Barriers to Natural Ventilation Design of Office Buildings

National Report: Great Britain

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NatVent™
Overcoming technical barriers to low-energy natural ventilation in office type buildings in moderate and cold climates
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1. INTRODUCTION

The objective of the study described in this report is to identify the perceived barriers which restrict the implementation of natural or simple fan assisted ventilation systems in the design of new office type buildings and in the refurbishment of existing buildings. The perceived barriers are identified by structured interviews based on questionnaires among leading designers and decision makers. The interviews have focused on general knowledge, viewpoints, experience and perceived problems with natural ventilation in office type buildings and on the decisions actually taken in specific building projects.

Mechanical ventilation systems are often installed in office buildings where good natural ventilation would have been sufficient to obtain comfortable indoor climate and good air quality. It is important to identify the barriers which restrict the implementation of natural ventilation systems which then leads to the decision to install mechanical ventilation plants in office buildings where it is not strictly necessary. Knowing the barriers is the first step in providing solutions to overcome them and to our knowledge, this is the first time such a study has been carried out.

This report describes the results of the interviews performed in Great Britain. The main results of each countries interviews will be compiled in a final European report. The final report will summarise the identified common problems with the implementation of natural ventilation systems and to gain experience from countries that have solved some of the problems. The final report will also give recommendations on how to overcome the identified barriers.

This report is an output from the NatVent™ project which is part funded by the European Commission DGXII within the JOULE programme 1994-1998 and under contract: JOR3-CT95-0022. The UK work in the project is also part funded by the British Department of the Environment.

The study is part of a pan-European project NatVent™. The NatVent™ project team would like to thank all the interviewees, designers and decision makers for the knowledge and experience they have brought to the project and for their invaluable time they have spent.

The identification of perceived barriers to the design of natural ventilation for office buildings is the first work package of the NatVent™ project being carried out under the JOULE programme. The two other work packages in the NatVent™ project are:

- Performance of naturally ventilated buildings.
  The aim is to evaluate the performance of twenty existing buildings designed specifically for natural ventilation.

- 'Smart' technology systems and components.
  The aim is to develop systems, components and solutions to the barriers and shortcomings identified in the first two work packages. This work package includes:
  - Air supply components suitable for high pollution and noise loads
  - Constant (natural) air flow inlets
  - Advanced natural ventilation systems with heat recovery
  - 'Smart' components and 'intelligent' controls for night cooling
  - Integration of ‘smart’ systems for year-round performance
The *NatVent™* project is performed by nine organisations in seven central and northern European countries. The project is co-ordinated by the Building Research Establishment Ltd, BRE (GB). The other partners are:

Centre Scientifique et Technique de la Construction, CSTC (BE)  
Danish Building Research Institute, SBI (DK)  
TNO Bouw (NL)  
AB Jacobsen & Widmark, J&W (SE)  
Technical University, Delft (NL)  
Willan Building Group (GB)  
Norwegian Building Research Institute, NBI (NO)  
Sulzer Infra Laboratory (CH)
2. METHOD

The perceived barriers to natural ventilation design of office buildings are identified in an in-depth study with structured interviews among leading designers and decision makers: architects, consultant engineers, contractors, developers, owners and the governmental decision maker responsible for regulations and standards.

Interviews with the users of office buildings are not included in this study, since they are not involved making the decisions in the design stage. The users perception of the indoor climate is part of Work Package 2: ‘Performance of naturally ventilated buildings’, where physical parameters e.g. ventilation rates, room temperatures and indoor air quality are measured and compared with the users responses. The interviews were conducted as part of work package 1 and consists of two parts.

1) General view on natural ventilation in office buildings.
   This part focus on general knowledge, viewpoints, experience and perceived problems with natural ventilation systems in office type buildings.

2) Specific building project.
   This part focuses on the decisions actually made during the design or refurbishment of an office type building.

Both parts of the interview were, in general, performed with all interviewees.

The interviews were performed among:

10 Architects
  7 Consultant engineers
  2 Contractors
  2 Developers
  3 Owners
  2 Governmental decision maker (responsible for regulations and standards)

The number of designers and decision makers interviewed are limited due to limited financial resources in the project. The persons interviewed were selected with the intention to also identify the variety in opinions and viewpoints on natural ventilation in office buildings.

The interviews were based on two questionnaires to be completed in during an interview. The first questionnaire covered ‘General views on natural ventilation in office buildings’ and the second covered ‘Specific building project’.

The questionnaires were designed to facilitate the performance of statistics on the viewpoint of the interviewee with ample space for additional comments, remarks and viewpoints not included in the actual questions.

The questionnaires were completed by the interviewee and the interviewer working together with the interviewer guiding the interviewee in understanding the questions if necessary. If a question couldn’t be answered by the interviewee or was irrelevant to the interviewee it was indicated in the questionnaire.
2.1 Questionnaire on general view

The questionnaire concerns general views on natural ventilation in office buildings. The questionnaire comprises of 14 subjects:

1. Interviewee
   Identification of the interviewee

2. Organisation
   Description of the organisation: type, disciplines, number of employees and building types.

3. Knowledge
   Knowledge on mechanical ventilation, heat recovery, mechanical cooling, ordinary natural ventilation and special design natural ventilation in offices including special ventilation windows, advanced vents, internal ventilation openings, roof openings etc. The questions were answered by indicating the knowledge on a specific 5 point scale ranking from ‘None’ to ‘Thorough’.

4. Experience
   Ventilation experience in the organisation focusing on the extension of new and refurbished office buildings designed or owned by the interviewee’s organisation. Also questions to identify the percentage of buildings with: mechanical ventilation, ordinary natural ventilation and special design natural ventilation in the offices.

5. Project fee
   Type of project fee received by architects and consultant engineers for the design of office buildings. Questions were asked to identify the percentage of projects with fee paid as: fixed fee, percentage of construction cost, per hour rate or other type of payment for design.

6. Natural ventilation in cellular offices

7. Mechanical ventilation in cellular offices

8. Natural ventilation in open plan offices

9. Mechanical ventilation in open plan offices

General views on perceived advantages or problems with either natural or mechanical ventilation in cellular and open plan offices. The questions asked under subjects 6, 7, 8 and 9 are identical and only the ventilation system and the office type differs. The questions concern: design, viability of products, performance in practice, controllability and costs and were answered by checking the same 5 points scale as used in subject 3.

10. Your source of natural ventilation knowledge
    Possible sources are: standards, guidelines, building studies, experience, own design and other.

11. Expected future use of natural ventilation in office buildings
Expected future use of natural ventilation in office buildings designed or owned by the organisation. The question were answered by checking a specific 5 points scale ranking from ‘Decreasing’ over ‘Unchanged’ to ‘Increasing’. The interviewees were also asked why they have this expectation. Requirements restricting the use of natural ventilation in offices. Perceived restriction in the use of natural ventilation in offices from requirements in building codes, norms, standards, working condition codes etc. The question were answered by checking a 5 points scale ranking from ‘None’ to ‘Comprehensive’ and by indicating which code, norm or standard that includes the restrictions.

12. Desirable new design tools for natural ventilation
   Possible new sources and design tools could be source books, guide lines, examples, simple or advanced computer programmes etc.

13. Desirable new components for natural ventilation
   Possible new components could be air inlets, control systems etc.

2.2 Questionnaire on specific building project

The questionnaire concerns one specific building project. The building could be either newly constructed or newly refurbished and could be with either natural or mechanical ventilation. The buildings were selected by the interviewee to be typical. The questionnaire comprises 5 subjects:

1. Interviewee
   Identification of the interviewee

2. Building
   Identification of the building and indication of key figures including building name, address, building type, year of construction, year of refurbishment (if any), site (urban, sub-urban, industrial or rural), m²-floor area, number of storeys, building depth from facade to facade and storey height.

3. The design
   Description of the actual design of the ventilation system and the building design parameters with influence on the ventilation demand and the ventilation system design. The design were described by checking a row of boxes for each room type in the building: offices, meeting rooms, canteen, corridors, stairways, entrance hall, atria, lavatories and others. The design specification includes:

<table>
<thead>
<tr>
<th>Ventilation system:</th>
<th>Mechanical ventilation, mechanical exhaust, natural ventilation, heat recovery, night time ventilation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mechanical cooling:</td>
<td>In ventilation system, cooled ceilings</td>
</tr>
<tr>
<td>External openings:</td>
<td>Ordinary windows, special ventilation windows, ordinary vents, advanced vents, stack ducts, ventilation chimneys, roof openings, ducted air supply</td>
</tr>
<tr>
<td>Internal horizontal flow openings:</td>
<td>Doors, ventilation openings, open connection</td>
</tr>
</tbody>
</table>
Ceilings: High ceiling, false ceiling, exposed heavy structure

Floor and walls: Exposed heavy floor, internal walls, external walls

4. Background for the design

Indication of critical parameters in the ventilation system design and in the relevant parts of the building design. The critical parameters were prioritised for each of the room types on a 5 point specific scale ranking from ‘1. low’ to ‘5. high’. The critical parameters includes:

- **Winter conditions**: Room temperatures, indoor air quality, draught
- **Summer conditions**: Room temperatures, solar loads, internal heat, draught
- **Controllability**: Individual control
- **Noise**: Internal noise, external noise
- **Pollution and odours**: Internal air and external air pollution or odours
- **Safety**: Fire regulations, security
- **Costs**: Construction, operating and maintenance costs

5. Biggest influence on chosen design

Indication of biggest influence on the chosen design. The influence could be from: architect, consultant engineer, contractor, owner, developer, investor, user, the actual building site, requirements in codes, norms, standards or from other. The influence were prioritised on the same 5 point specific scale as used in subject 4 above.
3. RESULTS

The main results of the interviews are described in this chapter.

3.1 The Interviewee

The ten architects interviewed represent some of the leading British architect offices. They have between 8 and 100 employed. They annually each design 5-25,000 m² floor area in new office buildings and 400-20,000 m² in refurbishment of office buildings. Most of them also design other types of buildings e.g. opera houses, stadia, retail outlets, leisure centres, university buildings, hotels.

The seven consultant engineers interviewed represent some of the largest British consultant engineer offices. They have between 120 and 4,000 employed. They annually design 9-10,000 m² floor area in new office buildings and 5-10,000 m² in refurbishment of office buildings. All of them also designs other types of buildings and constructions.

The two contractors interviewed represent some of the largest British contractors. They have approximately 4,000 employed each and deals with all types of buildings and constructions such as hospitals and prisons. One of them constructed a 100,000m² office building.

The two developers interviewed represents finance and property investment companies. They annually invest in a floor areas of 10-30,000 m² in new offices buildings and 5-10,000m² in refurbishment of offices buildings.

The three owners interviewed were local authority, education and investor. The floor area was between 900-1,700m² for new building and refurbishment is an ongoing process. They were unable to give details on floor area for this.

The governmental decision makers were from the Department of the Environment (DoE) and are responsible for government polices.

3.2 General View

Overall natural ventilation in cellular offices had very good comments except on one aspect. There were no problems with ease of design; performance in terms of cooling, draught and odour control; individual and local control; or with costs both for installation and running and maintenance. User satisfaction seem to be generally good. However, it was felt that external noise and pollution were major problems.

There were similar comments expressed with natural ventilation in open-plan offices although it was felt that there was poor control by individuals, both local and central. Performance was expressed as poor to average but user satisfaction was rated as average to very good. Again external noise and pollution were seen as major problems.

Mechanical ventilation in both cellular and open-plan offices attracted comments that were in general very good in terms of ease of design, performance, user control. However,
installation costs, running and maintenance costs were seen generally as very high in comparison to the natural options.

3.2.1 Knowledge on ventilation

Figure 1 shows the interviewees perception of their own knowledge on the five topics: mechanical ventilation, heat recovery, mechanical cooling, ordinary natural ventilation and special designed natural ventilation. A specific 5 point scale ranking from 1- None to 5-Thorough is used to indicate the level of knowledge.

The interviewees indicated their level of knowledge on the five topics based on the knowledge they felt was necessary to perform their normal task in the design or decision process which was relative to their profession. It is possible to compare the level of knowledge between the professions based on the results as the results can only be used to compare the relative knowledge of the five subjects group by group.

Overall the interviewees have a lower knowledge on special designed natural ventilation compared to their knowledge on mechanical ventilation in offices. Exceptions are the Consultant Engineers who have a high level of perceived knowledge on all types of ventilation.

The knowledge of the remaining groups were very similar although most accepted that their knowledge on mechanical ventilation was better then natural ventilation.

Figure 1. The interviewees perception of own knowledge
3.2.2 Experience

Figures 2 and 3 show the interviewees relative experience with mechanical ventilation, ordinary natural ventilation and special designed natural ventilation in new offices and refurbished offices respectively. The relative experience is the per cent of mechanical or natural ventilated offices designed, constructed or owned, measured by the floor area or alternatively by the number of office buildings.

The relative experience in new offices with mechanical ventilation is much higher than that of ordinary natural ventilation but the contractors and developers had very little or no experience of natural or special designed ventilation. The average experience across most groups showed that both types of natural ventilation were on a similar level (10-15%) but mechanical ventilation was by far the most experienced option; however, this changed with refurbished offices as shown in Figure 3. Owners and architects had more relative
experience with ordinary natural ventilation than with mechanical ventilation in refurbished offices.

3.2.3 Project fee
The type of fee received by the interviewed architects, consultant engineers and contractors for the design of office buildings is shown in Figure 4. The possible fee types are: Fixed fee, percentage of construction costs and per hour rate.

![Figure 4. Type of fee received by the architects and consultant engineers for the design of office buildings](image)

Both architects and contractors usually get paid as a percentage of the construction costs of a project although consultant engineers get paid at a fixed fee rate. The fees depend on the clients and what is required at the time of negotiations.

3.2.4 Design
The interviewees perception of the design of natural and mechanical ventilation in cellular and open plan offices regarding ease of design, availability of design guidelines and advise, availability of products, flexibility to building use and user satisfaction are shown in Figure 5. A specific 5 point scale ranking from 1- Poor to 5- Excellent is used to indicate the interviewees perception of the design.

In general there are no significant differences between the interviewees perception of the ease of design in the four cases:
- Natural ventilation in cellular offices
- Natural ventilation in open plan offices
- Mechanical ventilation in cellular offices
- Mechanical ventilation in open plan offices.

Interviewees emphasised that the ease of design also depends on the complexity of the system e.g. whether it is a simple or an advanced natural ventilation system. Perhaps because of this there are large individual variations in the viewpoints.
Flexibility of design seemed to be rated the poorest but generally most of the areas were rated very good. The naturally ventilated options rated best with the user for satisfaction but mechanical ventilation was rated better for ease of design, guidelines, products and flexibility.

![Figure 5. The interviewees perception of the design of natural and mechanical ventilation in cellular and open plan offices](image)

Nearly all interviewees found that the availability of design guidelines and advice and the availability of products were better for mechanical ventilation systems compared to natural ventilation systems. There are no significant differences in this between cellular offices and open plan offices.

In general the interviewees expect the same level of user satisfaction in natural open plan and mechanical cellular ventilated offices. The interviewees expect a little higher user satisfaction in naturally ventilated cellular offices than in mechanical open plan ventilated offices.

Although users liked to have natural ventilation in their offices, they felt that results could not be guaranteed whereas mechanical ventilation could (providing it did not breakdown). One architect stressed that he avoided mechanical ventilation whenever possible in open plan offices.

### 3.2.5 Performance in practice

The interviewees perception of the performance in practice of natural and mechanical ventilation in cellular and open plan offices regard cooling effectiveness, draught minimisation, ability to remove odours and pollutants, ability to prevent ingress of odours and pollutants, insulation against external noise, generation or transmission of internal noise are shown in Figure 6. A specific 5 point scale ranking from 1- Poor to 5- Excellent is used to indicate the interviewees perception of the performance in practice.
In general the interviewees expected a better performance in practice of mechanical ventilation systems than of natural ventilation systems regarding cooling effectiveness, draught minimisation, ability to remove odours and pollutants, ability to prevent ingress of odours and pollutants and insulation against external noise. They regarded ingress of odour and external noise to be the two main problems with natural ventilation and scored less than 2 on the scale although with external noise, there was very little difference (if any) between both natural and mechanical ventilation.

Performance in practice depends upon the design of the system whether it is well designed or ordinary designed. One engineer stated that in their experience, mechanical ventilation is fitted later after poor performance of natural ventilation in cellular offices.

3.2.6 Controllability
The interviewees perception of the controllability of natural and mechanical ventilation in cellular and open plan offices regard central controllability, local controllability (per office) and individual controllability (per person) are shown in Figure 7. A specific 5 point scale ranking from 1- Poor to 5- Excellent is used to indicate the interviewees perception of the controllability.

In general the interviewees felt that there was an excellent central controllability of mechanical ventilation systems and very poor central controllability of natural ventilation systems especially in cellular offices.

The expected local controllability of natural ventilated cellular offices has the highest rating compared to the other three groups. Natural ventilation open plan had an equal rating for central, local and individual control.

A few interviewees commented on the fact that the controllability very much depends on the design and simple ease of use in natural ventilation systems.
The expected individual controllability of the natural ventilation in cellular offices is higher than the expected individual controllability of the natural ventilation in open plan offices and the expected individual controllability of mechanical ventilated cellular offices is a little higher than the expected individual controllability of mechanical ventilated open plan offices. Local and individual control is perceived to work better for natural ventilation but central control is perceived to work better for mechanical ventilation. This however depends on the complexity of the systems used.
3.2.7 Costs
The interviewees' perception of the costs for natural and mechanical ventilation in cellular and open plan offices regarding installation costs, running costs and maintenance costs are shown in Figure 8. A specific 5 point scale ranking from 1- Inexpensive to 5- Expensive is used to indicate the interviewees' perception of the costs. All interviewees expected installation costs, running costs and maintenance costs to be much higher for mechanical ventilation than for natural ventilation. Running costs were perceived to be much smaller in naturally ventilated offices and overall seemed to be the cheaper option. However, one consultant stated that the running costs for natural ventilation could increase due to the possibility of winter abuse; concern that windows could be left open resulting in increased heating demand.

3.2.8 Source to natural ventilation knowledge
The interviewees' sources to natural ventilation knowledge with regard to standards, guidelines, building studies, experience, own design and others are shown in Figure 9. The scale is the per cent of interviewees using a source type.

The general opinion among the interviewees is that there is huge lack of good sources to natural ventilation knowledge although many had learned from experience and involvement with natural ventilation in buildings. Most of the interviewees mentioned Building Regulations, Building Standards, BRE Digests and BRE Technical Papers as sources. The named sources to natural ventilation knowledge are:

- Building Regulations
- Building Standards
- BRE Digest
- BRE Technical Papers
- CIBSE Guide
- Periodic journals - professional & trade magazines
- BSRIA
- BRECSU Best Practice

Figure 9. The interviewees source to knowledge of natural ventilation

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3.2.9 Expected future use of natural ventilation

The interviewee's expectations on the future use of natural ventilation in offices are shown in Figure 10. The expectation is indicated on a specific 5 points scale ranking from 1- Significant decreasing over 3- Unchanged to 5- Significant increasing.

The developers closely followed by the architects have the highest expectations of an increase in the use of natural ventilation in offices. The three owners have expectations of an unchanged or decreased use of natural ventilation but one owner stated that they would want to continue use of natural ventilation because of its low running costs and improved internal environment (staff want it). Both contractors expected increased use of natural ventilation in offices as one of them felt that mechanical ventilation systems are becoming increasingly complicated and do not run as they were originally designed to. Overall, there is an expected increase in the use of natural ventilation.

Typical reasons mentioned by the interviewees for expecting increased use of natural ventilation in offices are:

- Green issues
- Lower running/maintenance costs
- Public/client awareness of natural options
- Complicated, sophisticated and difficult mechanical systems - not easy to use
- More individual control
- Market led by clients
- Possible future EC regulations
- Capital saving on initial building costs

Typical reasons for expecting unchanged use of natural ventilation in offices are:

- Conservative approach, stick with what they know
- Lack of knowledge on natural ventilation techniques
- Inner city pollution
Typical reasons for expecting decreased use of natural ventilation in offices are:

- Increased outdoor air pollution
- Market trend - perceived as less desirable property for tenants
- Lack of real design guides

3.2.10 Restricting requirements in codes

The interviewees perception of requirements in building regulations, codes, norms and standards restricting the use of natural ventilation in offices are shown in Figure 11. Restrictions to the use of natural ventilation in offices mentioned by the interviewees include:

- Poor attitude of mechanical engineers who are very conservative
- Large resistance from developers/tenants perspective
- Fire regulations
- Process by which speculative offices are designed and funded
- Clients - have an overriding influence
- Public Health requirements
- Interaction of building with wind

![Figure 11. The interviewees perception of requirements in building regulations, codes, norms and standards restricting the use of natural ventilation in offices](image)

3.2.11 Desirable new design tools

The desired new design tools for natural ventilation mentioned by the interviewees depends on their proficiency. In general the interviewed architects requests include:

- Guidelines for architects to use very early in the design process
- Simple computer programmes
- A way of demonstrating the performance of natural ventilation to the client early in the design process
- Successful built examples to act as a president to influence client
The interviewed consultant engineers seek:
- More well documented case studies
- Source books
- Simple and advanced computer tools
- Authoritative guide essential
- Simplified climatic data on wind, solar, cloud cover and temperature risks
- More information on real comfort criteria

The interviewed contractors desires realistic heat load data and updated guides. They would like to see computer programmes which allow for change in the site and its surroundings after completion of original design.

One interviewed developer needed more experience of existing buildings and increased use of computer models. The other would look to designers or consultants for this aspect of construction work.

Of the interviewed owners, more accessible and affordable guides, source books and tools needed to be available to all consultants. Tools were required to encourage integration of all disciplines in the design process and issues of thermal comfort and life cycle costings. Only one owner felt that nothing was required as they had achieved what they wanted.

3.2.12 Desirable new components
The desired new components for natural ventilation mentioned by the interviewees depended on their proficiency.
In general the interviewed architects requested:
- Control systems
- More specific product design
- High performance windows and vents available ‘off the shelf’ rather than ‘specialist kit’
- Design against performance specification which sub-contractors must meet rather than to a particular product.

Of the interviewed consultant engineers, low pressure loss components, good windows and controllable flow openings with low infiltration when closed were desired. Daylight enhancement at back of rooms coupled with natural ventilation systems was also a desire. Although they generally felt that new components were starting to now come through.

The interviewed contractors longed for air inlets with filtration and noise baffles. Simple controls (not via networks or people passing on messages) and the need for more expertise in a packaged approach was required.

The developers desired cheaper integrated components available ‘off the shelf’. Of the interviewed owners two wanted the ability to secure open windows for night ventilation would be very useful and one had no view.

4. SPECIFIC BUILDING PROJECT
The interviewees also completed the questionnaire on a specific building project. The results in the figures in this section of the report are the average of all the buildings included in the interviews. The governmental decision makers did not complete this section.

4.1 The buildings
There were various different types of buildings. Office, retail outlet, workshops, studio’s, residential care centre, headquarters, exhibition hall, light industrial unit and a concert hall. The building sites varied. Only two were on industrial land, one on a Business Retail Park, one on rural land, two on Greenfield, six on suburban and eight on urban land. Size of the buildings varied between 400m$^2$ in rural areas to 50,000m$^2$ in suburban areas.

4.2 Design
Most of the designs used mechanical ventilation although natural ventilation was used in corridors, stairways and atria. Almost all used some form of mechanical exhaust system especially in meeting rooms and toilets. The majority of buildings had ordinary external window openings but a surprising number had special windows and advanced vents particularly in offices and meeting rooms.

The interviewees responses indicated that the use of false ceiling were commonplace. The buildings which had high ceiling usually encompassed the use of exposed heavy structures. Some buildings used a combination of both false ceilings and high ceilings with exposed heavy structures. With the use false floors, lightweight walls and partitions were also used. Most of the buildings had exposed heavy floor and exposed heavy internal walls. A few buildings also used exposed heavy external walls.

One interviewee used natural solar assisted exhaust with small input fans to ensure airflow/acoustic isolation/night cooling. Another used air drawn through heavy floor slabs for some offices in atrium. Another used waffle concrete slab design to increase thermal connection between slab and room and another stated that up to 6 m from facade is natural ventilation and the rest is mechanical ventilation with meeting rooms designed for 10 ach and offices 3 ach.

4.3 Critical parameters
Off all the interviewees, the highest critical parameter indicated was summer room temperatures incorporating solar loads and internal heat loads. Maintenance costs were also indicated as a high parameter and a number of interviewees indicated a high level for lavatories and canteens for internal air pollution and odours.

One interviewee stated that all the factors listed are critical and each and every factor must be successfully solved. A few of the interviewees declined to answer in the manner suggested and just marked the category which they considered to be very important. Only one was unable to comment.
4.4 Influence

The interviewees perception of the persons or conditions having the biggest influence on the chosen design is shown in Figure 13. Again each interviewee were allowed to point out a maximum of 5 critical parameters and were ask to prioritise them from 1- Low to 5- High.

Architects were the ones indicated as having the highest influence on design of buildings with owners coming a close second. Consulting engineers, developers, users and building site were rated as having similar levels of influence.

In a few cases, other was indicated. This other was identified as client, letting agent, commercial considerations and planning permission. One had little knowledge as to who had the biggest influence and another found it very difficult to prioritise between the list.
5. SUMMARY AND CONCLUSIONS

The objective of the study was to identify barriers restricting the implementation of natural or simple fan assisted ventilation systems in the design of new office type buildings and in the refurbishment of existing such buildings. The perceived barriers are identified in an in-depth study with structured interviews based on questionnaires among leading designers and decision makers. The interviews have focused on general knowledge, viewpoints, experience and perceived problems with natural ventilation in office type buildings and on the decisions actually taken in specific building projects. The interviews were performed among: 10 architects, 7 consultant engineers, 2 contractors, 2 developers, 3 owners and 2 governmental decision makers.

5.1 Conclusions

The interviews identified that there was good knowledge of both natural ventilation and mechanical ventilation with a greater experience of mechanical ventilation. There was a significant lack of knowledge and experience on special designed natural ventilation. From the questions asked, it was clear that guide sources to natural ventilation with working examples was required with more accurate calculations.

Desirable new design tools included demonstrable performance of natural ventilation, well documented and monitored case studies, updated CIBSE guides and more simple and advanced computer program design tools. The use of accurate data included wind/cloud cover/temperature, wind pressure coefficients, real comfort data, realistic heat loads, air change rates and thermal comfort/productivity.

Generally the interviewees accept that mechanical ventilation has higher running and maintenance costs and that natural ventilation is the cheaper option but this is difficult to persuade clients as it is more ‘desirable’ to attract tenants to purpose built offices with mechanical ventilation. It is seen as a more attractive offer. It is necessary to educate letting agents and tenants on the benefits of natural ventilation with proven examples to back this up.

Room temperatures at summer and heat loads were felt to be the most important design parameters. Finally, it was apparent that architects have the biggest influence in design of buildings over all the other groups.

5.2 Recommendations

It is necessary to encourage the wider uptake of naturally ventilated office buildings and to expedite natural ventilation as a main design option for new and refurbished offices. Considerable good air quality with high user satisfaction and low energy consumption, installation and maintenance costs were all noted as positive aspects of natural ventilation.

Simple, energy efficient, low cost natural ventilation have to be developed and tested so that the use of natural ventilation in the majority of ordinary office buildings are not a technical difficulty but a simple and well approved design solution.
Guidelines and building standards have to be improved to have a technical and legal background for the design and use of natural ventilated office buildings. The guidelines should also include simple and easy to use calculation rules for the design of natural ventilation.

Simple easy to use computer programmes and design tools that can be used in the early design process by architects, consultant engineers or design teams to analyse the advantages and disadvantages of different ventilation systems need to be developed.

The development of better and improved control systems is required to increase the number of locations and types of office buildings where natural ventilation is obviously the best choice.

General knowledge on natural ventilation must be improved. Among architects, consultant engineers and possibly also contractors the improved knowledge must come from basic education, post education, source books and building studies. The improved knowledge needs to be supplied by simple and easy to understand descriptions and working examples.

The adjustment of the fee structure may also be necessary for the design of office buildings to pay the designers for the energy, indoor climate and total cost advantages of design solutions and not for the amount of equipment installed in the building.
ANNEX I: TYPICAL VENTILATION SYSTEMS IN OFFICE BUILDINGS

The objective of this Annex is to give some background knowledge on typical ventilation systems in British office buildings and on the British tradition on office ventilation. The description is based on the authors immediate knowledge and information collated from various sources. It must therefore be considered as such and not as a scientific or statistical work.

1. Background

In 1992, UK commercial office buildings accounted for 90 km$^2$ of the total non-domestic building stock of some 1,050 km$^2$ gross floor area. An estimated 30 km$^2$ of office building is air conditioned, a number which has approximately trebled since 1980 largely with new construction. There is also much office-like space in buildings in other sectors, in particularly distributary trades, education, health and in industry. The extra area is not quantified but it could be around 100 km$^2$ and mostly naturally-ventilated and cellular.

The UK market is different from that in many other European countries. Much of the space is rented, with typical leases of 25 years (though now falling to 15 years) and was built or converted speculatively. Owner-occupiers are also subject to these trends since few organisations can be confident of their building needs for more than a few years ahead and so have to be sure that they can sell their building. There was a surge of new office buildings in the 1980s in the UK, in part to meet the demands of IT and to suit multi-national tenants. Many were deep-plan, sealed and fully air-conditioned, often with variable air volume (VAV) systems and central atria. A change in planning regulations in 1980s also led to a rapid growth in out-of-town business and industrial parks, some with high proportions of air-conditioned offices.

However, in recent years, increased concern over the adverse environmental impact of energy has encouraged the design and construction of energy efficient buildings, many of them suited to natural ventilation.

2. Natural Ventilation

Natural ventilation is defined as ventilation driven by the natural forces of wind and temperature. It is intentional and, ideally, controlled. It should not be confused with infiltration, which is the unintentional and uncontrolled entry of outdoor air through cracks and gaps in the external fabric of the building.

Natural ventilation is not just about operable and openable windows. It is rather a holistic design concept which is now being used in the architectural design of large offices and other building types. Design is centred on using passive ventilation, based on the stack (temperature) effect and wind pressure differentials, to supply fresh air to building interiors even when the windows are closed. As part of this process, designs incorporate atria or internal stairwells which, in some instances, use low energy fans to provide assisted natural ventilation (i.e. low energy ventilation).

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2.1. Overall strategy for natural ventilation design

Good design is based on the principle that adequate ventilation is essential for the health, safety and comfort of building occupants, but that excessive ventilation leads to energy waste and sometimes to discomfort. The strategy therefore is to ‘build tight - ventilate right’. That is, to minimise uncontrolled (and, usually, unwanted) infiltration by making the building envelope airtight while providing the required ventilation with ‘fresh’ air in a controlled manner. It should be emphasised that a building cannot be too tight - but it can be under-ventilated. For an overall successful natural ventilation strategy, the three issues of:


- Building tightness;
- Good ventilation for occupants;
- Natural ventilation design;

need to be considered together in an integrated manner.

As said earlier, natural ventilation is the movement of air through a building driven by wind and buoyancy induced >stack= pressures. Wind-induced pressures on a building depends on wind direction, its speed and the shape of the building and wind speed; they are also affected by the surrounding built/natural environment. Air density differences between inside and outside air (caused by air temperatures) induce buoyancy forces. These independent forces interact to produce the ventilation air flows. It is then important to be aware that in naturally ventilating a building, two distinct strategies have to be developed for; one for the winter and the other for the summer.

2.2. Winter ventilation

The key issue for winter ventilation is the control of the indoor air quality (IAQ). Natural ventilation as a strategy for achieving acceptable air quality is essentially based on the supply of air to a space to reduce (by dilution) the pollution concentration on the space. Once building related pollution sources are avoided, the only requirement is for 5 l/s per person to address the occupant criterion.

Some simplified guidance on satisfying this requirement has been developed in the UK3. This work showed that trickle ventilators of sizing 400 mm² per m² of floor area can provide the necessary >background= ventilation to satisfy average office occupant densities (of 10 m² per person). In the UK, these ventilators were shown to be capable of providing the fresh air required to maintain metabolic CO₂ levels at or below 1000 ppm (which equates to the 5 l/s criterion) for average external weather conditions.

These trickle ventilators consist of slot ventilators located either in the window frame or incorporated into the window pane. In the latter, the ventilator has a flange of the same thickness as the glass and lies in the same plane forming a structural part of the glazing. Trickle ventilators are also frequently provided with a damper mechanism which allows user control of the ventilation opening - a significant and positive feature which makes natural ventilation attractive to the user.

2.3. Summer ventilation

Summer ventilation is usually linked to the control of internal temperature. Control of the air flow rate is in itself not so important. The issue is that of overheating in the summer.

To avoid overheating, the air flow rates may need to exceed what is required solely to satisfy occupants’ needs. As a result, sizes of openings are totally different to that used for winter ventilation. As part of this process, it is important to ensure adequate distribution of fresh air within the space to enhance comfort conditions and freshness.

**Single-sided and cross ventilation**

Depending on the requirement, spaces can be ventilated either by single-sided or cross ventilation. Single-sided ventilation (SSV) occurs when large, natural ventilation openings (such as windows and doors) are situated on only one external wall. Exchange of air takes place by wind turbulence, by outward openings interacting with the local external airstream and by local stack effects. Rules of thumb for SSV indicates that windows with openable areas of at least 1/20th of the floor area can ventilate spaces to a depth of about two and a half times the height of the room, i.e. a depth of 7.5 m for a 3.0 m high room.

Cross ventilation occurs when the inflow and outflow openings in external walls have a clear internal path between them. A rule of thumb indicates that, through this means, spaces can be ventilated to a depth of about five times its height, i.e. 15 m depth for a 3 m height. Flow characteristics are determined by the combined effect of wind and temperature difference. Cross ventilation depends on windows (or other openings) on opposite sides of the building being opened sufficiently; this needs the cooperation of occupants. The effectiveness of ventilation in deep spaces can be affected by internal partitions and obstacles. The latter generally affects only air movements which can then be increased locally, by ceiling fans for example.

**Stack ventilation**

Stack ventilation is used to describe those strategies where natural driving forces (and sometimes assisted using low-energy fans) promote an outflow from the building, thereby drawing in fresh cool air via ventilation openings at low level. Careful siting of these intakes provides opportunities for relatively uncontaminated air to be drawn from sheltered internal courtyard areas (rather than from the roadside). Such strategies provide means whereby windows facing busy roadsides could be kept closed to minimise possible vehicular noise and air pollution.

Stack ventilation can be driven either by temperature differences between stack temperature and the outside, or by wind pressures or a combination of both. It is essentially cross ventilation as far as the individual spaces are concerned, in that air enters from one side of the space and leaves from the opposite side. The air may flow across the whole width of the building and be exhausted via a chimney, or it may flow from the edges to the middle to be exhausted via a central chimney or atrium.

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4 Building Research Establishment, Natural ventilation in non-domestic buildings, BRE Digest 399, (October 1994)

If the air flow is temperature driven, it is said\(^6\) that this method of ductless ventilation works best with open planned offices and at least three floors. Similarly, buoyancy is improved as the stack height increases. This results in critical dimensions of total height of the stack, and the height from the ceiling of the top floor to the top of the height.

Stack pressures can be enhanced by using \(>\text{solar}=\) chimneys in which glazed elements are incorporated into the chimney structure. Wind pressures can also be utilised by placing the outlet in a negative wind pressure zone relative to the inlet. In such designs, since air flows into the building at low level (and exhausted at the higher level), care has to be taken when determining the different sizes of ventilation openings in each floor of the building if equal ventilation rates are required. A relatively simple procedure to do this is now available\(^5\).

3. **Mechanical Ventilation**\(^5,\)\(^6\)

Mechanical ventilation, as opposed to natural ventilation, makes use of fans to supply and extract fresh air to and from the building This is usually provided when the plan form of the building means that natural ventilation may not be able to penetrate to the core areas, where the building is subject to excessive and unacceptable levels of external noise, or where filtration or other treatment is required. Any conditioning of air is therefore restricted to filtration and heating. Mechanical ventilation can be sub-divided into three categories: supply only, extract only and balanced.

3.1. **Supply-only ventilation**

Supply-only ventilation results in pressurisation of the building which resists the entry of infiltration air and any pollutants that might be present in the outside air. One increasingly common approach is to use a low level displacement ventilation\(^8\) system, with natural ventilation via atria or lightwells to provide the exhaust. Appropriate design principles need to be employed since the exhaust is by natural means.

3.2. **Extract-only ventilation**

Extract-only ventilation can be used to extract internally generated pollutant at source, e.g. near a photocopier. Extract only ventilation can be used to provide the supply air in situation where a lower quality environment is acceptable (e.g. toilets and underground car parks). Extract only ventilation relies on natural ventilation inlets and these have to be designed accordingly.

3.3. **Balanced ventilation**


\(^8\)Displacement ventilation is a form of balanced ventilation in which the supply air \(>\text{displaces}=\) rather than mixes with the room air. Pre-conditioned air at 2 to 3 K below ambient room temperature is introduced to the space at low level and at a very low velocity (~ 0.1 to 0.3 m/s). Gravitational effects encourage the incoming air to creep at floor level until it reaches a thermal source, e.g. occupant. The air then rises around the heat source and into the breathing source prior to extraction at ceiling level.
Balanced ventilation combined extract and supply systems as separately ducted networks. Typically, air is supplied and mixed into occupied zones and is extracted from polluted areas. Air flow pattern is established between the supply to the extract areas which should be supported by air transfer grilles between rooms. Balanced systems almost always incorporate heat recovery using a plate heat recovery unit or similar air to air system. This enables pre-heating of the incoming air. It is this potential for heat recovery that is often used to justify the additional capital and operating costs.

4. Air Conditioning

The phrase is often used to represent a wide variety of levels of service, from mechanical ventilation to sophisticated systems giving close control of temperature and humidity. The degree of sophistication required affects the type of plant selected and, to some extent, both capital and operating costs. Not all types of plant offer all the features that may be required. In the following section, extracted from EEO Good Practice Guide 71, is reserved for systems providing cooling of air as a minimum.

There are three generic types of air conditioning systems with many variations available within each:

- **Centralised air systems**, in which all the heating and cooling is carried out in a central plant room and conveyed to the rooms by ductwork.
- **Partially centralised air/water systems**, in which centrally cooled or heated air is further heated or cooled at entry to the rooms.
- **Local systems**, in which all operations are performed locally.

The potential for variations and combinations of types of system is limited only by the designer’s imagination.

For example, in relatively large spaces (open plan offices, hotel lobbies, etc.) with outside walls it is common to separate the system which deals with the outside wall (perimeter), where the need for winter heating is the greatest, from the interior space. Often a central air system may serve the interior, and radiators or skirting heaters may be used at the perimeter. Alternatively two separate central air systems may be used.

Since it is easier to control heating rather than cooling, most centralised and partially centralised systems reheat air which has previously been over-cooled. The waste incurred can be minimised by careful design and control.

The following discussion is intended to describe the principal options for air conditioning.

4.1. Centralised air systems

These systems are typically based around a pre-packaged air handling unit (AHU) which consists of a fan, and combinations of heating and cooling coils, filters, humidifiers and control dampers. They may also include packaged heat pumps and an exhaust fan and/or the facility to recycle exhaust air back into the building. The AHU would normally be located within a plant room with chillers and boilers located nearby.

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When outside air is cooler than desired in the air conditioned space, fresh air can be introduced and chilling is not required. In the UK, this free cooling should be made available to minimise the need for refrigeration.
AHUs can be configured to serve several different types of distribution system:

**Constant volume single zone** systems are simple, relatively low cost and easy to commission, but cannot provide adequate control for areas (zones) with different and simultaneous heating or cooling needs. Several separate systems may be required to serve different zones, increasing capital costs and plant room space.

**Variable air volume (VAV)** systems address the problem of zones with different requirements by varying the quantity of air supplied to each zone. The air is supplied at a constant temperature through thermostatically controlled damper units (referred to as VAV boxes). The volume of air and hence the amount of cooling is varied to meet the requirements of each zone. There is normally the facility to reset the constant temperature.

The use of VAV boxes means that some maintenance of the boxes themselves, which are usually located in ceiling voids, must be carried out in the occupied space. However, maintenance requirements are low, and this should not be a major obstacle.

Within the VAV concept the designer has several options open to him, including fans to recirculate room air and bypassing of air which is not required back to the extract fan (rather than simply reducing the flow). Recirculating fans reduce the problem of supplying widely varying volumes of air through a single diffuser without creating draughts, but can introduce noise into the room and add to maintenance requirements.

Bypassing of air by VAV boxes does not affect comfort in the rooms and simplifies system design. However, this approach fails to take advantage of two potential benefits of the VAV system. Firstly the cooled zones will not all require maximum cooling at the same time, and selection of the AHU taking into account the reduced requirements of some areas should reduce capital costs.

Secondly, in most applications maximum cooling is required for very few days each year and a true variable volume system will result in much lower air requirements for most of the time. This will result in significant energy savings from reduced fan power and heating and cooling of air.

VAV systems are primarily for buildings with a year round cooling demand. They can normally be smaller than the equivalent multi-zone system because the design does not need to allow for full cooling simultaneously in all zones.

**Dual duct systems** can incorporate either constant volume or VAV principles. As the name implies, two ducts are used, one carrying heated and one cool air to the space, where the air is mixed in a thermostatically controlled mixing box, usually mounted in a false ceiling.

These systems give accurate control of space temperature, but capital costs and space requirements are relatively high because two sets of ductwork are required. In their constant volume form, dual duct systems will often mix air which has been heated (using energy) with air that has been cooled (using energy).
4.2. Partially centralised air/water systems
The common factor with these systems is that a central AHU, as described above, is used but further conditioning in the room may be locally controlled.

Partially centralised multizone and VAV systems allow free cooling by damper control at the central air handling unit.

Centralised air systems with reheat of both constant volume and VAV types are available where the central air supply is further heated or cooled to room requirements by additional heating or cooling coils (batteries). In constant volume systems this greatly improves controllability and the ductwork can be configured to serve rooms with quite different requirements (referred to as >Constant volume multizone= systems). Heating and cooling coils can be located either within ceiling voids (partially centralised system) or in the plant room (fully centralised system). In the latter case this can increase capital costs and space requirements, since separate ducts must run between plant room and each zone.

In VAV systems usually only reheating coils are provided located within the VAV box (>VAV with reheat=). This has the disadvantage that hot water must be piped to the VAV boxes and there is some potential for leaks within the occupied areas. The system does, however, give good control for areas with widely varying loads, and reheat need only be applied to some VAV boxes where heating needs are greatest, for example in perimeter areas.

Inductions systems use air from the central AHU (primary air) injected through nozzles to induce circulation of room air over a coil to which heating or cooling is applied. Primary air is generally limited to the minimum amount of fresh air required for ventilation, and the opportunities for free cooling and humidity control are therefore restricted. Hot and chilled water is supplied to each room by two pipe (one supply, one return), three pipe (hot and chilled supplies, common return) or four pipe systems (hot and chilled supplies and returns). Only four pipe systems give good control and energy efficiency and should always be used.

Centralised control of induction systems is complicated but most units are fitted with manually controlled dampers to control the flow of re-circulated air.

Central plant room and ductwork space requirements are low although the induction units themselves are often mounted below windows occupying floor space. Ceiling mounted units are available but not widely used.

Each induction unit requires maintenance and cleaning which must be carried out in the occupied area. The hissing sound of the primary air issuing through nozzles can also cause a noise nuisance in the occupied area.

Fan coil systems are similar to induction units except that air is moved by a fan, rather than induction. Fresh air can be supplied from an AHU or drawn directly from outside by the fan (not common in UK). In some types of unit this fresh air can be used to provide free cooling as described above.
Units can be perimeter or ceiling mounted, and modern fans are surprisingly quiet. Noise can still be a problem, however, and maintenance of a large number of units can be difficult.

Induction unit and fan coil unit systems normally have a full fresh air supply from the air handling unit. This provides the minimum fresh air requirement and is therefore a much lower volume than an equivalent multizone system. It requires reduced AHU and duct size, although induction systems may have an increased requirement over fan coils due to the need to induce room air.

Where heating and cooling is required at induction or fan coil units, four pipe systems must be used.

**Unitary heat pump systems** are available which use a constant temperature water (two pipe) loop for the hot and cold sources. Heating (from a boiler) or cooling (often from a cooling tower) is supplied by the water loop in the central plant room area. The heat pump units, which incorporate fan coil units, use this loop to provide or take away heat when cooling or heating is required by the room.

### 4.3. Local systems

The phrase comfort cooling is more appropriate to most local systems since summer cooling only is normally provided. Other air conditioning functions such as fresh air supply, humidity control and heating are not necessarily available.

These systems are characterised by the installation of one unit per conditioned zone when only small parts of a building require conditioning or if conditioning is to be introduced one room at a time.

**Through-wall packaged units** are popular in Mediterranean areas but unusual in the UK. The units are generally a small refrigeration unit with an integral air circulation fan. Air is drawn from the room, cooled and returned. Heat removed from the air is passed to the outside of the wall and rejected to outside air.

The units are simple, low capital cost, easy to use and offer the facility for local user adjustment but poor space temperature control due to sensor location and on/off control action. They require wall mounting, can be noisy and are not generally very efficient. The maintenance requirements of a large number can be difficult and most units do not readily adapt to central control. Some units offer heating by electric elements which can be expensive in use.

**Packaged Asplit units** are much more popular in the UK. The room mounted part of the unit resembles a fan coil unit, but cooling is provided by refrigerant rather than chilled water. The refrigeration part of the unit can be located away from the occupied area. They offer more sophisticated control than through-wall packages. Some units offer variable speed compressors and sophisticated modulating temperature control with remotely mounted sensors. Advantages and disadvantages are much as for through-wall units, but much of the maintenance is now outside the occupied area. Multi-split package systems are also an option where several room coolers are connected to one refrigeration unit. Individual control of room coolers is generally not possible with this system.
**Individual reversible heat pumps** are available as through-wall and split unit systems. In these the refrigeration can work in reverse, pumping heat into, as well as out of, the room (i.e. heating as well as cooling).

**Variable refrigerant flow rate systems** are relatively new. They are a special case of multi-split package heat pump systems. Several room coolers are connected directly to a single outdoor refrigeration unit. The refrigerant flow rate can be varied using a variable speed compressor in response to changes in cooling requirements. A sophisticated control system enables switching between heating and cooling modes. In more sophisticated versions indoor units may operate in heating or cooling model independently of others. This latter arrangement offers potential energy savings when heating and cooling are required simultaneously in different zones.

These systems can be advantageous where no plant room is available and where a number of zones have different cooling and heating requirements. They offer great flexibility but, as with all distributed systems, maintenance costs may be significant.
ANNEX II: REQUIREMENTS IN CODES RELATED TO NATURAL VENTILATION

This Annex gives an overview of requirements in British building regulations, occupational health regulations, standards, codes etc. related to natural ventilation systems or simple fan assisted ventilation systems in office buildings. The objective is to identify requirements possibly restricting the implementation of natural ventilation systems or simple fan assisted ventilation systems in office building. Requirements related to mechanical ventilation in office building are included in the overview if they can also be used on natural ventilation systems or simple fan assisted ventilation systems. From a legal point of view all ventilation systems including a fan e.g. simple fan assisted ventilation systems would be considered to be mechanically ventilated systems and must fulfil the requirements to mechanical ventilation systems.

Relevant documents

- provides information on basic guidelines for ventilation of domestic dwellings and non domestic buildings.

- provides information on basic guidelines for prevention of fire spread through ventilation systems and other aspects of building design.

- provides information on guidelines and requirements on design, construction installation and practices for buildings in the UK.

BS 8233: British Standard code of practice for ‘Sound insulation and noise reduction’ for buildings.
- provides information on noise control in and around buildings.

- provides information on recommendations that should be observed for natural ventilation of buildings for human occupation.

- provides information on relevant UK data that should be utilised when designing buildings.

- provides information on how best to maximise external view and internal illuminance, by design of windows.

provides information on standards of general ventilation and fresh air requirements in the workplace.

Requirements

The text in ‘italic between quotation marks’ are quotations from the documents.

<table>
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<tr>
<th>Topic</th>
<th>Document</th>
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<td><strong>Ventilation rates</strong></td>
<td>CIBSE (B)</td>
<td>Guideline: recommended total air supply to offices should be between 4-6 ach</td>
</tr>
<tr>
<td></td>
<td>CIBSE (B)</td>
<td>‘It is probable that summertime ventilation rates will need to be at least 10 ach in the UK’</td>
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<tr>
<td></td>
<td>BR 95 (B)</td>
<td>Requirement: for adequate background ventilation opening should be (a) 4000 mm$^2$ for floor areas up to 10 m$^2$, and (b) 400 mm$^2$ per m$^2$ for floor areas greater than 10 m$^2$.</td>
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<tr>
<td>BS 5925:19</td>
<td></td>
<td>Requirement: the minimum outdoor air supply rate to private office to reduce the impact of heavy smoking is 1.31 s$^{-1}$ m$^{-2}$ or 8 l s$^{-1}$ per person (the greater of the two values must be used). The recommended outdoor air supply rate to private offices is 12 l s$^{-1}$ per person.</td>
</tr>
<tr>
<td><strong>Ventilation systems</strong></td>
<td>BR 95 (F)</td>
<td>Requirement: ‘Ventilation openings can include any means of ventilation (whether it is permanent or closeable) which opens directly to external air, such as the opening parts of a window, louvre, airbrick, progressively openable windows, or window trickleventilator. It also includes any doors which opens directly to external air. Ventilation opening should have a smallest dimension of at least 8 mm other than a screen facia, baffle etc. so as to minimise resistance to the flow of air’.</td>
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<tr>
<td>BS 5925</td>
<td></td>
<td>Requirement: ‘Mechanical ventilation is an absolute necessity in rooms or spaces requiring ventilation which cannot be adequately supplied by natural means, such as where unfavourable external environment conditions, e.g. noise, dust, pollution etc.’.</td>
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<tr>
<td><strong>Fire Safety</strong></td>
<td>BR 5925</td>
<td>Requirement: ‘where a ventilation duct does not form part of a protected shaft (or is not contained within one); a) the duct should be fitted with an automatic fire shutter where it passes through a compartment floor, and b) the opening of the duct should be fire stopped.’</td>
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<tr>
<td></td>
<td></td>
<td>‘where a ventilation duct forms part of a protected shaft (or is contained within one) the duct should be a) fitted with automatic fire shutters at the inlets to the shaft and outlets from it unless some other provision (such as a shunt duct) is made to reduce as far as practicable the risk of fire spreading from one compartment to another, and b) constructed and lined only with materials that will reduce as far as practicable the risk of fire spreading from one compartment to another.’</td>
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</table>
|                        |           | ‘if ventilation duct forms part of an air recirculating system the following additional precautions should be taken to prevent smoke being recirculated around the building. One or more optical smoke..."
detectors which respond to the scattering or absorption of light by smoke particles in a light beam, should be fitted in the ductwork and can be capable of initiating changes in the operation of the ventilation system so as to divert vitiated air containing any smoke from the outside of the building if the smoke reached an optical density of 0.5 dB/m’

CIBSE (B) Requirement: ‘Ventilation systems must be balanced so that the internal air movement is away and not towards escape routes. Ventilation with recirculation requires smoke detectors in the return air duct to shut down the circulation fans or to direct the return air to outside the building. Overriding control of the damp is to be provided for the use of the fire brigade.’

Noise BS 8233 Requirement: minimum sound insulation between offices is 35 dB. Minimum sound insulation between an office and another type of room is 45 dB.

CIBSE (A) Requirement: noise levels should not exceed 60 dB for management offices, 63 dB for small offices and 70 dB for other offices.

Filtration BS 5925 Requirement: ‘Where the outdoor air quality is particularly polluted or where clean air is required indoors, the incoming ventilation air needs to be filtered.’

Draught CIBSE (B) Requirement: ‘In designing a building it is important to ensure that it will not become uncomfortably hot during sunny periods i.e. that the maximum peak temperature should not frequently exceed, say 27°C.’

Guideline: Dry resultant temperatures in general and private offices should not exceed 20°C

Windows BS 8206 Requirement: minimum window area to achieve a satisfactory view out of a room is 20% of wall area from within the room, for rooms with a depth of less than 8m. The value for a room of depth between 8 - 11m, 11-14m and greater than 14m is 25%, 30% and 35% respectively.

Indoor Air HSE (EH22) Requirement: ‘Fresh air (for ventilation) is clean air that has been drawn from a source outside the building and is not polluted from discharges from flues, exhaust ventilation systems and process outlets.’

‘Fresh air is required for several reasons; a) for respiration ..... b) to dilute and remove airborne impurities created by occupants of a room ..... c) to dilute other airborne impurities present in the room......’

CIBSE (A) Requirement: the maximum recommended concentration of CO2 for 8 hour occupation is 0.5%. For most applications RH should be between 40% and 70%.