Proceedings of the Institute of Acoustics

NOISE CRITERIA IN BUILDING SERVICES DESIGN

N R Jarman

Vernon Cole Associates, TGP House, 45-47 High Street, Cobham, Surrey KT11 3DP

1. INTRODUCTION

This paper reviews various methods of rating building services noise within buildings. The methods respective merits and their applications in the UK and USA are discussed. Suggestions are made to revise the CIBSE guidelines.

2. RATING METHODS

The building services rating methods considered in this paper are: dBA, Noise Criteria (NC), Noise Rating (NR), Preferred Noise Criteria (PNC), Room Criteria (RC), Balanced Noise Criterion (NCB). The five sets of curves are reproduced in figures 1& 2

dBA
Not commonly used to set specific building services noise criteria in the UK, it is used as an internal noise descriptor in documents such as BS8233: 1987 (Ref.1) and the BREEAM documents, such as those for existing and new office buildings (refs. 2 & 3.).

Noise Criteria (NC)
Developed by Beranek (ref. 4), as a means of evaluating existing noise and of specifying design goals. Their development was based upon research on noise levels within offices, which concluded that criteria should be based upon speech interference and loudness levels. The curves were updated by Schultz (ref. 5), to suit the preferred octave bands 63-8kHz. Originally adopted by ASHRAE, but now their preference is to use RC (ref. 6.).

Noise Rating (NR)
Developed for rating external noise intrusion (ref. 7) NR curves have, within the UK, commonly been adopted as the method of rating building services noise within buildings. It is the method recommended by CIBSE (ref. 8). In many situations building services noise rated by the NC and NR systems will produce similar figures. However, NR can be slightly more tolerant of some low frequency noise, NC more tolerant of high frequency noise.

Preferred Noise Criteria (PNC)
Developed by Beranek, Blazier & Figwer (ref. 9), these are used in the same way as NC curves. They differ from NC in that they are less tolerant of both high frequency and low frequency noise.

Room Criteria (RC)
Adopted by ASHRAE as their preferred method of specifying criteria, these were developed by Blazier (ref. 10). Above RC 50 it is recommended NC curves are used. They are more complicated to use than the NR, NC or PNC systems. A noise is assessed by calculating a speech interference level (SIL), averaging the levels in the octave bands 500, 1000 and 2000kHz. The calculated SIL is the RC number. A bracketed descriptor is then attached to the RC number.

The descriptor is defined by plotting the noise spectrum against the relevant RC curve (which it will be noted extends down to 16Hz). If at 500Hz, or below the plotted spectrum exceeds the designated RC curve (as defined by its SIL) by more than 5dB in any band, the sound is considered (R), rumbly. Above 1kHz an excess above the designated RC curve of more than 3dB means the sound is considered (H), hissy. If there is projection of more than 3dB above the general spectrum in a designated band it is designated tonal, (T). If the spectrum extends into the area marked A on the chart it is designated (RV), meaning a sound which is of such a level as to introduce perceptible vibration in surfaces of light building construction. Criteria in the ASHRAE guide are expressed in terms of neutral spectra (N), where the plotted spectra exceeds designated RC curve by less than 5dB (up to 500Hz) and 3dB (above 1kHz).

Balanced Noise Criteria (NCB)
This is a further assessment method developed by Beranek (ref. 11). To assess noise levels in a space the ANSI recommended SIL is calculated (average octave band levels 500-4kHz). If this figure is less than the specified NCB, stage one of the criteria is met. The measured noise level is then plotted against the NCB curves. If the low frequency noise (31.5-500Hz) exceeds the NCB curve that is 3dB higher than the measured SIL, then the low frequency content is unacceptable. If there is audible rattling or perceptible vibration, then this too is unacceptable. Finally the best fit NCB curve to the plotted recorded levels (over the range 125-500Hz) are compared to the plotted recorded levels over the range 2k-8kHz. If these exceed the NCB curve, then the sound is too hissy.

The assessment method is intended to be applied to noise levels in occupied spaces. Therefore to determine the acceptable building services noise levels, the measured or estimated activity/noise levels have to be deducted from the set NCB criterion to give the building services octave band criteria. At the end of the project, it is intended the building services noise measured plus activity noise assumed/measured are totalled in order to determine compliance with the NCB specification.

3. APPLICATION OF DIFFERENT RATING SYSTEMS

dBA is little used in the UK (or USA) to generate criteria for building services noise within buildings. Whilst being simple to measure, and providing information on loudness, the unit does not take account of the spectral content in the way that other rating systems do. The unit can therefore be a poor guide to quality of building services noise, dBA can be used to assess intermittent building services noise such a lift car noise (ref. 12).

By far the most commonly used systems of setting criteria are NR and NC. A survey by the author of buildings (all in the UK) reviewed in the CIBSE Journal "Building Services" over the last few years shows almost exclusive use of NR and NC to rate building services noise, with NR leading NC by a ratio of 7 to 2. Other systems, such as PNC, were only used for concert/opera auditoria. In all these cases for other areas of the buildings NR was used.

In the USA, NC continues to be widely used (e.g. ref. 11) despite ASHRAE's endorsement of the RC system.

To understand why this is the case, one must look at how criteria are used and evidence of satisfaction or dissatisfaction with the end result.

NC and NR are used to describe building services noise alone. For a set criteria, there are set values for each octave band. The acoustic engineer can readily design noise control measures, considering fan noise, system generated terminal noise and airborne/structureborne sound from plantrooms. There can be limiting sound power levels set for system components against which manufacturers' proposals can be compared, considering sound making benefits when appropriate. At the end of the project, the resultant building services noise levels can be established (turning the system on and off to check for external noise intrusion if need be) and compared directly with the criteria. If significant excesses are found, the cause can be established and (hopefully) remedial action taken.

It is the lack of the simplicity which makes the RC and NCB system in particular unattractive. This and other concerns on the RC, PNC and NCB systems I discuss below.

RC System

The RC system is at best a system to describe existing services noise rather than one to design to. But even as a descriptor, it can give a misleading picture. The RC figure is only determined by the levels in the frequencies 500-2kHz. If the sound quality descriptor is (R) there is no indication as to how severe the rumble is. Two very different noises could, for example, both be described as RC 25 (R), but also described as NR 25 and NR 42.

The sound quality descriptor RV is to be used universally, but is only relevant to light weight buildings. A particular problem with RC's is in using them to set criteria. Ultimately, one is dependent upon achieving the set SIL, in order that the designed low frequency noise content is not described as rumbly. A commissioning engineer would naturally assume RC 32 (R), means a sound too rumbly, not one that is lacking in mid band noise.

Beranek (ref. 11) is also critical of RC's on a number of points including:

a. Their derivation was only based on research in offices where noise levels were rated acceptable.
b. That the RC curves are in fact parallel lines, where evidence suggests that with increasing SIL, the amount by which the low frequency noise may exceed the mid band and high frequency noise decreases. This is reflected in NR, NC, PNC and NCB curves.
c. The low frequency bands are set too low to be economic.
d. No research was performed outside offices to justify extending the curves significantly upwards or downwards.
e. Whilst describing an acceptable spectrum shape, they ignore other shapes that can also be acceptable

PNC

Proposed to replace NC, two of its co-developers, Beranek and Blazier later proposed the NCB and RC systems. Originally they argued the following points in the systems favour:

1. Levels in low frequency bands adjusted to conform to contemporary data on the threshold of hearing for continuous noise.
2. Levels of lowest and highest frequency bands adjusted to reduce possibility of complaints of hiss, rumble or mechanical vibration in rooms.
3. Introduction of 31-Hz band (not in NC, but included in NR).

Beranek later criticised PNCs, pointing out that the tests which led to the proposals were only preference tests. No test was performed to establish which noise levels, if exceeded, would cause serious complaint. Beranek also concluded that the low frequency levels were set too low to be met economically in offices.

NOISE CRITERIA IN BUILDING SERVICES DESIGN

NCB

NCB is intended as a descriptor of total noise, from which building services noise criteria are derived. For the acoustic engineer this creates difficulties as very often one cannot predict what the occupational noise will be. Offices will commonly be designed to be capable of cellularisation, so some areas may have desk top computers, fax machines and photocopiers, whereas others have none. What will be in what area will be unknown to the acoustic engineer working for the speculative office developer. Add to this that on one or more sides of the building may be traffic noise intrusion, one could end up with considerable confusion, and several different criteria over one floor of an office building. Ultimately of course the occupier may change his mind as to where open plan and private offices will be. At the end of a project, there could be confusion over whether or not set criteria have been met or not. The practice of using the "best fit" curves between 125 and 500Hz to determine whether a sound is too hissy is open to interpretation.

To meet a set NCB criteria, the mid band levels (giving the SIL) can be lower than the value required to give the NCB criteria. However, if the mid band noise is low, the low frequency and high frequency noise have to be lower too, regardless of the absolute levels, in order to avoid the noise being unacceptable as a result of being too rumbly or hissy. So as with RC, if there is a failure to meet the required criterion because of noise failing the "rumble test", is it because there is too much rumble or not enough mid band noise? It could be a contractual nightmare. Beranek recognises some of the difficulties in setting building services criteria based on NCB (ref. 11).

The acoustical engineer can make an educated guess of the activity noise from information in the literature... (S)he can determine how much lower the HVAC levels should be and give that spectrum to the supplier with the hope that the resulting combined noise level will meet the desired NCB curve.

In his paper Beranek undertook a verification exercise of NCB curves taking some examples of noise levels in buildings that had been found to be unacceptable. The 23 examples used verified the approach. Undertaking the same exercise on the same results using NR curves and CIBSE recommended criteria, only two (out of the 23) examples could possibly be within NR specifications, being offices with noise levels of NR 37 and 40. (With both these noise levels could be adjusted to within NCB recommended criteria (ref. 13), by either reducing low frequency noise or increasing mid band noise). The mean of 68 unoccupied offices, described as acceptable in NCB terms correspond to NR 36. This conclusion would not seem to justify a move away from using NR in the vast majority of building services specifications.

On the speculative offices front, where traditionally noise criteria are specified in the range NR/NC 35-40, there is further evidence for not changing. In 1994, the British Council for Offices published a best practice guide to provide a common design standard for the urban offices (ref. 14). Investors, occupiers, developers and letting agents contributed to the guide which covers structural loading, environmental performance, indoor air quality, lighting, fire and security issues. Noise is not covered in the document. Apparently, it was discussed in the working party, but as there was no significant disagreement within the industry, on what noise levels should be, it was decided not to include it.

4. RECOMMENDED NR CRITERIA

CIBSE are currently reviewing Guide A1 "Environmental Criteria for Design". They are not proposing to change from using NR. It is therefore timely to propose updating the recommended criteria for assessing broad band continuous noise.

Auditoria & Studios:	**NR Value**
Concert Halls, Opera Houses	15-20
Recording Studios	15-25
Theatres	20-25
Cinemas, Lecture Theatres	25-30
Hospitals:	
Audiometric rooms	20-25
Single bed wards	30-35
Multiple bed wards	30-40
Operating Theatres	30-40
Hotels:	
Bedrooms	25-35
En suite Bathrooms	35-40
Conference/Banqueting Facilities	30-35
Lounges	30-40
Restaurants and Bar	35-40
Offices:	
Purpose designed Boardrooms, Conference Rooms & Executive Offices	30-37
Private, Open Plan, General & Speculative Offices	35-40
Toilets & Circulation Spaces	40-45
Banking Halls	40-45
Computer Rooms	50-60
Atria and General Reception Areas	40-45
Retail:	
Small Shop Units	35-45
Department Stores, Shopping Malls, Public Houses	40-45
Food Supermarkets, Main Sales Areas	45-55
Restaurants/Canteens	35-45
Kitchens	45-55
Residential:	
Bedrooms	25-30
Living Rooms	30-35
Public Buildings:	
Council Chambers	25-30
Law Courts	25-35

Libraries, Museums, Galleries	30-35
Swimming Pools & Sports Halls	40-45
Car Parks	50-55
Educational Buildings:	
Music & Drama Space	20-25
Language Laboratories/Large Lecture Rooms/Teaching Rooms for 35 plus with Communication over 8m	25-30
Small Lecture Rooms/Teaching Rooms for 15-35 people with communication over distances not more than 8m	30-35
Teaching Groups of less than 15 people with communication over distances not more than 4m, Resource Areas	30-40
Circulation/Workshops/Practical Areas	40-45

Particular criteria should be selected for individual projects. In selecting and working with criteria one should:

1. Have regard to other noise within the space, either generated internally or due to external noise intrusion.
2. Recognise that criteria selected at the top end of the quoted range may, in some cases, give rise to some complaint, in particular if of a "rumbly" or tonal nature.
3. Recognise that in light weight buildings, with noise levels rising above 70dB at 16 & 31.5Hz there is an increasing likelihood of induced audible rattles or perceptible vibration in light weight partitions and ceiling constructions.
4. Have regard to the possible masking benefits of building services noise: (a) to assist with providing privacy in open plan offices, between cellular offices or between private rooms and waiting areas, (b) of other extraneous intermittent or tonal intrusive noises.
5. Have regard to the likely eventual noise spectrum, and the other characteristics. If an undesirable tonal sound is predicted or the noise will be impulsive or intermittent, a -5dB correction to the criteria should be applied.
6. Where a building services system creates noise levels which change gradually with time, have regard to the likely noise levels that will exist for most of the time. For an office VAV system, a criterion to be achieved with the system operating at 80% volume may be appropriate. For rooms used for sleeping, consider day and night noise levels.

The above thinking is largely based on current practices as in the CIBSE Journal, guidance in BS8233 and related documents and references to this paper.

4. REFERENCES

{1} BS8233 1987 "British Standard Code of Practice for Sound Insulation and Noise Reduction for Buildings.
{2} BREEAM (Building Research Establishment Environmental Assessment Method) Version 1/93 "An Environmental Assessment for New Office Designs.
{3} BREEAM Version 4/93 "An Environmental Assessment for Existing Office Buildings.

{4} L L BERANEK, "Revised Criteria for Noise In Buildings" Noise Control 3, 19-27 (Jan 1957)
{5} T J SCHULTZ, "Noise Criteria Curves for Lift with the USAS1 Preferred Frequencies", J. Acoustical Society of America. 43, 637-638 (1968).
{6}ASHRAE - Applications Handbook 1991.
{7} C W KOSTEN & G J VAN OS, "Community Reaction Criteria for External Noises", Proceedings of NPL Symp. No.12 on Control of Noise, 1962, HMSO.
{8} CIBSE Guide A1 "Environmental Criteria for Design" (1986))
{9} L L BERANEK, W E BLAZIER & J J FIGWER, "Preferred Noise Criteria (PNC) Curves and their Application to Rooms", J Acoustical Society of America, 50, 1223-1228 (1971).
{10} W E BLAZIER, "Revised Noise Criteria (RC Curves) for application in the acoustical design of HVAC systems". Noise Control Engineering 16(2) March-April (1981).
{11} L L BERANEK, "Balanced Noise Criterion (NCB) Curves" J Acoustical Society of America, 86 (2) 650-664 (1989).
{12} CIBSE Guide Volume D "Transportation Systems in Buildings" Appendix A9.1 (1993).
{13} L L BERANEK, "Application of NCB Noise Criterion Curves" Noise Control Engineering Journal, September-October 1989.
{14} British Council for Offices "Specification for Urban Offices" (1994).

NOISE CRITERIA IN BUILDING SERVICES DESIGN

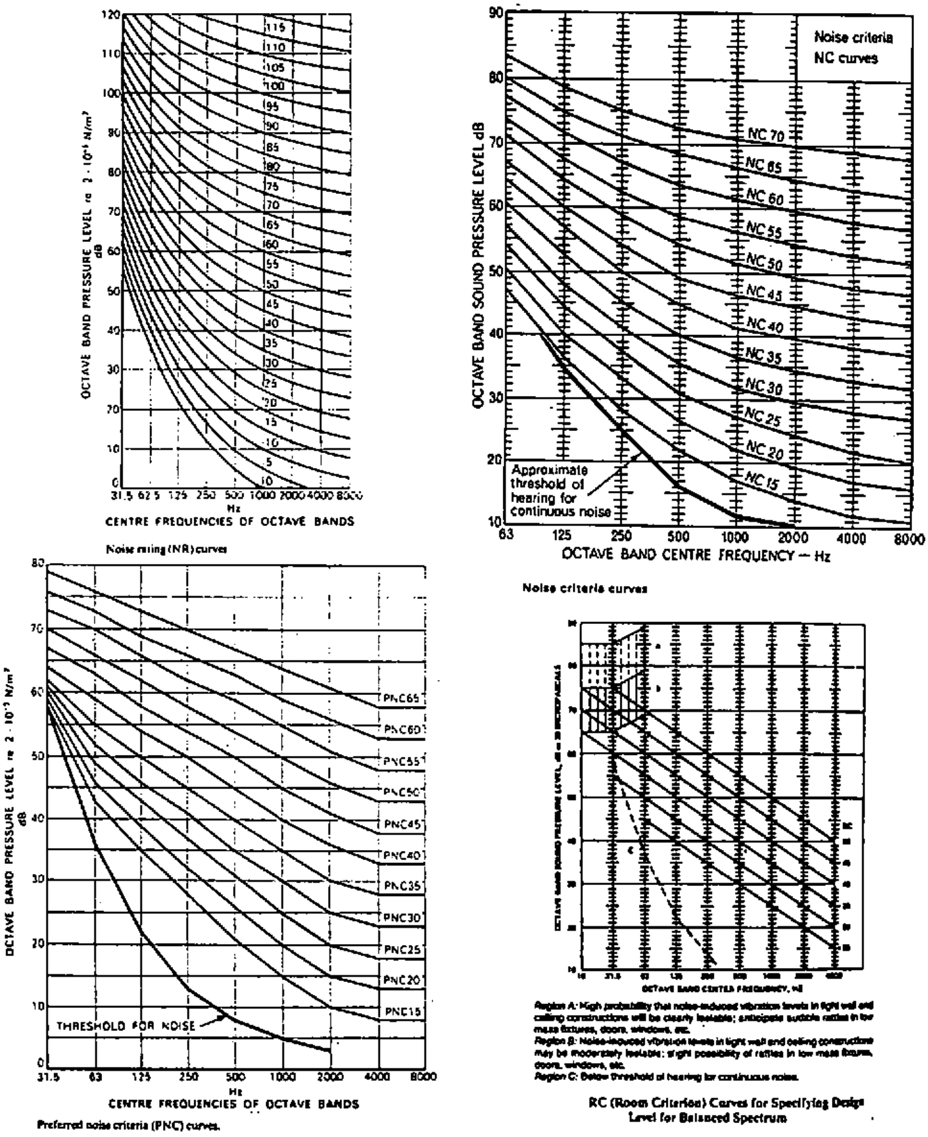
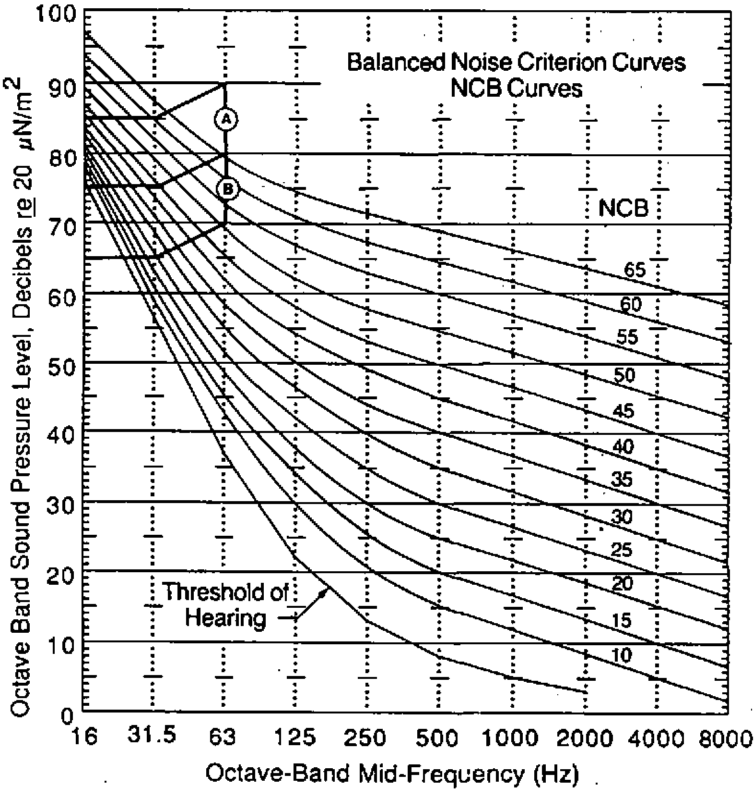


Figure 1: NC, NR, PNC & RC Curves



—Balanced noise criterion (NCB) curves for occupied rooms. Octave-band sound-pressure levels of the magnitudes indicated in or above Regions A and B (obtained from Blazier) may induce audible rattles or perceptible vibrations in lightweight partitions and ceiling constructions (e.g., thin plaster or gypsum board on metal framing) as follows:
Region A and above: Clearly noticeable vibrations
Region B: Moderately noticeable vibrations

Figure 2:

NCB Curves