PROBLEMS IN RESIDENTIAL DESIGN FOR VENTILATION AND NOISE

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1. ABSTRACT

This paper addresses three broad problems in residential design for achieving sufficient ventilation provision with reasonable internal ambient noise levels. The first problem is insufficient qualification of the ventilation conditions that should be achieved while meeting the internal ambient noise level limits. Requirements from different Planning Authorities vary widely; qualification of the ventilation condition is proposed.

The second problem concerns the feasibility of natural ventilation with background ventilators; the practical result falls between Building Control and Planning Authority such that appropriate ventilation and internal noise limits may not both be achieved. Greater coordination between planning guidance and Building Regulations is suggested.

The third problem concerns noise from mechanical systems that is currently entirely unregulated, yet again can preclude residents from enjoying reasonable indoor air quality and noise levels simultaneously. Surveys from over 1000 dwellings are reviewed, and suitable noise limits for mechanical services are identified. It is suggested that commissioning measurements by third party accredited bodies are required in all cases as the only reliable means to ensure that that the intended conditions are achieved in practice.

2. INTRODUCTION

The adverse effects of noise on residents are well known; the general limits for internal ambient noise levels are described in the World Health Organisations Guidelines for Community Noise (GCN)[1], Night Noise Guidelines (NNG)[3] and BS 8233[2]. On the basis of these documents it may be generally considered that a level of 30 dB(A) in bedrooms represents the lowest observed adverse effect level (LOAEL). The adverse impact of inadequate ventilation upon health and well-being is extensively documented[4-10]. Insufficient ventilation can also lead to adverse effects on the building fabric, and there are instances of mould growth in modern dwellings which once again can impact upon health and well-being.

Part F of the Building Regulations requires that there shall be adequate means of ventilation provided for people in the building; Approved Document F (AD-F)[15] describes the meaning of “adequate”. As buildings have become more airtight[12] the importance of, and requirement for, adequate provision of controlled ventilation has changed significantly. Although AD-F makes thirty references to noise, with recommendations to specific noise standards, noise levels are not regulated with ventilation provision.

This paper addresses three broad problems in residential design for achieving ventilation provision with reasonable internal ambient noise levels. The problems are for the residents who will occupy these buildings, rather than for any particular group of designers. Requirements to limit noise levels in new dwellings are described in planning conditions. The first problem is due to insufficient qualification of the ventilation conditions that should be achieved while meeting the internal ambient noise level limits.

The second problem is with the provision of natural ventilation in new dwellings. While noise limits may be required by planning conditions, ventilation provision is regulated by the Building Control Body (BCB). The BCB may permit opening windows for ventilation, while the response to the planning condition assesses noise levels with windows closed, or a lesser provision of ventilation than required for the occupants. This problem has become more widespread as the required provision of trickle vents has increased[13, 14, 15] to the point where it is practically unfeasible in many dwellings.

The third problem is noise from mechanical ventilation provision. Mechanical ventilation is increasingly adopted to meet more onerous energy performance requirements, or to limit the potential for external noise ingress. While there are recommendations to limit noise from mechanical services, this is not generally measured or controlled unless there is a specific contractual requirement to do so. Evidence from other European countries indicates that when it is not regulated, noise from mechanical services frequently causes so much annoyance to occupants that they turn down the system operating point, or turn it off. Evidence suggests that lower noise limits from mechanical services are also appropriate.

The problems identified in this paper result in new dwellings currently being built that do not enable residents to enjoy reasonable internal air quality and noise levels simultaneously. The ventilation requirements and conditions under Part F are described first. Analysis and discussion of natural ventilation provision is then discussed, followed by consideration of noise from mechanical systems.

3. VENTILATION REQUIREMENTS

Ventilation is the supply and removal of air from a building. AD-F notes that ventilation is to be provided for the following purposes:

- To provide outside air for breathing
- To dilute and remove pollutants in the air, including odours
- To control excess humidity, particularly in rooms such as bathrooms and kitchens.

AD-F identifies three distinct ventilation conditions:

- Whole building / dwelling ventilation - provided continuously when occupied
- Extract ventilation from wet rooms - provided intermittently when required
- Purge ventilation - provided throughout the dwelling, intermittently

The provision of “adequate ventilation” includes meeting all these requirements at different times. Ventilation air may also be used as a means to cool buildings – i.e. to assist in the provision of thermal comfort, but this is not controlled under AD-F. In this respect AD-F may be understood to relate to ventilation that occurs during the heating season. AD-F gives three methods of compliance for new dwellings:

- Providing the ventilation rates shown in Tables 5.1a and 5.1b of AD-F. These are the performance requirements for any ventilation system.

- Following the guidance provided for the four types of systems outlined in section 5 of AD-F. Where mechanical ventilation is used for either supply or extract, the minimum ventilation rates required are shown in Tables 5.1a & 5.1b of AD-F. Where background ventilators (also referred to as "trickle vents" within AD-F) are employed, sizing charts are provided to determine the minimum provision. These systems are discussed in more detail below, as they are the most common means of compliance.

- Meeting the performance criteria set out in Appendix A of AD-F. These criteria are exposure levels of various indoor air pollutants; this method is provided for reference, and forms the reasoning behind the minimum ventilation rate based on floor area, which is frequently overlooked by designers and commissioning engineers.

AD-F describes four types of ventilation Systems for dwellings, summarised below; there is more detailed guidance in the Domestic Ventilation Compliance Guide[16].

3.1 System 1 – Background vents with intermittent extract

Background ventilators are considered to provide whole dwelling ventilation; this is then supplemented by intermittent mechanical extract from wet rooms (such as kitchens, bathrooms and utility rooms). Purge ventilation is generally provided by opening windows. System 1 is often the default ventilation strategy, bearing most resemblance to traditionally established systems and expectations. The effective area described in AD-F for trickle vents is based upon a meteorological wind speed of 4 m/s at 10 m height, a difference pressure across the vent of 0.6 Pa and 1 Pa for single and multi-storey dwellings respectively and a temperature difference of 15°C between internal and external conditions. Where the temperature difference, or wind speed, is less than that discussed in AD-F then the suitability of the ventilation provision may be questioned; this condition is not a matter that is addressed by this paper.

3.2 System 2 - Passive Stack Ventilation (PSV)

This system comprises vertical ducts to roof terminals from wet rooms. Polluted air is drawn up the ducts by wind or stack effects. The replacement air is considered to be provided by means of background ventilators. Purge ventilation is generally provided by opening windows.

3.3 System 3 – Continuous mechanical extract (MEV)

This type of ventilation system extracts air from wet-rooms. The replacement air is provided by means of background ventilators, or infiltration may be relied upon where the design air permeability is greater than 5 $m^3/(h.m^2)$. The system can be either a centralised system, comprising a single fan ducted to serve multiple rooms, or a decentralised system where individual fans extract air from each room. The systems have two ventilation rates - trickle and boost. The trickle rate must meet the minimum ventilation rates in Table 5.1b in AD-F, and the boost setting must meet those in Table 5.1a for continuous extract - minimum high rate. Purge ventilation may be provided by opening windows.

3.4 System 4 – Continuous mechanical supply and extract with heat recovery (MVHR)

Warm moist air is extracted from wet rooms via a system of ductwork. The air then passes through a heat exchanger before being exhausted to outside. Incoming fresh air is pre-heated as it passes through the heat exchanger before being supplied to habitable rooms such as the living room and bedrooms. The systems in AD-F have two ventilation rates - trickle and boost, and must meet the same minimum ventilation rates for each state as MEV. Purge ventilation may be provided by opening windows. Background ventilators are not required.

3.5 Purge ventilation

There is guidance in AD-F for the provision of opening windows so as to allow for purge ventilation at a rate of 4 air changes / hour (4 ach). This guidance is based on a presumed 3°C temperature difference between internal and external conditions with a 2.1 m/s local wind speed. Where the temperature difference between inside and out, or wind speed, is less than that discussed in AD-F then the suitability of the ventilation provision may be questioned; this is not a matter that is addressed by this paper. AD-F presents a simplification of more complex guidance in BS 5925[20] to which it still refers for the more sophisticated calculation. If not provided with opening windows, mechanical systems are presumed.

The guidance classifies window opening sizes to provide the required purge ventilation rate as follows:

Window type	Open area assumed	Opening angle	Open are requirement
Hinged or pivot windows	Height x width of opening part	≥ 30°	1/20th of room floor area
		≥ 15°, < 30°	1/10th of room floor area
		< 15°	Not suitable for use
Sliding sash	Open area	-	1/20th of room floor area

Table 1: Purge ventilation using openable windows

AD-F provides guidance for a number of ventilation conditions. These are explored in more detail during the following section, as are further ventilation conditions that relate to acoustic design.

4. NOISE ASPECTS OF VENTILATION CONDITIONS

AD-F provides for a range of ventilation conditions in order to address the various demands imposed by occupation.

4.1 Whole building ventilation

It would seem entirely appropriate to achieve indoor ambient noise level limits while providing whole building ventilation, as this is required continuously while the building is occupied. This should be the minimum requirement under any planning condition to limit external noise ingress.

4.2 Control of humidity in wet rooms

For the control of humidity from bathrooms and kitchens, extract ventilation rates vary depending on whether extract is provided intermittently (as with Systems 1 or 2) or there is continuous extract from MEV or MVHR. The intermittent extract rates required are similar to purge ventilation rates, while the minimum high rates required for continuous extract are generally lower. While high noise levels under intermittent extract conditions may be annoying and are reported anecdotally[28], no systematic research of acceptable levels has been identified. Some informative research is discussed in section 7 concerning the minimum high rate for mechanical extract, but more research is needed to inform acceptable noise limits for intermittent extract.

4.3 Purge ventilation and over heating

The requirement for purge ventilation is in AD-F is described as:

"..to aid the removal of high concentrations of pollutants and water vapour released from occasional activities such as painting and decorating or accidental releases such as smoke from burnt food or spillage of water. Purge ventilation is intermittent, i.e. required only when such occasional activities occur."

As for intermittent extract, tolerance of noise levels under purge ventilation conditions has not been widely researched, and is not widely reported, although interactions have been noted between noise, air quality, thermal comfort and lighting[21].

Although thermal comfort is not addressed by AD-F, purge ventilation may be used to control overheating. Whilst the relationship between noise, temperature and comfort in a residential environment is not well explored some studies have been undertaken. Research by Santos and Gunnarsen revealed that a decrease in noise level of 7 dB gave the same decrease in annoyance as a 1^{o}C reduction in operative temperature[22]. Separately, Clausen et al. found that, within a temperature range 23-29^{o}C, a 3.9 dB change in noise level had the same effect on comfort as a 1^{o}C change in operative temperature[23].

It is reasonable to suggest that purge ventilation and sleep may not be compatible as purge ventilation is intermittent and may thus disturb sleep. Therefore if purge ventilation is necessary to control overheating, an occupant may choose to sleep with the windows open overnight.

The provision of purge ventilation (4 ach) may be considered by mechanical means, using the same system components as for whole building ventilation. However, the purge ventilation rate is likely to be at least 9 times the whole dwelling ventilation rate, if the whole dwelling rate is based on the minimum of 0.3 l/s.m^2. Fan noise would increase by many tens of decibels for this increase in flow, consequently the fan would need to be significantly oversized as compared to the whole building ventilation rate. Operation for whole building ventilation would then be at much lower levels of mechanical efficiency. Ducts would need to be sized sufficiently to prevent regenerated noise becoming excessive. For example, in a 40 m^2 flat, the primary duct may need to be 300 mm diameter to limit regenerated noise. The requirements for a mechanical system to provide the required purge flow while meeting the preferred noise level limits is not therefore considered to be particularly practical, sustainable or affordable, despite sometimes being required by planning conditions; this matter is discussed further in section 5.

On the basis that natural and mechanical purge ventilation, as well as night time window opening, can in certain circumstances be reasonably excluded (on the basis of sleep disturbance) a means of mechanical cooling provision may be a necessary consequence of providing suitable standards of indoor environmental quality. Acoustic issues associated with mechanical cooling should therefore also be a consideration.

More research is required to identify acceptable noise levels under purge ventilation conditions. These limits may be different for external noise ingress, if purge ventilation is provided with opening windows, or for noise from mechanical services. The role of purge ventilation in controlling overheating should also be qualified, to enable reasonable internal environmental quality, but this is beyond the scope of this paper. The following sections consider the acoustic implications of designing to achieve whole building ventilation rates for the various Systems described in AD-F.

5. REQUIREMENT TO LIMIT NOISE LEVELS IN DWELLINGS

Requirements to control external noise ingress into new dwellings are described in planning conditions, generally where environmental health officers identify external noise as being a concern. Some local authorities describe levels of external noise sufficient to warrant a planning condition in their local plans, others determine the requirement on a case by case basis.

In our experience local planning authorities (LPAs) lack a singular coordinated method for stipulating how noise related concerns may be addressed. For instance, planning conditions may require a scheme of sound insulation against external noise with windows shut and another means of ventilation provided, or refer to a scheme of acoustic glazing or acoustic vents. Planning conditions may make no reference to, or requirement for, associating ventilation provision and noise levels, or they may call for internal ambient noise levels to be achieved when windows are open for amenity, irrespective of ventilation provision. Some LPAs require that the internal ambient noise levels are achieved during purge ventilation provision.

Without a coordinated methodology and standard it is not possible to ensure consistent and appropriate environmental noise standards at a national level; suitable technical guidance on this matter would be beneficial. While Planning Policy Guidance Note 24 "Planning and Noise" (PPG 24)[18] has been revoked; the National Planning Policy Framework[19] is yet to have accompanying technical guidance. In view of the forgoing discussion, it is suggested that internal ambient noise level limits identified in this paper should be achieved whilst ventilation is provided at the whole building ventilation rate.

It is also our experience that it is not common practice for planning conditions to identify noise limits specifically for mechanical ventilation systems within dwellings. When a mechanical system is running on its minimum low rate AD-F refers to BS 8233 and recommends, but does not require, that noise levels do not exceed 30 dB(A) in bedrooms and living rooms. AD-F also prefers that noise levels should be lower; this consideration is discussed in more detail later in section 7.2; as a “recommendation” this noise criteria remains unregulated. Currently Part E of the Building Regulations governing the Resistance to the Passage of Sound, described in Approved Document E (AD-E) do not address the penetration of external noise into a dwelling, nor the noise levels that are to be achieved within a dwelling from building services[17]. Until the appropriate place for legislation to control these aspects is determined, LPAs could regulate noise from mechanical services with a planning condition exactly as for external noise ingress.

6. NATURAL VENTILATION PROVISION: SYSTEMS 1 AND 2

This section explores the constraints and limitations of providing trickle ventilators within residential buildings. The general calculation method for the sound insulation provided by façade elements is described in BS EN 12354-3[27]. The application of this Standard and manufacturers’ literature for the sound insulation of their products is used in the assessment below. Six varieties of through-frame trickle vents of nominal 4000 mm^2 free area were tested[24], and shown to have a typical $D_{n,e,w}$ (C_{tr}) of 34 (-1) dB. The equivalent area of such vents is typically a little over 2,500 mm^2. The sound insulation provided by various elements and partially open windows has been extensively researched and documented[24, 25]. The EU SCATS project[26] for example accepted that, at an open window, the noise attenuation is 10–15 dB.

The example dwellings examined below have been taken from Appendix C of AD-F. Systems 1 and 2 require nominally equal provision of background ventilators and are therefore subject to the same acoustic constraints. It is noted that the greater the sound level difference the lesser the impact that external noise will have upon internal noise levels.

6.1 Systems 1 and 2: Ground floor flat

The example in Appendix C of AD-F shows that in a single bedroom, ground floor flat of 36 m^2 floor area, the total equivalent area of background ventilators should be at least 35,000 mm^2. Such a dwelling may only have windows in the bedroom and living room; as such around 17,500 mm^2 equivalent area would be required in each. Given that a typical through-frame trickle vent may have an equivalent area of a little over 2500 mm^2 while being somewhere between 400 and 500 mm long, the total length of trickle vents required would be in the region of six or seven linear metres. This extent of window frame is unlikely to be available in a dwelling of this size. Disregarding these practicalities for the time being, based on typical through-frame slot vents, seven units may be required to provide the required equivalent area, and the sound level difference into the small bedroom in example C1 of AD-F is some 19 dB with standard trickle vents.

It may also be noted that if the design air permeability is less than 5.0 m^3/m^2.hr, an additional 10,000 mm^2 of background ventilator effective area is required to be provided. This would increase provision to 45,000 mm^2, with consequential implications for sound insulation. Even more significantly, however, if the flat has a single exposed façade, the area of background vents determined from Table 5.2a is required at both low and high level within the window - i.e. the area is doubled. This would appear to offer increasingly few possibilities for natural ventilation without a bespoke design, as well as being practically unfeasible with background ventilators.

6.2 Systems 1 and 2: Semi-detached house

Example C5 of AD-F shows that for a semi-detached house of 84 m^2 floor area, the total equivalent area of background ventilators should be at least 40,000 mm^2. With five habitable rooms and two wet rooms, let us assume 2,500 mm^2 equivalent area in the kitchen and bathroom, leaving 35,000 mm^2 required between the dining room, living room, and three bedrooms. Noting as above this would typically require three through frame trickle vents each around 450 mm long, in each habitable room.

Again disregarding practicalities, with three typical through-frame slot vents, the sound level difference into the small bedroom in the example of AD-F is some 21 dB. This may be compared with a typical sound level difference through 4-16-4 mm double glazing, assuming a window area that is 10 % of the floor area, of 31 dB for road traffic noise. Hence the limiting factors are due to the ventilation detail and room volume, not the glazing.

6.3 Challenges in natural ventilation provision

The examples above illustrate how sensitive the façade sound insulation design is to the ventilation strategy, and how the background ventilator requirement is a function of not only the internal floor area and number of bedrooms, but also the design air permeability, the height of the dwelling above ground level and the number of exposed façades. The practicality of incorporating the number of background ventilators calculated is often unfeasible. Evidence demonstrates that Building Control frequently accept that partially open windows may be relied upon for compliance with Part F, whether or not appropriate provision of background ventilators is made [28]; however the ability of such a strategy to provide adequate ventilation is highly questionable, and clearly this undermines any façade sound insulation performance.

Building Control and Planning are separate functions; there is generally no coordination between them - so that the means of compliance with Building Regulations is of no concern to the LPA. Hence the LPA may be satisfied that façade sound insulation is achieved with suitable glazing and perhaps one or two trickle vents (depending on their views), while Building Control may simultaneously consider that opening windows may be required to provide the ventilation. The occupants may therefore choose suitable internal noise levels or adequate ventilation, but not both.

When considering noise ingress through glazing, the glazed area is typically proportional to the floor area and hence room volume, so that the sound level difference is roughly independent of room size. When considering ventilation openings, the sound level difference is a function of room volume only. Hence meeting the requirement for background ventilators is typically the most significant constraint in controlling external noise ingress into small rooms, thereby limiting the potential for using System 1 or 2. The significantly increased requirement for background ventilators with Systems 1 and 2 in the current version of AD-F over previous versions can mean that they are now acoustically unfeasible on sites where previously they were acceptable.

Although there has been some work to develop methods to assess openings for natural ventilation that control noise without unduly restricting air flow[29], there are no general solutions widely available for residential design. “Acoustic” trickle vents are widely available, and can provide higher levels of attenuation, however the acoustic attenuation also often typically reduces the airflow performance. Effective acoustic designs therefore tend to be so much larger than “standard” type vents that it is entirely impractical to incorporate the effective areas calculated into the façade. Bespoke natural ventilation design solutions are available from a few manufacturers[30], but the impact on the façade is generally significant; this requires a commitment from the developer and architect early in the design process to adopt these solutions.

Another significant problem with natural ventilation solutions is their misuse by occupiers, who may not operate trickle vents appropriately[28]. While it is appropriate that trickle vents are controllable, it may be that a wider understanding of the necessity for sufficient ventilation in modern buildings will take time to gain hold in general consciousness.

Window opening behaviour has been demonstrated to be far from simple, and is not easy to predict when there is more than one variable affecting the indoor environment[31]. It is understood that the question of whether it is reasonable to design ventilation systems that require occupants to open their windows periodically is currently being addressed by German courts[32]. This follows the introduction in Germany, in 2009, of the stricter ventilation standards within DIN 1946-6.

7. MECHANICAL VENTILATION PROVISION: SYSTEMS 3 AND 4

Since 2002 one of the driving forces to improve standards of energy efficiency in National regulations has been European legislation[33]. These changes in standards have in turn lead to the more extensive use of mechanical ventilation with heat recovery. Awareness of the issues associated with the provision of mechanical ventilation and noise pre-date this more recent, larger scale adoption of the technology, although it would appear that the pitfalls that have been identified historically may not have been widely considered. For instance, in the Netherlands, the more recent, widespread and increasing use of mechanical ventilation has lead to much controversy[34] which could no doubt have been avoided had the lessons been heeded. To date the implications of mechanical ventilation have been more thoroughly reviewed in other countries, and that research is discussed below.

7.1 System 3: MEV

With MEV, as noted previously, building leakage may be relied upon for make up air, but this relies upon assumptions about both the design and as-built air permeability. Hence it may be considered prudent and appropriate to include trickle vents providing an effective area of 2,500 mm^2 in each habitable room. Inclusion of just 2,500 mm^2 effective area into the examples in 6.1 and 6.2 would result in a sound level difference of 28 dB and 26 dB respectively with standard background ventilators; when only one vent is required, it is usually practical and feasible to use “acoustic” trickle vents, and hence achieve greater attenuation as required to control external noise ingress.

This ventilation strategy may currently present the lowest level of acoustic risk for designers as extract is typically made from rooms that are not noise sensitive i.e. bathrooms and kitchens;

however, MEV still requires coordinated consideration. Balvers et al[34] found that in 67 % of cases ventilation units were located in positions that increased the chances of ventilation noise. The location of the ventilation unit, or ventilation units in the case of decentralised systems, is therefore an issue that needs to be addressed in order to mitigate noise related concerns. Stevenson et al[46] note excessive noise arising from poor ductwork in MEV systems on a small development that they studied. In order to control noise levels occupants were reported to have the habit of keeping the MEV ventilation rate low. Stevenson et al also note one instance where the noise from the pump of the domestic heating system was a cause for complaint. The non-acoustic drawbacks of MEV relate to energy use and comfort; the fans used to establish air flow require energy, hence the appeal of MVHR. Trickle vents are also subject to mis-operation by occupiers.

7.2 System 4: MVHR

In a 1997 Swiss study, Dorer[35] et al suggested that sound levels should be evaluated in comparison to the background noise, as historically ventilation systems had been based on natural systems without mechanical noise. Although this is not generally practical, those researchers also concluded that sound levels according to the Swiss standards of the time for system noise, 30 to 35 dB(A), were too high, and that acceptable ventilation system noise should be 20 - 25 dB(A).

In another 1997 study, Veld et al[36] considered that the acceptance and appreciation of ventilation systems is mainly determined by the perceived indoor air quality, thermal comfort and noise. Three aspects of noise were noted – external noise ingress, system generated noise, and cross-talk through ventilation ducts between rooms. In particular, it was noted that noise related to the ventilation system and components can result in users turning off the ventilation system or closing vents; actions that have a correspondingly negative influence on ventilation and indoor air quality.

At the turn of the millennium a UK study of 50 low-energy rental dwellings, Alexander et al[44], reported criticisms relating to noise and established that noise was one of the main reasons for switching ventilation back to "normal" (presumed to mean natural ventilation). In 2002 Concannon[48] noted that noise levels from mechanical systems of 30 to 45 dB(A) are typical in single-family dwellings if no sound reduction measures are present. Macintosh and Steemers[45] reported upon a study in 2005 of 58 urban UK homes with MVHR systems. Complaints by occupants about noise from the inlets were observed. A limited number of sound level measurements were undertaken with windows both open and closed. It was remarked that in one case, the ventilation system was almost as noisy as having a window open.

In 2007 Kurnitski reported on a Finnish study of 102 newly built houses[37]. He concluded that only 57 % of the dwellings were capable of complying with the ventilation regulations of 0.5 ach with a noise level in living rooms and bedrooms not exceeding 28 dB(A). Complaints about ventilation noise were found to correlate with the maximum noise level in bedrooms when the ventilation system was operated at its <u>maximum</u> fan speed, the boost setting. The as-used average sound pressure level, including background noise, was recorded to be 22 dB(A); cases of noise levels as low as 17 and 18 dB(A) were recorded. Measurement periods with a background noise level below 20 dB(A) were available in all houses. Systems were generally operated at the level at which noise was tolerable, despite the ventilation rate being inadequate at those settings. Noise levels up to 30 dB(A) were described as "too noisy" by more than 40 % of respondents.

In 2008, Hasselaar[38] inspected 500 homes with measurements and interviews with occupants. He noted that noise of fans limits the occupiers' use of higher set points for the required ventilation volumes, and the rooms became polluted as a result. Similarly Hady et al[39] note from a survey of 100 homes that the noise level at the set point was so high that users operated systems at lower levels, and significant adverse health effects were the result of insufficient ventilation.

Many of these findings were identified again by Balvers et al[34] in 2012, following surveys of 299 homes in the Netherlands. At the time of the study noise levels were unregulated. With the mechanical systems set to provide the required flow rates (or highest possible where they did not comply), noise levels exceeded 30 dB(A) in one or more bedrooms in 86 % of homes with MVHR. The ventilation unit was considered to be in an inappropriate place, such as in a bedroom cupboard, in 53 % of homes; and silencers were not properly installed on either the supply or exhaust ducts in 66 % of cases. Not surprisingly, most users do not operate ventilation systems as recommended because of high noise levels. In 2012, the Dutch introduced a regulation to limit noise at 30 dB(A) from mechanical ventilation systems in living rooms and bedrooms.

7.3 Appropriate noise limits for MEV and MVHR

Finnish guidance[47] published in 2008 requires that noise from HVAC systems in residential rooms does not exceed 28 dB(A), with a limit of 24 dB(A) for a better quality indoor environment. For all standards of internal environment, noise levels in kitchens must not exceed 33 dB(A). The standard for certified PassivHaus dwellings is a limit of 25 dB(A) in both living rooms and bedrooms[41]. For all residential design, not just that using MVHR, BS EN 15251[40] recommends a living room design range of 25 to 40 dB(A) with a default design value 32 dB(A) and a bedroom design range of 20 to 35 dB(A) with a default design value 26 dB(A).

Kurnitski et al[37] undertook a survey examining the dependency between the maximum noise level in bedrooms and ventilation noise complaints. An upper limit threshold of 22 dB(A) resulted in < 10% complaints and an upper limit threshold of 25 dB(A) resulted in < 20% complaints. Based upon this same research a significant dependency was found between the maximum fan speed of the ventilation unit (boost) and complaints, rather than the whole dwelling ventilation rate. Under this scenario complaints of < 20% could be applied to the boost condition with the consequence that, at the continuous extract minimum low rate (as AD-F), the number of complaints for the majority of time would fall nearer to, or within, the < 10% threshold. UK research is required to determine if attitudes are similar.

The message from the above literature review of over 1000 homes is clear, and has been found on numerous occasions in multiple countries: if noise levels from mechanical systems are not regulated, they are generally excessive and consequently many people opt – in ignorance – to live with inadequate ventilation and suffer the risk of the associated health effects, rather than tolerate excessive noise levels.

8. COMMISSIONING

Although the noise issues relating to mechanical ventilation have not been extensively researched in the UK, deficiencies in air flow rates are already widespread[42], despite the requirement in the 2010 Part F for commissioning to be undertaken by a “competent person”. No doubt acousticians would agree that commissioning checks on performance are only effective if there is also a requirement for the person carrying out the measurements to be independently accredited by a third party, as the only way to mitigate pressure brought to bear on the tester by the contractor. Testing on completion is risky for contractors; they need to be able to effectively manage the risk, which would mean that systems would need to be appropriately designed. Our current experience includes inspection of MVHR units which have not even been tested for noise emissions as described in BS EN 13141[43]; suppliers of MVHR systems can lack the knowledge and expertise to design appropriate noise control measures even where data is available.

Unless MVHR noise levels are included within the Regulatory framework, and are backed up with commissioning requirements, it is likely that no regard will be given to them. If noise levels are not regulated, ventilation systems may not be tolerable to occupants. It is suggested that it may be a requirement in AD-F to control noise to suitable levels along with adequate flow rates.

Until regulation of noise from mechanical services becomes a statutory duty, LPAs could also regularly stipulate the need for commissioning noise measurements for MEV and MVHR to demonstrate that adequate conditions have been achieved, whether or not external noise is an issue for those sites. In our experience commissioning measurements are very seldom conditioned by LPAs; without this requirement there is very little or no enforcement of the conditions.

9. CONCLUSION

Three significant problems with achieving suitable ventilation and reasonable noise levels have been identified and discussed. The first problem is due to insufficient qualification of the ventilation condition that should be achieved while meeting the internal ambient noise level limits. It is suggested that as a minimum, the provision of whole dwelling ventilation in accordance with AD-F should be assessed and controlled to meet suitable noise limits, which may differ for external noise ingress and mechanical services noise.

The second problem concerns the practical provision of sufficient trickle vents if a natural ventilation strategy is sought; the sensitivity of the façade sound insulation design to the details of the ventilation requirements must be considered early in the design. It is noted that the trickle vent provision may also rely on the design air permeability. The example calculations demonstrate that natural ventilation - System 1 or 2 - requires so many trickle vents that if installed, the achievable performance may be only marginally better than opening windows. Evidence demonstrates that there is often significant under-provision of the necessary quantity of vents in practice; this means that the Building Control body may consider that opening windows provide the required ventilation, while the sound insulation strategy offered to the LPA relies on windows being closed.

The third problem can be mechanical ventilation that is unacceptably noisy to the occupants. A common reason of occupant mis-operation of mechanical ventilation systems is noise. If these systems are to be acceptable and used appropriately, it is imperative the noise emissions are regulated, and that the commissioning requires both airflow and noise levels measured by organisations with third party accreditation. It has been noted that AD-F, referring to BS 8233, recommends that noise levels from mechanical systems, when providing ventilation at the whole dwelling ventilation rate, do not exceed 30 dB(A) in bedrooms. The literature review above however suggests that this may be above the LOAEL. More UK specific research is needed to confirm appropriate upper limits; the BS EN 15251 default values of 26 dB(A) for bedrooms and 32 dB(A) for living rooms could be used in the mean time, although this bedroom level may result in complaints from more than 20 % of dwellings.

Evidence suggests that the upper limit threshold should relate to the continuous extract, minimum high rate (boost) rather than the whole dwelling ventilation rate, as currently proposed by AD-F. Further UK specific research is required to determine suitable noise limit levels for boost ventilation rates from MEV and MVHR. Further UK specific research is also required into acceptable noise levels for the provision of intermittent extract and purge ventilation, from both external sources and mechanical services; owing to the complete lack of data they may be temporarily excluded from consideration within design.

It is considered that Part F of the Building Regulations may be the appropriate place to provide statutory noise limits, and a requirement for commissioning noise measurements from mechanical services. In the mean time, LPAs could stipulate noise limits from mechanical systems within dwellings when there are no external noise issues identified. Greater coordination between the Approved Documents and technical guidance to accompany the NPPF is considered essential. It is suggested that the gap between LPA and Building Control may be bridged if planning conditions refer to a “scheme of acoustic design to enable appropriate internal ambient noise levels to be achieved whilst ventilation is provided at the minimum whole building ventilation rate as described in Approved Document F”. This type of condition would cover both natural and mechanical systems, depending on what is employed on a particular development, and enable separate limits for each. A requirement for commissioning measurements is considered appropriate in all cases.

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