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DESIGN GUIDE FOR NOISE, VENTILATION AND OVERHEATING IN RESIDENTIAL DEVELOPMENTS

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The Association of Noise Consultants has formed a working group to develop guidance on acoustic conditions and design when considering both the provision of ventilation and mitigation of overheating; there is currently scant guidance on a holistic approach to these aspects of internal environmental quality. The guidance produced will clarify the relevant definitions of ventilation and overheating, give quantitative guidance as to how to assess internal noise levels and provide examples of acoustic design solutions. Currently, where residential developments rely on opening windows as a means to mitigate overheating, there can be a compromise between allowing excessive noise ingress with windows open, or excessive temperatures with windows closed. This problem is exacerbated by the move towards better insulated, more airtight buildings and the need, particularly in urban areas, to consider development on noisier sites. This paper presents an overview of the ventilation, overheating and noise issues for residential development that form the basis of the design guidance.
Keywords: Overheating, Façade, Ventilation, Noise, Residential

1. Introduction

A working group has been formed by the Association of Noise Consultants (ANC) in response to an identified urgent need to provide guidance on acoustic conditions and design when considering both the provision of ventilation and prevention of overheating. The guidance produced by the group will take the form of a design guide for acousticians provisionally titled 'Acoustics, Ventilation and Overheating Guidance' ('AVOG'). In the first instance, the AVOG will consider only residential development exposed to transportation noise sources. This paper describes the work in hand that has progressed since the earlier presentation of this work [1].

Problems in residential design for ventilation and noise have been described by Harvie-Clark et al [2]. The need for adequate ventilation is outlined in Approved Document F [3] and designs to achieve this have been well developed. The evolution of Part L of the Building Regulations has required increasing energy efficiency, which is achieved in part through increasing air tightness and enhanced thermal insulation. However, there are no specific requirements relating to overheating in dwellings as part of the UK Building Regulations; the emerging consequence of increasing air tightness and thermal insulation is leading to greater potential for excessive temperatures.

The current standard method of cooling a dwelling is either:

- via the opening of a window or other façade element to allow an increase in air flow and equalisation of temperatures between inside and outside, or
- via incorporation of mechanical cooling which generally requires space allowance for an external condensing system, ongoing maintenance (and therefore cost) and is not the preferred option in terms of energy efficiency.

Where a non-acoustically-attenuated opening in the façade (e.g. a window) remains the only provision for prevention of overheating and the dwelling is located in a noisy area, the occupant is presented with a choice between uncomfortably high noise levels or uncomfortably high temperatures. There are currently risks involved which the AVOG hopes to reduce, namely:

- health risks for occupants
- design risks for consultants; and
- legal risks for developers.

This design guide being developed intends to provide:

- an explanation of current definitions of ventilation and overheating;
- an indication of potential forms of acoustic criteria that could be used for design;
- examples of design solutions and case studies.

There is presently limited data on criteria and solutions and thus it is envisaged that the AVOG will be an ever-evolving document, to be updated and improved as further information becomes available. This paper presents an overview of the ventilation, overheating and noise issues for residential development that will form the basis of the AVOG.

2. Ventilation

2.1 Approved Document Part F

Ventilation requirements for dwellings (and other buildings) in England are covered under the Building Regulations 'Approved Document F – Means of Ventilation, 2010 Edition' (ADF). The Guide will describe purpose and typical provisions for ventilation under the Building Regulations. Ventilation may also provide a means to control thermal comfort but this is not controlled under the Building Regulations. Part L addresses minimising energy use due to the effects of solar gain in summer.

Table 1: ADF - Adopted Ventilation Strategy

Type of Ventilation	Location / Reason for Ventilation	When is this required?
Whole Building (Whole Dwelling) Ventilation (see Note 1)	To provide fresh air to the building and to dilute and disperse residual water vapour not dealt with by extract ventilation as well as removing water vapour and other pollutants which are released throughout the building.	Continuously
Extract Ventilation	From rooms where most water vapour and/or pollutants are released, e.g. due to activities such as cooking, bathing or photocopying. This is to minimise their spread to the rest of the building.	Continuous or intermittent
Purge Ventilation	Throughout the building to aid removal of high concentrations of pollutants and water vapour released from occasional activities such as painting and decorating or accidental releases such as smoke form burnt food or spillage of water.	Occasionally

ADF describes three types of ventilation provision and associated ventilation rates. The types of ventilation are summarised in Table 1. It is noted that '*purge ventilation provisions may also be used to improve thermal comfort, although this is not controlled under the Building Regulations.*' ADF provides details of four template "Systems" which comply with this strategy for new dwellings in Section 5 of ADF and that can be adopted to demonstrate compliance – see Table 2.

With regard to the provision of purge ventilation within habitable rooms, the approved document provides the following note: '*There may be practical difficulties in achieving this (e.g. if unable to open a window due to excessive noise from outside.*'. No objective guidance is provided as to what constitutes an "excessive" level of noise.

Table 2 : Summary of ADF Ventilation Systems

Ventilation System	Provision with AD-F System / purpose		
	Whole dwelling ventilation	Extract ventilation	Purge ventilation
System 1: "Natural ventilation"	Trickle vents	Intermittent extract fans	Typically provided by opening windows
System 2: Passive stack ("natural")	Trickle vents and passive stack ventilation	Continuous via passive stack	
System 3: MEV	Continuous mechanical extract – normal level	Continuous mechanical extract – boost	
System 4: MVHR	Continuous mechanical supply and extract – normal level	Continuous mechanical supply and extract – boost	

3. Thermal Comfort and Overheating

3.1 Definitions

ISO 7330 [4] describes thermal comfort as:

'*that condition of body and mind which expresses satisfaction with the thermal environment'*

Part of providing thermal comfort in a residential building is avoiding 'overheating'.

In the Zero Carbon Hub (ZCH) discussion paper 'Next Steps in Defining Overheating' [5] the following definition of overheating in dwellings is provided:

'*In a general sense, by overheating we mean the phenomenon of excessive or prolonged high temperatures in homes, resulting from internal or external heat gains, which may have adverse effects on the comfort, health or productivity of the occupants.*'

3.2 Building Regulations

There are no specific requirements relating to overheating in residential dwellings as part of the UK Building Regulations. Both Part F (see Section 2.1) and Part L1A of the Building Regulations [6] briefly mention overheating but do not provide detail on what constitutes overheating. In the section on 'buildings other than dwellings' Approved Document F refers to Part L2A of the Building Regulations [7] for guidance, however this guidance is related to limiting solar gains rather than avoiding overheating.

Approved Document L1A provides guidance on limiting the effects of heat gains in summer although no objective performance standards are identified. However, reference is provided to the SAP 2012 [8] Appendix P assessment methodology and this document includes a simplified test for overheating risk. In Part L2A of the Building Regulations [7] (conservation of fuel and power in new buildings other than dwellings) further information on overheating is provided in the section on limiting thermal gains:

'*…the developer should work with the design team to specify what constitutes an acceptable indoor environment in the particular case, and carry out the necessary design assessments to develop solutions that meet the agreed brief. Some ways of assessing overheating risk are given in CIBSE TM37 and, for education buildings, in BB101.*'

It should be noted that the above applies to buildings 'other than dwellings' but this information has been included as it is the only direct reference to assessing overheating that is contained in the Building Regulations.

3.3 The London Plan

Policy 5.9 of the London Plan [9], 'Overheating and Cooling', advocates that '*major development proposals should reduce potential overheating and reliance on air conditioning systems and demonstrate this in accordance with the following cooling hierarchy:*

1. *minimize internal heat generation through energy efficient design*
2. *reduce the amount of heat entering a building in summer through orientation, shading, albedo, fenestration, insulation and green roofs and walls*
3. *manage the heat within the building through exposed internal thermal mass and high ceilings*
4. *passive ventilation*
5. *mechanical ventilation*
6. *active cooling systems (ensuring that they are the lowest carbon options).*'

This clearly prioritises the use of opening windows (or other means of passive ventilation) to control overheating over more energy-intensive, mechanical solutions.

3.4 Overheating Criteria and Guidance

There is no universally accepted definition of what constitutes overheating in residential dwellings. However, there are two main methods of identifying if overheating is likely to occur that are used by building services engineers. These are the 'Fanger' model (described in ISO 7730, BS EN 15251, CIBSE TM36 and CIBSE Guide A 2006 [10]) and the 'adaptive thermal comfort' model (described in CIBSE Guide A 2015 [11] and TM52 [12]). These methods are summarised in Table 3.

Table 3 : Overheating Criteria

CIBSE Guide A - 2006	Provides absolute criteria (temperatures and durations) for where overheating is likely to occur in residential buildings (living rooms and bedrooms)
CIBSE Guide A - 2015	Provides criteria to assess the risk of overheating based on adaptive comfort (this takes into account that people acclimatise to extended periods of hot weather)

It should be noted that the adaptive thermal comfort criteria (CIBSE Guide A 2015) are based on research for commercial buildings and therefore may not be applicable in residential environments, as occupants have more adaptive opportunity in dwellings. Therefore the CIBSE 2006 methodology is currently more regularly used for dwellings.

3.5 Zero Carbon Hub and Upcoming CIBSE Guidance

The ZCH have produced a number of documents on the subject of overheating. In their 'Next Step in Defining Overheating' discussion paper [5] they make recommendations for defining overheating in new dwellings and assessing the potential for these buildings to overheat in future.

The paper recommends an initial approach for risk assessing and defining overheating and the ZCH propose that their recommendations be adopted in principle by the relevant government departments as national policy. The ZCH paper also notes that CIBSE are to produce a paper clarifying their current advice on the assessment of overheating. In relation to the upcoming CIBSE paper the ZCH paper states:

'*Their [CIBSE] paper will recommend that overheating criteria is chosen based on the type of ventilation or cooling strategy to be installed. It will state that for "homes that are predominantly naturally ventilated, including homes that have Mechanical Ventilation with Heat Recovery (MVHR) with good opportunities for natural ventilation in the summer, should be assessed using the adaptive method described in CIBSE TM 52."*', And

'*Homes that are predominantly mechanically ventilated, "including homes with MVHR that have no opportunities or restricted opportunities for opening windows, should be assessed using the fixed temperature method, and the rooms should not exceed an operative temperature of 26 ˚C in the summer, for more than 3% of the occupied hours..."*'

4. Existing Noise Guidance

4.1 Noise from Mechanical Services

Upper limits for indoor noise levels from mechanical services are given in Table 1.5 of CIBSE Guide A, although no limits are given for bathrooms, toilets or circulation areas. Section 4.3.6 of ADF also gives guidance on noise levels that should not be exceeded by a continuously running mechanical ventilation system on its minimum low rate. The noise limits described in CIBSE Guide A are applicable for the ADF whole building ventilation condition (see Table 1). It is not explicit what noise limits should apply to mechanical services for the ADF purge ventilation condition or when plant is operating to control overheating.

There is much evidence from other countries that where mechanical ventilation services are too noisy, the occupants will either turn the system down or off entirely. Kurnitski et al [13] measured the noise levels, and found a strong correlation between ventilation noise complaints and the noise level in dB(A) in the main bedroom at the maximum fan speed. Many others such as Balvers [14], and more recently Brown & Gorgolewski [15] have found that noise is frequently a reason that occupants disable their mechanical ventilation system. This finding is often revealed where studies have investigated indoor air quality (IAQ); these researchers rarely measured the actual noise levels present as that was not the focus of the study, so that there is little data in the literature to inform the range of levels that may be acceptable. It is likely that the A-weighting is a poor descriptor for ventilation system noise, as it under-rates the significance of the low frequency components at low levels.

4.2 Noise from External Sources

Upper limits for indoor ambient noise levels resulting from external noise sources are defined in Table 4 of BS 8233 [16]. The limits described in BS 8233 are generally taken as being applicable for the ADF whole building ventilation condition (see Table 1). This typically implies noise levels with trickle ventilators in the open position but windows closed. It is not explicit what indoor ambient noise limits should apply for the ADF purge ventilation condition or when ventilation is provided for the purposes of overheating control.

A conservative approach would be to assume that it should be possible to prevent overheating whilst meeting the noise limits described in BS 8233. However, this would encourage the use of more energy-intensive mechanical ventilation and cooling solutions without regard for the possibility that occupants may accept higher noise levels for limited periods, particularly where they have control over their conditions.

5. AVOG Proposals – Mechanical Services

5.1 Part F Ventilation

Table 4 summarises the proposed AVOG guidelines for internal ambient noise levels resulting from mechanical services during ventilation to meet Part F requirements. Given that purge ventilation is only required occasional (refer to Table 1) and would be under manual control, it is suggested that no indoor noise limit need apply in the room being purged.

The CIBSE criteria are based on current UK guidance; they may not be suitable for all types of residential development. Lower noise levels may be appropriate and the proposed classification system from Cost Action TU0901 [17] may be used as a guide. The CIBSE criteria are based on steady, broadband noise sources. Noise sources with particular characteristics are likely to be less acceptable and corrections may be applied for characteristics such as tonality, intermittent or unsteady sources. The ANC Good Practice Guide for the Measurement of Noise Levels in Buildings may be consulted for further information [18].

Table 4: Suggested noise levels for mechanical services noise during ventilation to meet Part F requirements

Ventilation	System type and	Internal ambient noise level (IANL)

Condition	noise sources	
Part F – Whole Dwelling Ventilation	Systems 1, 3 and 4 (Refer to Table 1)	Approved Document F (at minimum low ventilation rates) At higher ventilation rates: Comfort criteria from CIBSE Guide A, Table 1.5 and / or Acoustic Classification System from COST TU 0901
Part F – Purge Ventilation	Manually controlled fan exchanging a minimum 4 air changes per hour	None in room being purged Consider criteria above for adjacent rooms in the same dwelling.

5.2 Overheating Condition

Table 5 summarises the draft AVOG guidelines for internal ambient noise levels resulting from mechanical services used to control overheating. Higher noise levels may be acceptable in some operating scenarios, where the occupants may control the equipment to operate at higher duty to manage thermal comfort.

Table 5: Suggested noise levels for mechanical services noise for systems used to control overheating

Ventilation Condition	Typical System or Design Solution	Internal ambient noise level (IANL)
As required to achieve overheating criterion	Mechanical ventilation of ambient air at a rate higher than whole dwelling ventilation	Comfort criteria from CIBSE Guide A, Table 1.5 and / or Acoustic Classification System from COST TU 0901
	Mechanical system introducing cooled air	

6. AVOG Proposals – External Noise Sources

6.1 Introduction

The guidance in this document considers only noise sources without a specific character. Noise has a specific character if it contains features such as a distinguishable, discrete and continuous tone, is irregular enough to attract attention, or has strong low-frequency content. The noise levels that are suggested in relation to overheating condition assume a steady road traffic noise source but may be adapted for other transport noise sources.

6.2 Part F Ventilation

Table 6 summarises the draft AVOG guidelines for internal ambient noise levels resulting from external noise sources during ventilation to meet Part F requirements. Given that purge ventilation is only required occasionally (refer to Table 1) and would normally be under manual control, it is suggested that no indoor noise limit need apply in the room being purged.

Table 6: Suggested noise levels resulting from external noise sources Part F ventilation conditions

Ventilation Condition	Possible System or Design Solution	Desirable Internal Ambient Noise Level (IANL) from external sources of noise.
Part F - Whole Dwelling Ventilation	Systems 1, 2, 3 and 4 (Refer to Table 1)	Guideline values from Table 4 of BS 8233
Part F – Purge Ventilation	Option 1: Opening external window(s) meeting requirements described in Appendix B of ADF. Option 2: Manually controlled fan extracting 4 air changes per hour.	No specific acoustic criterion needs to be met.

Table 7: Guidance for assessment of noise from external sources relating to overheating condition

External Noise Level at Façade		Basis (assuming partially opened windows achieve an outside to inside level difference of 15 dB [19])	Risk Category
$L_{Aeq,T}$ Daytime [07:00-23:00]	$L_{Aeq,8hr}$ Night-time [23:00 – 07:00]		
≤ 55 dB		Daytime: Internal levels not expected to exceed 40 dB $L_{Aeq.}$ Consistent with achieving reasonable internal conditions (Note 7 to Table 4 of BS 8233).	Low
	≤ 50 dB	Night-time: Internal levels not expected to exceed 35 dB L_{Aeq}. Consistent with achieving reasonable internal conditions (Note 7 to Table 4 of BS 8233).	
> 55 dB and ≤ 65 dB	> 50 dB and ≤ 55 dB		Medium
> 65 dB		Daytime: Internal levels expected to exceed 50 dB L_{Aeq}. Speech communication will be affected.	High
	> 55 dB	Night-time: Internal levels expected to exceed 40 dB L_{Aeq}. Health hazards are not excluded at these noise levels.	

6.3 Overheating Condition

Where higher rates of passive ventilation form part of the strategy for meeting overheating criteria, it may be reasonable to allow higher levels of noise during the period where control of overheating is required. There are no universally accepted guidelines which apply for this scenario and any potential adverse effect will depend on the duration and level of noise. There is limited specific research available that considers this issue. There is various guidance and research that can be used to assess short-term/temporary higher noise levels inside dwellings in terms of the following effects:

- Daytime annoyance
- Daytime interference with activities (conversation/telephone)
- Night time sleep disturbance (using noise parameters such as L_{Aeq})
- Night time sleep disturbance (using parameters for individual events L_{Amax}/SEL etc.)

A decision must be made regarding the appropriate averaging period to use for the daytime period. The averaging period should reflect the nature of the noise source, the occupancy profile and times at which overheating might be likely to occur. The values presented in Table 7 should not be regarded as fixed thresholds and reference should also be made to relevant dose-response relationships. The risk of an adverse effect occurring will also depend upon the time duration and regularity that residents are likely to be exposed to an increased level of noise in overheating condition. Regular individual noise events should also be appropriately considered.

Existing references [16, 19, 20, 21, 22, 23] have been used as a basis for developing the AVOG guidance for assessment of noise relating to overheating condition. Table 7 gives an overview. The AVOG will provide more details regarding the proposed assessment procedure and the basis for the proposed guidelines. A worked example will also be provided for information.

7. Future Research

There is an urgent need to understand the noise levels that occupants are being subject to in their own homes in the UK, and the level of noise that they may find acceptable. These findings would then highlight the extent of the potential problem in the UK, where noise levels are not regulated.

The authors are not aware of existing research studies on the inter-dependence of acoustic and thermal comfort in dwellings or the indoor level from external sources that may be acceptable to occupants on a short term basis when the alleviation of overheating is required. Perceived occupant control over the environment is key to higher tolerance of less than ideal conditions. It is recommended that appropriate research should be undertaken on the basis of both lab studies on relatively small groups under closely controlled conditions and also field studies on larger groups to assess behaviour in real-life conditions.

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