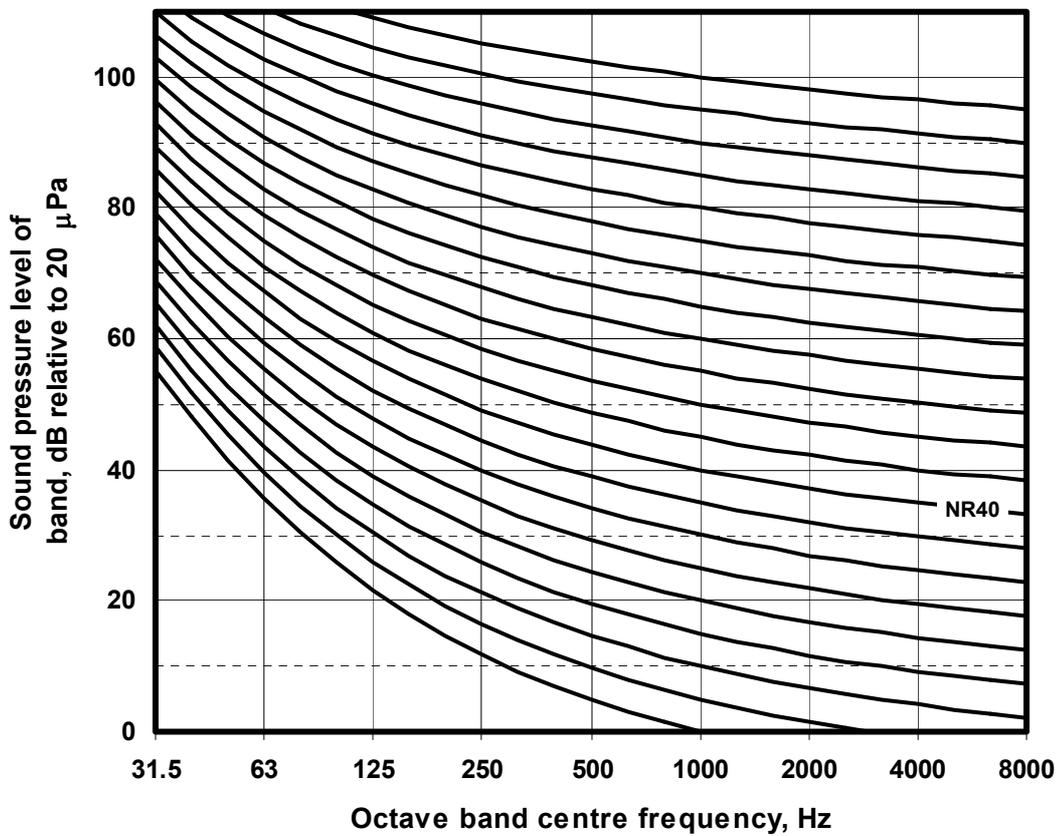


Fig. 2 Noise Rating curves for non-programme areas.  
(The NRXX curve passes through the value XX at 1000 Hz, as indicated by 'NR40').



## **Acoustics Committee Note number 1988/1 Criteria for airborne sound insulation.**

The attached document is a proposed model specification for airborne sound insulation.

The need for such a specification has arisen because of the changes in the BBC's approach to building projects. Using external consultants we can no longer expect to control projects by informal discussions.

It is intended that this specification document be issued to or incorporated into the other documents issued to a consultant, either within (eg. ACED) or outside the BBC, as the expected and contracted performance of the subject of the contract.

In each individual case it is for the users, that is Radio, Television, External Services, News and Current Affairs or the Regions, to define the detail contents of the specification. This proposal is intended to form the basis of such a specification. It attempts to cover all aspects of the field measurement of airborne sound insulation. For reasons of technical difficulties, it does not attempt to cover the problem of impact noise. Impact noise is covered by the companion specification "CRITERIA FOR BACKGROUND NOISE LEVELS" (Acoustics Committee Note 1992/1).

Inevitably, this approach has resulted in the inclusion of some aspects which we have not hitherto considered to any significant extent. It may also have resulted in the inclusion of seemingly quite arbitrary performance details which are, nevertheless, open to serious abuse if not specified at all.

Likewise, there may be parts of the specification which are of no direct interest to the users but which must be included for completeness in the event of legal proceedings for an alleged failure to complete a contract.

We may not assume any specialist knowledge on the part of the consultant that does not fall within his domain.

The format is based on the style of British (and incidentally ISO, etc.) Standards, giving only the briefest background explanation. Such standards should be familiar to consultants. Likewise, all material which is not absolutely necessary has been omitted. The specification is neither a design guide nor a 'statement of case'.

This model does not represent a further increase in the stringency of the insulation criteria. It merely formalises the situation already existing. In any case, the actual specifications in individual cases may be set to be different to those given here. However, it should be noted that there might be consequential effects on other aspects of the design that arise as a result of deviations from these recommended criteria.

## **CRITERIA FOR AIRBORNE SOUND INSULATION.**

### **1 Scope.**

#### **1.1 General.**

This specification describes the criteria, the method of measurement and the tolerances for airborne sound insulation in BBC premises.

#### **1.2 Application.**

The most critical areas are those in which programmes are to be made. Other areas may also require the same criteria because of the critical assessment of programme material which occurs in them.

The least critical areas are those without any direct programme connection, such as offices and other ancillary rooms. The criteria for these are less stringent but are nevertheless applicable.

Although this specification gives the normal criteria values for some circumstances, the actual numerical values to be applied in individual cases will be specified individually.

#### **1.3 Tolerances.**

The tolerances which are to be applied to the criteria reflect the different sensitivities of the types of rooms. Programme areas have more stringent tolerance limits than non-programme areas.

#### **1.4 Parameters specified.**

This specification covers the following aspects of airborne sound insulation

- a) The absolute values of the insulation criteria
- b) The distribution of the insulation values with frequency.
- c) The tolerances to be applied.
- d) The equipment to be used for measurement.

#### **1.5 Test Specification.**

This specification also covers the method of carrying out the measurement of the sound insulation in practical situations.

## **2 Object and general requirements.**

### **2.1 Object.**

The sound insulation between any two separated areas is a function of their locations and the building structure between them. Most commonly the areas will be rooms used for different purposes but, sometimes, one may be an open space - for example, the building exterior. For the purposes of producing or assessing broadcast programmes, the interference caused in one area by sound from another must not be excessive.

Even in non-critical rooms, such as offices, there is an upper limit to the level of interference which the occupants can tolerate.

In general, there will be a minimum sound insulation requirement in both directions between two areas but one of these directions will be more stringent than the other and will, therefore, set the specification. In other cases, there will be a requirement in only one direction.

For financial reasons, the insulation values specified are not usually sufficient to reduce interfering noise to below the threshold of human hearing. Background noise level in the receiving room (normally from the mechanical ventilation system) is relied upon to mask interference which would otherwise be audible. If this background noise is not present as specified, or is too low in level, audible interference may be unacceptable even though the sound insulation meets its specification.

Ideally, the sound insulation specification would be met exactly but, in practice, there must be sufficient tolerance to allow for some design and construction margins. There is no acoustic penalty in exceeding the sound insulation requirement. Therefore the tolerances are lower limits only.

The object of this specification is to ensure that the appropriate criteria and tolerances are interpreted in a consistent manner and that the measurements are carried out in accordance with a unified method.

### **2.2 Requirements.**

Throughout this document the directives "shall" or "must" refer to mandatory specifications. Other directives refer to optional specifications.

### 3 Definitions.

The definitions of terms used in this specification can be found in the International Electrotechnical Vocabulary (I.E.V.), Chapter 801, Acoustics and Electroacoustics. For convenience, some of the terms are also defined (less formally) here.

#### 3.1 Sound insulation.

The reduction in the amplitude of a sound as a consequence of an acoustic barrier or of distance. For all field specifications and measurements to which this specification relates the sound insulation is measured as a Sound Level Difference.

#### 3.2 Noise (acoustic).

Any unwanted acoustic energy within a room.

#### 3.3 Noise (electrical).

A random or near-random electrical variation.

#### 3.4 Background noise.

The inevitable acoustic noise within a room which results from sources both external to and within the room, by virtue of its location and associated services.

#### 3.5 Sound level.

Common contraction of "sound pressure level". 20 times the logarithm of the rms sound pressure relative to 20  $\mu$ Pa.

#### 3.6 Frequency.

The number of cycles per second of a sound. Measured in units of 'Hertz' (Hz)

#### 3.7 $L_{eq}$ .

Equivalent level. The steady sound level which would have the same average sound power as a time-varying level.

#### 3.8 Sound Level Difference.

The numerical difference between the sound pressure levels on two sides of a partition.

#### 3.9 Warble-tone.

A test signal consisting of a sinusoidal waveform of variable frequency which also has superimposed slow, narrow-band frequency modulation. Typical values for the modulation are a frequency of 10 Hz and a peak deviation of +10%.

### 4 General Parameters.

#### 4.1 Frequency characteristics.

The general forms of sound insulation criterion as a function of frequency are as shown in Fig. 1. They have low values at low frequencies and higher values at high frequencies, up to some frequency beyond which no further increase is required. This is generally characteristic of building partitions. They are specified graphically and must be measured in  $1/3$  octave frequency bands.

#### 4.2 Measurement.

The sound insulation between two areas is assessed using some form of acoustic excitation in one of the two areas (the source area) and sound level measuring device(s) in both areas (the source and the receive areas), either simultaneously or sequentially, to assess the resulting sound levels. The measuring device(s) must be fitted with a filter or set of filters to split the frequency range into one-third octave intervals. It is not sufficient for broadcasting purposes to use some overall measure such as the 'A-weighting' characteristic.

#### 4.3 Microphone positions.

The sound level difference is, by default, specified as the difference between two average values for sound level taken throughout the whole volumes of the two rooms. Each average value is obtained by repeating the sound level measurement at a number of places in the room and carrying out an averaging process, as defined in Section 6.3, on the resulting numbers. In some cases, usually in very large rooms or where there is otherwise a specific requirement, the areas to which the criterion relates will be specified.

## 5 Criteria.

Unless otherwise stated these criteria shall be taken to be applicable to the overall level difference between two rooms, not to any part or parts of the transmission path individually. Also unless otherwise stated, they shall be taken to be applicable when all doors and windows on any significant path for airborne sound between the two areas are closed.

The formal criteria and tolerances are limited to the frequency range including the one-third octave band centred on 63 Hz to that centred on 10000 Hz.

A large number of sound insulation criteria (~400) are currently defined for pairs of areas of all types. As examples, Figure 1 shows the normal criteria for the partition between

- a two Radio talks studios
- b two large Television studios
- c a Radio drama studio and a private office
- d a canteen and a Television sound control room.

## 6 Measurement.

### 6.1 Instrumentation.

The measurements of the noise levels shall be carried out using a sound level meter conforming to BS 5969:1981 (IEC 651:1979), Type 1 fitted with 1/3 octave filters conforming to BS 2475:1968 (IEC 225:1966) or the equivalent instrumentation.

The time-weighting response must be set to S (slow) or the equivalent.

Alternatively, a measurement of the  $L_{eq}$  over a 1 second period with instrumentation of equivalent accuracy will be considered to be effectively identical, provided that there are no substantial variations in the noise level during the 1 second integration period (see Section 7).

### 6.2 Method.

The measurement of the average sound level difference between two areas shall be carried out in general accord with the methods of BS 2750:Part 4:1980 (ISO 140/IV-1978) and BS 2750:Part 5:1980 (ISO 140/V-1978), the

essential principles of which are repeated here for convenience. However, no corrections shall be applied to the results for the area of the partition or the sizes or the reverberation time of either of the rooms.

#### 6.2.1 Generation of source sound field.

The sound may be generated in the source area by any convenient means which produces a spectrum adequate to cover the required frequency range but a loudspeaker is most commonly used. The test signal may be wideband noise or switched, filtered noise or gliding warble-tone.

The loudspeaker should be placed to give a sound field which is as diffuse as possible and so that the direct field is not dominant at the position of the partition.

#### 6.2.2 Measurement of the average sound fields.

To obtain the average value in each area measurements of the sound level in each frequency band shall be taken at several different microphone positions and the average value (see Section 6.3) of the results obtained for each frequency band. The number of these microphone positions shall be not fewer than five in rooms of less than 400 m<sup>3</sup> and at least ten in larger rooms. None of these positions shall be within 1 m of a wall, floor or ceiling surface. They should be distributed reasonably evenly throughout the volume of the room and should not be closer together than 2 m.

In very small rooms, that is of less than 50 m<sup>3</sup>, these requirements will not be realistic. In such circumstances, it will be necessary to use closer spacing of the microphone positions and/or fewer than five different positions.

In very large rooms or if otherwise specified, specific restrictions may be applied as part of the contract to the range of microphone positions.

In the receive area if the sound generated by the test method in any frequency band does not exceed by 6 decibels the noise from other sources in that band then the measurement shall be regarded as invalid. The sound level in the source area must be increased until a valid measurement is obtained or until it is shown that the minimum value of sound insulation indicated exceeds the relevant criterion.

At the beginning of the measurement session, at intervals of not more than 30 minutes thereafter and again at the end of the measurement the accuracy of the measurement system(s) shall be checked using an appropriate acoustic calibrator accurate to +0.5 dB.

### 6.3 Processing of results.

For each area and each frequency band the values obtained at each microphone position must be averaged to obtain the overall value for the area and for that frequency band. If all of the sample values to be averaged lie within a total range of 10 dB then the average can, with negligible error, be the simple arithmetic sum of the individual sample values divided by the number of samples.

If a 10 dB range does not contain all of the sample values then the more accurate logarithmic average is necessary. This is a true average of the noise energy in the area (see Appendix A).

The averaging process is repeated for all of the measured frequency bands for each area.

For each frequency band the average value of the sound level for the receive area is subtracted from that for the source area to obtain the sound level difference.

### 6.4 Presentation of results.

The results for the sound insulation should be presented in a graphical form as the sound level difference against frequency band. The recommendations of BS 6397:1983 (ISO 263(1975)) may be followed, see for example BS 4196:Part 0:1981 (ISO 3740-1980), but any reasonable presentation will be acceptable. The presentation must include the design criterion.

Any frequency bands in which, for reasons of excessive background noise, the measurement could not be made or was limited to a estimate of the minimum sound insulation only must be clearly indicated as such in the presentation of the results.

All presentations must include full details of the measurement - the definitions of the areas (that is, both the names by which they are known and that of the building), the date and approximate time of the measurement, the equipment used for the measurement, the number of microphone

positions and the type of the source area excitation. A dimensioned sketch of the location must also be included, indicating the sizes of the two areas, the dimensions and the construction (so far as it is known) of the partition.

## 7 Tolerances.

### 7.1 'Programme areas'

There is no acoustic penalty in values of sound insulation that exceed the criterion. Accordingly, all tolerances are specified in terms of adverse deviation, which is defined as the criterion minus the achieved sound insulation. It is set equal to zero if it would otherwise be negative.

In setting these tolerances it is recognised that there are difficulties in the design of partitions and the measurement of sound insulation at low frequencies. Accordingly, the tolerances have been divided into two frequency bands.

The permitted tolerances for areas in which programme making or critical assessment of sound quality are carried out (these include all areas covered by background noise criteria (i),(ii) and (iii), by criteria derived relative to them or other critical area criteria as specified) are as follows:

**Low frequencies.** In the frequency range 63 Hz to 200 Hz the average of the adverse differences shall be less than 6 dB and no individual adverse difference shall exceed 10 dB.

**High frequencies.** In the frequency range 250 Hz to 10000 Hz the average of the adverse differences shall be less than 2 dB and no individual adverse difference shall exceed 5 dB.

### 7.2 'Non-programme areas'

Non-critical areas have larger tolerances for sound insulation. However, this relaxation applies only if both of the areas fall outside the definition of critical area. In these cases the tolerance is that no adverse difference shall be greater than 10 dB.

## APPENDIX A: ENERGY AVERAGING

The average sound energy in the room is obtained from the results for the individual microphone positions by averaging the absolute sound energy represented by each result.

If the  $n$ th microphone position from a total of  $N$  has produced a noise level in a particular frequency band of  $L_n$  dB then the average for the room,  $L_r$ , is obtained from:

$$L_r = 10 \log_{10} \frac{1}{N} \sum_{n=1}^N 10^{L_n/10}$$

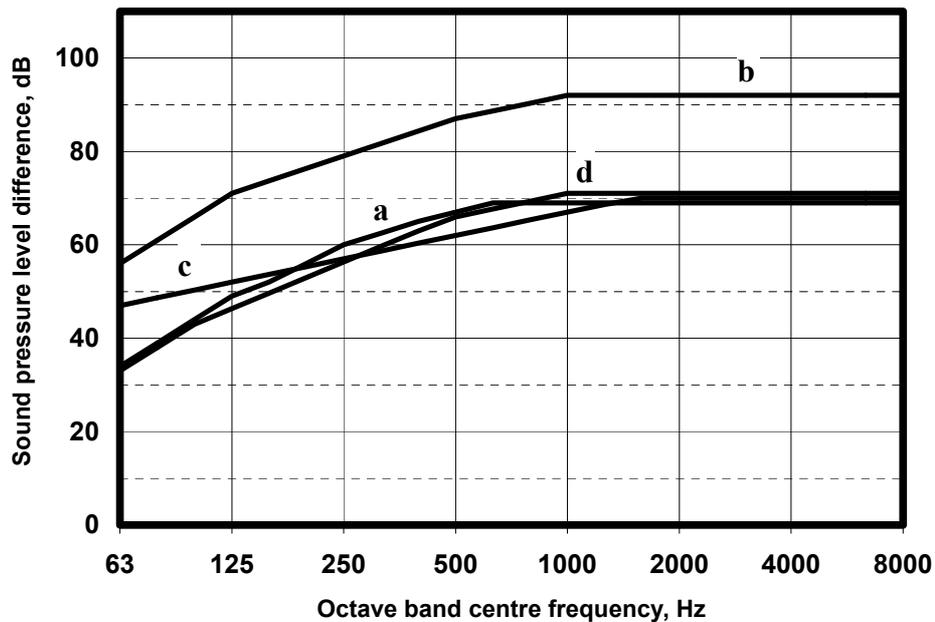


Fig. 1. Examples of sound insulation criteria

- a between two Radio talks studios
- b between two large general-purpose TV studios
- c between a Radio drama studio and a private office
- d between a Television sound control room and a canteen/kitchen

## Acoustics Committee Note No. 1990/3

### Guidelines for installation engineers - acoustic noise from technical equipment.

#### 1. Introduction

As technical equipment has become increasingly complex during recent years, component packing densities have also increased in order to contain individual items of equipment within modest overall dimensions. This has resulted in greater heat dissipation from equipment of a given physical size, coupled with difficulty in removing the heat by natural convection, even when aided by room ventilation or air conditioning. Some manufacturers have overcome the immediate problem by incorporating one or more cooling fans within the units, but this in turn gives rise to another problem - acoustic noise from the fans. In some technical areas, noise from cooling fans has reached a level that is intolerable to the staff working there, even where critical sound monitoring is not involved.

Transformers can be another source of intolerable noise - occasional examples contributing to background noise levels by humming excessively. A transformer identified as being noisier than normal should be replaced with a similar unit - perhaps even from the same batch - which generates less humming noise. Once installed, rogue transformers can get progressively noisier with time. Again, the remedy is to replace the noisy unit with one which is noticeably quieter.

The point has now been reached where positive steps need to be taken either to encourage manufacturers to minimise the noise generated by their equipment or to overcome the effect by removing the offending equipment from operational areas and occupied apparatus rooms. In practice, it is likely that both courses of action will have to be pursued.

Project leaders should be aware that some types of seemingly quiet office equipment can generate noise events whose levels are well above the noise criterion specified for the room in which they are to be installed. Examples of such equipment include: Facsimile machines, laser printers, photocopiers, disc drives and personal

computers. It is recommended that such devices are not installed in any areas where the BBC Noise Criteria apply (see Figure 1).

#### 2. Guidelines for installation

Installers or purchasers of specialised equipment may find themselves forced to accept equipment that does not meet noise criteria, for instance where other considerations of performance and price are overwhelming or where no alternative exists. Before making a commitment to the equipment the installer or potential purchaser should refer back to the BBC project leader who may be able to grant a relaxation of the acoustic noise requirement.

If replacement equipment is noisy, consideration should be given to the location of such equipment away from noise sensitive areas. For example, the equipment bays associated with a sound control desk have in the past been sited in the same room as the desk. The background noise criterion for a BBC television sound control room or radio studio cubicle would usually be specified as Criterion (ii) (Figure 1), which allows little scope for equipment noise. With the introduction of computer assisted desks, it has thus been found necessary to provide a separate room or acoustically isolated enclosure for the computer equipment.

Provision of separate rooms or enclosures for noisy equipment needs to be anticipated at the early stages of a project and is clearly easier to achieve in a new building than when re-equipping existing areas. Additional costs for building work, ventilation and electrical installation are likely to be incurred, so due allowance must be made in the estimate.

It may be necessary to divide the equipment normally installed in, say, the occupied vision apparatus room associated with a television studio into two groups, with the noisy items placed in a separate unoccupied area. This may be less convenient to both installers and users and of

course would not be necessary if the problem of acoustic noise could be eliminated by the manufacturers. For such occupied apparatus rooms it is recommended that the noise level from all sources should be less than NR 45 to prevent fatigue being experienced by staff (see Figure 2).

Because of the additive effect of several noise sources, individual items of equipment should not be installed in occupied apparatus rooms if the noise generated by each exceeds a level of 5 dB below NR 45 - ie NR 40.

Similarly, for equipment due to be installed in more critical areas, the noise from individual items should not exceed a level of 5 dB below the relevant BBC Noise Criterion.

### **3. Equipment purchased from manufacturers**

In order to contain the problem at source, manufacturers must be discouraged from producing equipment which generates excessive acoustic noise.

When equipment is ordered against a BBC specification, the specification should include a clause relevant to the background noise criterion for the room in which the equipment is to be installed. The noise from the equipment should not exceed a level of 5dB below that criterion as explained above.

Equipment manufacturers and installers are advised to seek expert assistance when attempting accurate measurements of equipment generated noise, but may find it useful to make for themselves a simple noise test to serve as a preliminary assessment of likely problems. The following procedure is offered.

#### **Requirements:**

1. A sound level meter to BS5969 or IEC 651 will be required.
2. A quiet environment must be found and measured - a quiet office or conference room may suffice. Using the sound level meter set to 'A' weighted and 'slow' response the background level must be no higher than 40dB(A) when measurements are to be made for occupied apparatus room equipment. For studios and monitoring rooms, a background

of 10dB(A) or less is required - typically to be found only in specialist acoustic environments such as those areas in which the equipment is due to be installed.

#### **Method:**

1. Place the equipment to be measured in the middle of the room, raised from the floor. It should be powered and made to operated in its noisiest mode. Listen carefully to the character of the noise - any noise component with a distinct pitch or a cyclical character is likely to prove unacceptable, as is any impact or percussive noise.
2. Using the sound level meter set as before, take measurements at a distance of 1m from the equipment at 6 points:- all four compass points, plus above and below, if possible. The highest of these should be taken as the indicator of noise level.

#### **Interpretation**

Equipment giving indications above 40dB(A) is likely to prove unacceptable in occupied apparatus rooms unless additional shielding is to be provided. If the equipment is to be the sole equipment in the room, then 45dB(A) may be acceptable.

It may be more difficult to achieve satisfactory results with standard commercial equipment, especially where large volume sales are being made to other customers who may be less concerned with the problem of acoustic noise. Nevertheless, the manufacturers should be pressed to reduce noise levels where possible. This may be achieved by use of quieter or fewer cooling fans, or possibly reducing the supply voltage to those fitted in the equipment. It is important that the suppliers are made aware of our concern now so that at least they may make due allowance in future designs.

### **4. Previous documentation**

This document supersedes the previous Acoustics Committee Note 1983/2.

LG/RW/RMC JUNE 1990

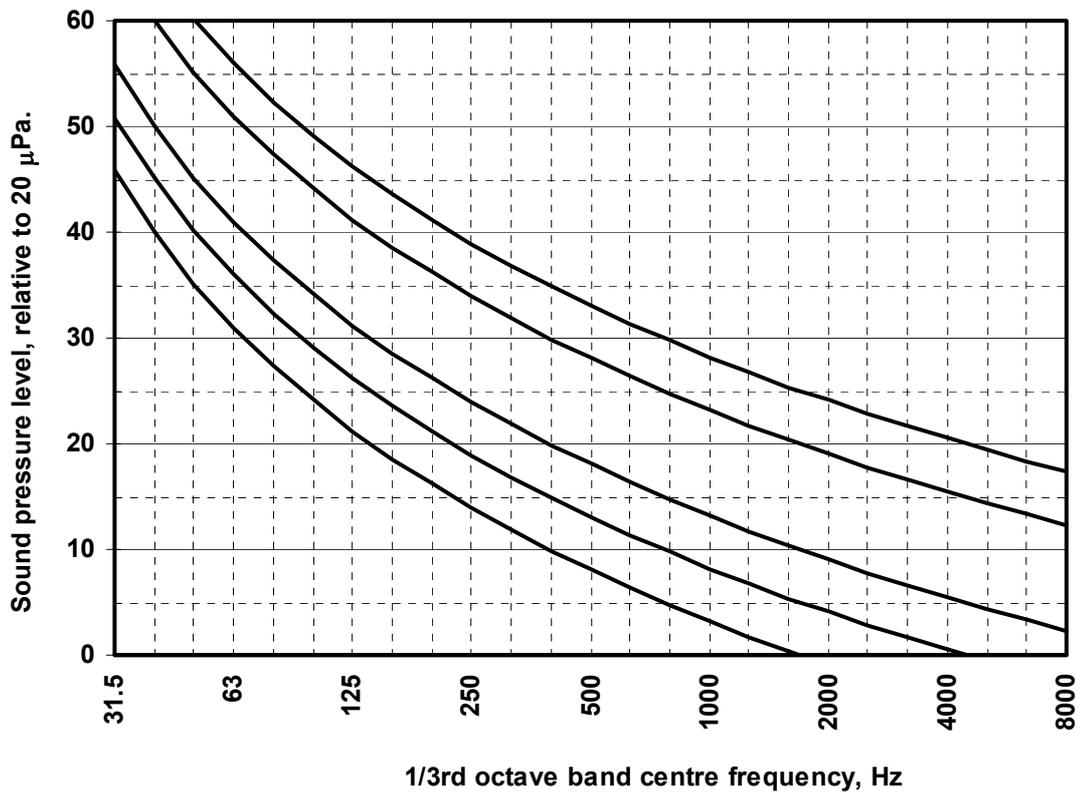


Figure 1. BBC Noise Criteria for maximum tolerable noise background noise in studios from ventilation systems. One-third octave analysis.

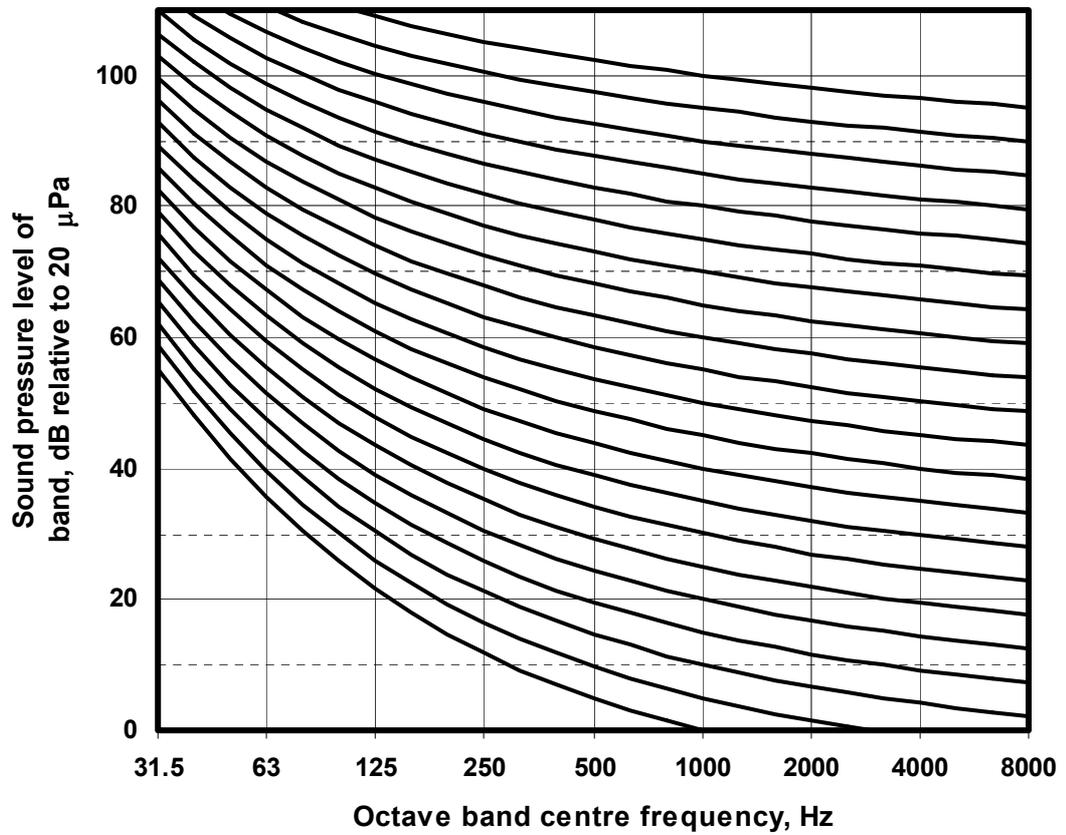


Figure 2. Noise Rating curves - octave analysis.



## Acoustics Committee Note No. 1990/4

### Guidelines for equipment manufacturers - acoustic noise from technical equipment.

Specifications for broadcast studios and technical areas normally include a criterion for the maximum permissible background noise level. Traditionally, these criteria have been directed towards the designers and manufacturers of ventilation plant in order that the noise from such plant should be kept down to an acceptable level. It is, however, important to recognise that the criteria relate to noise from all sources and this includes the technical equipment installed within the areas concerned.

#### Tolerable noise levels in occupied rooms.

Ideally, any noisy item should be sited in a separate apparatus room, or placed in an acoustically designed enclosure. Where this is not possible the level of equipment noise which can be tolerated depends on the background noise criterion for the room in which the equipment is to be installed. Because of the additive effect of several noise sources, the noise from individual items of equipment should not exceed a level of 5dB below the relevant criterion. See figures 1 and 2 for noise criteria curves and examples of their use.

#### Assessment of technical equipment noise.

Equipment manufacturers and installers are advised to seek expert assistance when attempting accurate measurements of equipment generated noise, but may find it useful to make for themselves a simple noise test to serve as a preliminary assessment of likely problems.

The following procedure is offered:

1. A sound level meter to BS5969 or IEC 651 will be required.
2. A quiet environment must be found and measured - a quiet office or conference room may suffice. Using the sound level meter set

to 'A' weighted and 'slow' response the background level must be no higher than 40dB(A) when measurements are to be made for occupied apparatus room equipment. For studios and monitoring rooms, a background of 10 dB(A) or less is required - typically to be found only in specialist acoustic environments such as those areas in which the equipment is due to be installed.

Method.

1. Place the equipment to be measured in the middle of the room, raised from the floor. It should be powered and made to operate in its noisiest mode. Listen carefully to the character of the noise - any noise component with a distinct pitch or a cyclical character is likely to prove unacceptable, as is any impact or percussive noise.
2. Using the sound level meter set as before, take measurements at a distance of 1m from the equipment at 6 points:- all four compass points, plus above and below if possible. The highest of these should be taken as the indicator of noise level.
3. Interpretation.

Equipment giving indications above 40 dB(A) is likely to prove unacceptable in occupied apparatus rooms unless additional shielding is to be provided. If the equipment is to be the sole equipment in the room, then 45 dB(A) may be acceptable.

For use in studios and monitoring environments, virtually any observable noise will prove to be unacceptable. Measurements will be difficult at these low levels, but anything above 10 dB(A) should be regarded as potentially unacceptable.

## **Designing for quiet.**

Cooling fans are common sources of excessive acoustic noise in equipment which is destined for noise sensitive areas. Different approaches to solving the problem of heat dissipation could significantly affect the amount of noise produced. For instance, vertically mounted component boards are easier to cool by natural convection than horizontally mounted boards. In addition, large slow moving fans are significantly quieter than small fast fans. It is to be hoped that, by prior knowledge of the BBC's acoustic noise specifications, manufacturers of technical equipment will be encouraged to reduce fan noise or even eliminate fans from their equipment designs.

## **Previous documentation**

This document supersedes the previous Acoustics Committee Note 1983/3.

(Note - the original document included the same noise criteria curves as given above. They are not repeated.)

# Acoustics Committee Note No. 1990/2

## Timing of acoustic tests.

### Introduction

In the BBC it is normal practice to carry out acoustic tests to ensure that specified acoustic standards have been achieved. The point of contact for these tests is Acoustic Architect, ACED - or other relevant person (now the project manager) - and the tests should be carried out at the following stages of a project design and construction:

### 1. Prior to any project commencement

This falls into 2 categories.

- (i) Where a project includes a completely new studio complex, a full airborne and vibration survey should be carried out to ascertain the extent of airborne noise and vibration levels on the new site. These provide essential design data which should be used in the planning and layout of any new project.

All airborne noise must be measured in a one-third octave analysis to provide information which can be related to building product data.

- (ii) Where the project is for the refurbishment of existing premises a full survey, again in one-third octaves, should be carried out to ascertain that the noise and vibration levels, sound insulation and reverberation times of technical areas meet the required standard; or if not, what remedial measures are required to meet the standards or user requirements. Measurements should still be made even if the refurbishment only involves replacement of technical equipment.

### 2. During construction

Preliminary sound insulation tests are usually carried out as soon as the studio observation windows, doors and ventilation duct installations are complete and prior to any acoustic treatment being installed. These particular tests are aimed at checking that the building structure is intact or alternatively identifying any acoustic problems

such as holes around observation windows, doors, ventilation ducts etc which could cause expensive remedial action if the faults were found after the areas had been finished and fully equipped.

All technical and electrical cable ducts must be fully pugged for these tests.

In large studios it is often desirable to carry out reverberation time measurements in the empty studio shell. Such tests are required to check that the structure and other building elements, such as ventilation ductwork or droppers are behaving as predicted and not providing unexpected absorption. Further reverberation tests may be necessary in large orchestral studios at different stages of the installation of the acoustic treatment and finishes.

### 3. On completion of the project

A full acoustic survey of the acoustics, sound insulation and noise levels should be carried out at the completion of all building work and with the technical equipment in position.

The main purpose of these final tests is to confirm that the necessary acoustic standards, as specified in the original project requirements, have been met or whether modifications or remedial work will be required.

### Previous documentation

This document supersedes the previous Acoustics Committee Note dated November 1981.

KAR/RW/RMC JUNE 1990

# ACOUSTIC PERFORMANCE SPECIFICATION FOR REVERBERATION TIME



**PROJECT :**

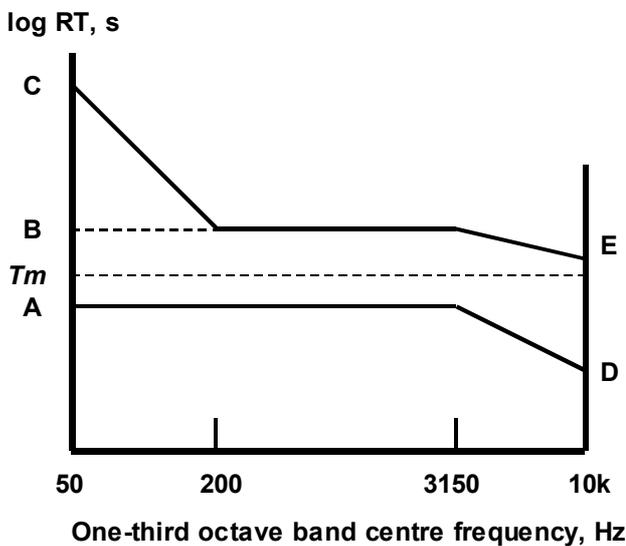
This specification applies to the following enclosed space :

**Location and Premises :**

**Room :**

The reverberation time averaged over the one-third octave bands with centre frequencies from . . . . Hz to . . . kHz shall lie in the range . . . s to . . . . s.

## Reverberation time specification



The permissible tolerance limits are expressed relative to  $T_m$ , the average of the measured reverberation times for the one-third octave frequency bands 200Hz to 3150 Hz.

Multipliers of  $T_m$  are :-

<b>A =</b>
<b>B =</b>
<b>C =</b>
<b>D =</b>
<b>E =</b>

The reverberation time specification shall apply for the enclosed space in the following state (delete as necessary)

- acoustically treated floor / walls / ceiling
- furnished with technical equipment / chairs / table / other .....
- equipped with variable absorbent finishes
- extended / retracted curtains / blinds

For each band in the range from 50 Hz to 200 Hz the reverberation time shall fall within the limits A.  $T_m$  and a straight line (on a logarithmic scale of reverberation time) drawn from C.  $T_m$  at 50Hz to B.  $T_m$  at 200 Hz.

For each band in the range from 200 Hz to 3150 Hz the reverberation time shall fall within the limits A.  $T_m$  and B.  $T_m$ .

For each band in the range from 3150 Hz to 10000 Hz the reverberation time shall fall within the two straight line tolerance limits (on a logarithmic scale of reverberation time) drawn from B.  $T_m$  at 3150 Hz to E.  $T_m$  at 10000 Hz and A.  $T_m$  at 3150 Hz to D.  $T_m$  at 10000 Hz.

**Specification by** ..... **Date** .....

**THIS DOCUMENT TO BE ISSUED TOGETHER WITH BBC REQUIREMENTS FOR MEASUREMENT, INSTRUMENTATION, TEST METHODS AND FORMAT FOR RESULTS PRESENTATION.**

# ACOUSTIC PERFORMANCE SPECIFICATION FOR BACKGROUND NOISE (BBC CRITERIA)

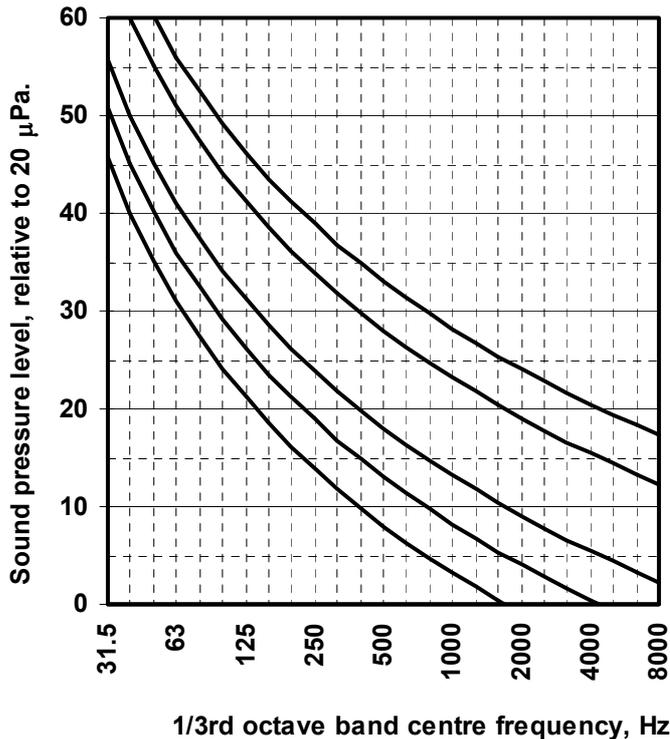


**PROJECT :**

This specification applies to the following space :

**Location and Premises :**

**Room :**  **Criterion :**



**Background noise criterion**

Hz	iii	ii	i	Vs	Vp
50	35.2	40.2	45.2	55.2	60.2
63	31.0	36.0	41.0	51.0	56.0
80	27.4	32.4	37.4	47.4	52.4
100	24.1	29.1	34.1	44.1	49.1
125	21.2	26.2	31.2	41.2	46.2
160	18.6	23.6	28.6	38.6	43.6
200	16.1	21.1	26.1	36.1	41.1
250	13.9	18.9	23.9	33.9	38.9
315	11.8	16.8	21.8	31.8	36.8
400	9.9	14.9	19.9	29.9	34.9
500	8.1	13.1	18.1	28.1	33.1
630	6.3	11.3	16.3	26.1	31.1
800	4.7	9.7	14.7	24.7	29.7
1000	3.2	8.2	13.2	23.2	28.2
1250	1.8	6.8	11.8	21.8	26.8
1600	0.4	5.4	10.4	20.4	25.4
2000	-0.9	4.1	9.1	19.1	24.1
2500		2.8	7.8	17.8	22.8
3150		1.6	6.6	16.6	21.6
4000		0.5	5.5	15.5	20.5

Measured values of sound pressure level shall be equal to or less than the specification in all of the one-third octave bands with centre frequencies from 50 Hz to 10000 Hz — subject to the following tolerances :-.

<b>Overall:</b>	The average of the sound pressure levels in every band shall fall within a range +0 to -10 dB relative to the specified criterion.
<b>Position:</b>	No individual microphone position shall give a sound level in any band more than 5 dB above the average value for the whole room in that band.
<b>Variation:</b>	There shall be no perceptible variation of the noise level over short time periods. This condition shall be deemed to be satisfied if there is a maximum variation in noise level of less than 5 dB for all operating conditions.
<b>Uniformity:</b>	There shall be no value which differs from the average of the values in the two adjacent bands by more than 5 dB.
<b>Low frequencies:</b>	For bands of 40 Hz and below the average noise level in each band shall not exceed a level which increases at 4 dB per band (12 dB per octave) from the specification for the 50 Hz band.
<b>High frequencies:</b>	For bands above the limit of the specified criterion the average noise level shall not exceed that specified for the high-frequency limit of the criterion

**Specification by** ..... **Date** .....

**THIS DOCUMENT TO BE ISSUED TOGETHER WITH BBC REQUIREMENTS FOR MEASUREMENT,  
INSTRUMENTATION, TEST METHODS AND FORMAT FOR RESULTS PRESENTATION.**

**ACOUSTIC PERFORMANCE SPECIFICATION FOR  
AIRBORNE SOUND INSULATION**



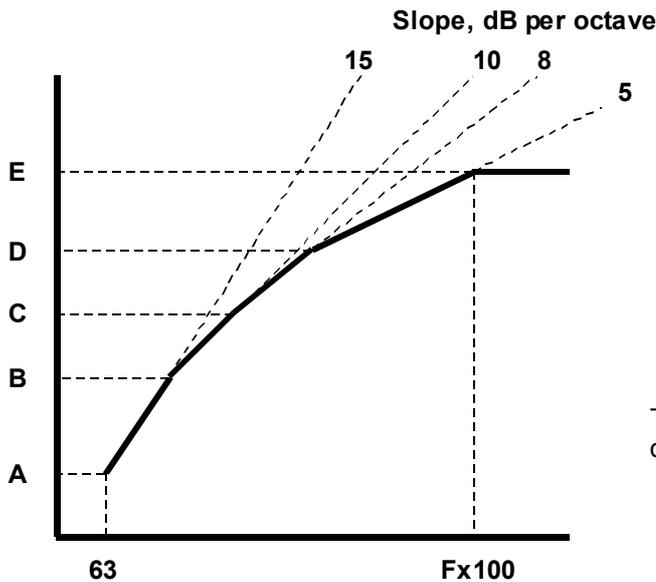
**PROJECT :**

This specification applies to all elements of the structure and services separating the following areas :

**Location and Premises :**

**Room 1 :**       **Room 2 :**

**Sound insulation specification**



A =	B =
C =	D =
E =	F =

This specification applies in both directions unless stated otherwise.

**One-third octave band centre frequency, Hz**

Values of sound pressure level differences shall be equal to or exceed the specification in all of the one-third octave bands with centre frequencies from 63 Hz to 10000 Hz – unless adverse deviations are permitted as described below :-

**Permissible adverse deviations.**

For the frequency bands from 63 Hz to 250 Hz the average of the adverse deviations should not exceed . . 2 . . dB and no individual adverse deviation shall exceed . . 5 . . dB.

For the frequency bands from 250 Hz to 10000 Hz the average of the adverse deviations should not exceed . . 2 . . dB and no individual adverse deviation shall exceed . . 5 . . dB.

**Masking noise.**

Where a background noise criterion applies to either room, this should be stated :-

**Room 1 :**      Criterion . . . .      **Room 2 :**      Criterion . . V<sub>s</sub> . .

**Specification by** ..... **Date** .....