A BREATH OF FRESH AIR

A new look at ventilation standards

The ASHRAE and Natural Ventilation Groups of CIBSE joined with the Building Research Establishment to sponsor a half day seminar to examine how the United States, Europe and, more particularly, Britain were responding to the recent intensive research into ventilation criteria.

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The Speakers

Dr Max Sherman is a Senior Scientist at the Earnest Orlando Lawrence Berkeley National Laboratory (LBL) California as well as the group leader of the Energy Performance of Buildings Group. He is also an active ASHRAE member and currently chairman of the ASHRAE Standards Committee.

Mr Steve Taylor PE is an HVAC designer and the principal of Taylor Engineering. He is also an active ASHRAE member and is currently chairman of the Standing Standards Project Committee for ASHRAE Standard 62. This presentation is based on his Committee's work.

Mr Peter Jackman is the Research Director of the Building Services Research and Information Association, Bracknell. He has spent many years in ventilation research and has published widely in this field. He is currently Chairman of the CEN Technical Committee TC 156 European ventilation standards.

Dr Martin Liddament is the Director of the International Energy Agency's Air Infiltration and Ventilation Association, University of Warwick Science Park, Coventry, with the responsibility for coordinating work on ventilation as part of the IEA Energy Conservation in Buildings and Community Systems Programme. He is the author of guides on many aspects of ventilation.

Dr Earle Perera is a key researcher at the Building Research Establishment, Garston, with special responsibility for wind tunnels, ventilation in public and commercial buildings and wind environment around buildings. He is active in Building Regulations and has published in this field.

Dr Geoffrey Brundrett (Chairman) is a Vice President of CIBSE, a member of ASHRAE and a member of the ASHRAE Group Committee.

Foreword

The key environmental topic for the last ten years has been the study of ventilation criteria. The traditional approach of supplying either enough outdoor air to overcome body odour or cigarette smoking whichever was the greater has been shown to be inadequate.

Ten factors have emerged or have been refined:

1. That the distinction between health and comfort is now much clearer. The health criteria have to be met. Comfort can be optional and is now much more predictable.

2. That the building components such as adhesives, insulants, sealants and solvents can all contribute to odour.

3. That the building contents such as books, carpets, polishes and furnishings can contribute to odour.

4. That neglected building services such as old air cleaning filters, contaminated heat exchangers and dirty ductwork can contribute to odours.

5. That many odours can be considered additively.

6. That ventilation effectiveness for both health and comfort should be assessed on the basis of the air quality at mouth and nose level.

7. That some air recirculation with filtration could be useful in removing contaminants introduced by the occupants themselves and their activities.

8. That satisfaction with air quality is very strongly determined by whether you have been in the building for some time or are just entering it.

9. That body odour strength is no longer considered to be linked to personal space. The old pioneering US research on this cannot be replicated today.

10. That everyone deserves the right to a clean and adequate outdoor air supply.

Each country has attempted to convey these findings into its national ventilation code for buildings and tried to deal with a subject, odour, in which the nose is still much more sensitive than any scientific instrument.

This seminar was planned at a time when the Chartered Institution of Building Services Engineers was at the discussion stage in bringing out a new ventilation code for Britain. The aim was to review the US and European thinking. The occasion was prompted by the willingness of Dr Max Sherman, Chairman of ASHRAE Standards, to visit us and for the three leading British researchers to share their thoughts, Dr Peter Jackman, Dr Martin Liddament and Dr Earle Perera. It was made possible by the generous sponsorship of the Building Research Establishment.

The seminar was overbooked and these proceedings are made available free of charge through the courtesy of CIBSE to all interested in the topic. The typesetting and layout was sponsored by the Heating and Air Conditioning (HAC) Journal.

My thanks to everyone who made it such a stimulating event.

Geoffrey Brundrett
CIBSE Vice President

Revising the ASHRAE 62 Ventilation Standard

Max Sherman and Steve Taylor (ASHRAE Standards Chairman and Chairman of 62 Ventilation Standards Committee)

There are several ASHRAE Standards that relate to ventilation either directly or indirectly in addition to Standard 62 Ventilation.

- Standard 55 specifies indoor environmental conditions necessary to provide thermal comfort.
- Standard 90 is a design standard for new construction to provide energy efficiency.
- Standard 100 is a broader standard relating to existing buildings. Both have a series (e.g. 90.1) for different building types.
- Standard 119 sets air tightness limits on dwellings for energy efficiency purposes.
- Standard 129 is a measurement technique to determine ventilation effectiveness.
- Standard 136 allows credit towards ventilation requirements for systems incorporating infiltration. It can be used in the residential section of Standard 62 Ventilation.
- Standard 152 will be a method of test to determine the efficiency of thermal distribution systems and impacts ventilation in air systems especially those with duct leakage.

All of the ASHRAE standards share the common theme of being focused at combining energy, environmental, and productivity issues. This focus is different from many of ASHRAE's standards which are focused on methods of test or specific classifications or procedures relating to the HVAC&R industry. Environmental factors affect productivity in a variety of ways. While Standard 62 focuses on health and comfort issue, there is a clear understanding that there is a link to productivity and satisfaction.

Standard 62 has been a significant contribution of ASHRAE for over a quarter of a century. As with all American National Standards, 62 must be maintained and revised as needed. The different versions of the standard have used different approaches and different rates to respond to the needs of the users at that time. It takes about 8 years to cycle through a revision of the Standard. ASHRAE is likely to convert this standard to *continuous maintenance* after this revision so that improvements can be incorporated at a faster rate with less turmoil.

Five key differences proposed for the new version of the standard are:

1. The new version will be written in mandatory language to make it possible to determine whether or not the standard has been met and to be able to be referenced by codes and specifications.

2. The calculus of the calculation is based on the principles of odour acceptability, but considers health. Previous versions did not have a clear philosophy for the ventilation rates.

3. The standard assumes no smoking, but an informational annex discusses how to achieve *comfort* when smoking is allowed. Previous versions assumed a 'moderate' amount of smoking.

4. Many specific energy considerations were included in the committee's deliberation.

5. The standard included operations and maintenance requirements to ensure that the building delivers what it is designed to do. Previous versions only dealt with design.

Calculating the **Design Ventilation Rate** is done using additivity of people-derived sources and building-derived sources. This additivity is a key assumption of the standard, is different from previous versions and follows from the similar additivity found by odour researchers. Because the committee 'liked' many of the numbers in the old standard, these new ventilation values were first calculated to leave the final result unchanged. Committee debate has subsequently modified some of these values.

Various Carbon Dioxide levels have been proposed. The revised guide recognises that CO_2 is not a pollutant of concern, but rather is merely a surrogate for occupancy (when other sources are properly taken care of). Demand controlled ventilation is allowed, but it is not simple linear control because of the need to dilute building generated pollutants.

Productivity may be enhanced by good air quality.

The life-cycle of the building has many distinct phases.

1. Design stage

2. Construction of the building

3. Commissioning before occupancy

4. Operation

5. Renovation as needs change

6. Demolition

The new version of Standard 62 will address all the phases of the buildings life that could impact the occupants. This life-cycle focus is a new addition. Because this focus is new, not as much effort is in the phases of the building other than design, but the new standard will contain much useful information about what needs to happen after design. To some this focus is in conflict with the desires of ASHRAE that Standard 62 be usable in codes, which normally only specify design requirements.

Many of the rates have remained basically unchanged from the 1989 version, but some have decreased. The current version also makes it a lot clearer as to what these rates mean. Retail premises and offices are unchanged, class rooms and conference halls have reduced ventilation.

The Standard's scope limits it to commercial, institutional and residential buildings. This change from previous versions reflects what is actually in the standard rather than any qualitative change. The committee's focus has primarily been on the non-residential buildings within the scope. The chapters which form the Standard are listed below.

1. Purpose
2. Scope
3. Definitions
4. Application and Compliance
5. General requirements
6. Design ventilation rates
7. Construction and start up
8. Operating & maintenance
9. Residential

Chapters 5-8 are the bulk of the standard and a single, stand-alone chapter (9) covers dwellings. The approach to residential buildings often makes different kinds of assumptions than the rest of the standard. There has been debate within the committee on whether or not to separate the residential part as a separate standard.

The title purpose and scope of the Standard as currently approved by ASHRAE is outlined below.

Title, Purpose and Scope for ASHRAE Standard 62R: Ventilation for Acceptable Indoor Air Quality

- To define the roles of and requirements for ventilation, source management and air cleaning in providing acceptable indoor air quality
- To specify methods for determining minimum ventilation rates
- To specific ventilation system design, operational, and maintenance requirements for various types of occupied indoor spaces
- This standard contains requirements for commercial, institutional and residential buildings space intended for human occupancy

- *This standard considers chemical, physical and biological contaminant as well as factors such as moisture and temperature that can affect human health and perceived air quality*
- *Thermal comfort is not included in this standard (see ASHRAE Standard 55)*
- *Considering the Diversity of Sources and contaminants in indoor air and the range of susceptibility in the population, compliance with the standard will not necessarily ensure acceptable indoor air quality for everyone*

The first three bullets are the purpose: Section 1.1, 1.2, 1.3

- 1.1 states the need for general requirements
- 1.2 is the ventilation rate requirements
- 1.3 defines the phases of the lifecycle covered

The next four bullets are the scope of the standard: Section 2.1 - 2.4

- 2.1 limits the buildings under consideration
- 2.2 limits the factors being considered
- 2.3 excludes thermal comfort from consideration
- 2.4 excludes special populations or unique buildings

A key aspect in writing the standard is to define at least qualitatively what the standard is trying to deliver. The most important definition in the standard is that of **acceptable indoor air quality** which sets the tone for what it contains. These definitions have had extensive debate within the committee and always represent a political as well as technical compromise to the issue of what can be done as opposed to what should be done. In the 1989 Standard acceptable indoor air quality was defined as 'air in which there are no known contaminants at harmful concentrations as determined by cognizant authorities and with which a substantial majority (80% or more) of the people do no express dissatisfaction.' The proposed change to this is to define acceptable air quality as 'air in an occupied space towards which a substantial majority of the occupants express no dissatisfaction and in which there are not likely to be known contaminants at concentrations leading to exposures that pose a significant health risk.'

Energy costs are one of the least significant parts of building-related costs, typically £12/m^2 compared with a productivity value of £1,800/m^2. Impacts on productivity are far more important to the economy than energy savings. Commercial buildings in the U.S. use a significant amount of national resources. There are some 6 billion square metres of commercial floor area using £60 billion of energy per year and with a renovation and construction rate of £130 billion pounds/year. Energy saving potentials are 30 - 50% in existing stock and 50 - 75% for new buildings.

Note: \$1/sq.ft = £36/sq.m

Unlike previous versions the 62 Revision sets minimum supply rates as well as minimum outdoor air rates. A **Minimum Supply Rate** is required to control human shed air borne contaminants, such as aerosolized virus, that can be filtered out. The minimum supply rate has the added benefit of making multiple space effects easier to calculate and of providing higher mixing rates. One area of concern regarding previous standards was the confusion between the air delivered to the breathing zone compared to the air entering the outside air intakes. The new version will explicitly address this issue by discussion ventilation effectiveness.

$$\text{Total ventilation} = \sum \frac{\text{Design outdoor air rate to space}}{\text{Ventilation effectiveness}}$$

An example of how the proposed ventilation rates will be used is illustrated in Fig 9 for a variety of non-residential buildings, allowing for diversity in occupancy and for typical ventilation system efficiencies.

The committee's focus has primarily been on the non-residential buildings within the scope. A single, stand-alone chapter (9) covers requirements for dwellings. The approach to residential buildings often makes different kinds of assumptions than the rest of the standard. Information is sometimes duplicated from chapters 5 and 6 in order to allow chapter 9 to be used without reference to the non-residential parts.

Special Issues for Dwellings

There are several things that are significantly different about the residential section than the rest of the Standard. As mentioned it is intended to be used separately from the rest of the standard.

For dwellings a single-whole house value is given. It is assumed that there is good mixing throughout the dwelling and that separating pollutants from different rooms is not necessary. Dwellings generally have a much lower level of design and, hence, control than do commercial buildings, so that the level of systems that can be assumed is lower. Kitchen, bath and toilet exhaust as well as whole-building rates have different moisture and energy implications in various climates. For dwellings we assume that the occupants have a much higher level of control over both the operation of the building and its systems and also the sources of pollutants that may be released into the air. The use of windows to provide both continuous trickle and transient purge of ventilation must be considered, but is difficult to quantify.

Multifamily units represent only 15% of the U.S. stock, but have special concerns that are addressed (e.g. common walls). For example, sharing air between flats is not acceptable, but within a flat it is.

The allowability of windows to supply local exhaust is a heated issue in the committee; currently it is only allowed in separate toilet compartments. There are three pathways to comply with the whole-building rate requirement. The first path is a mechanical ventilation system designed to provide the full amount of ventilation with or without heat recovery. The second method allows any design, but requires that it be demonstrated to work. This demonstration can be done through design calculations and can incorporate any combination of fans and infiltration. The third method is to rely on natural ventilation provided by windows opened by the occupants. All three methods require that the building be operated consistent with the path selected in the design.

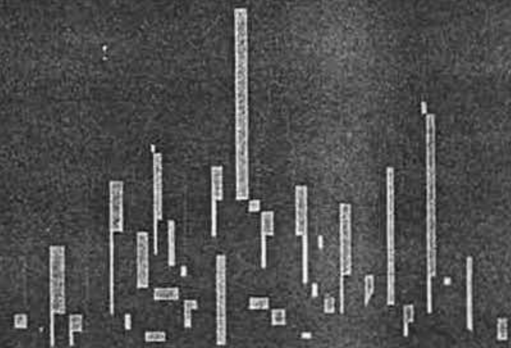
Acceptable Indoor Air Quality:

Ventilation Additivity

Design Outdoor Air Ventilation Rate CFM

People Component

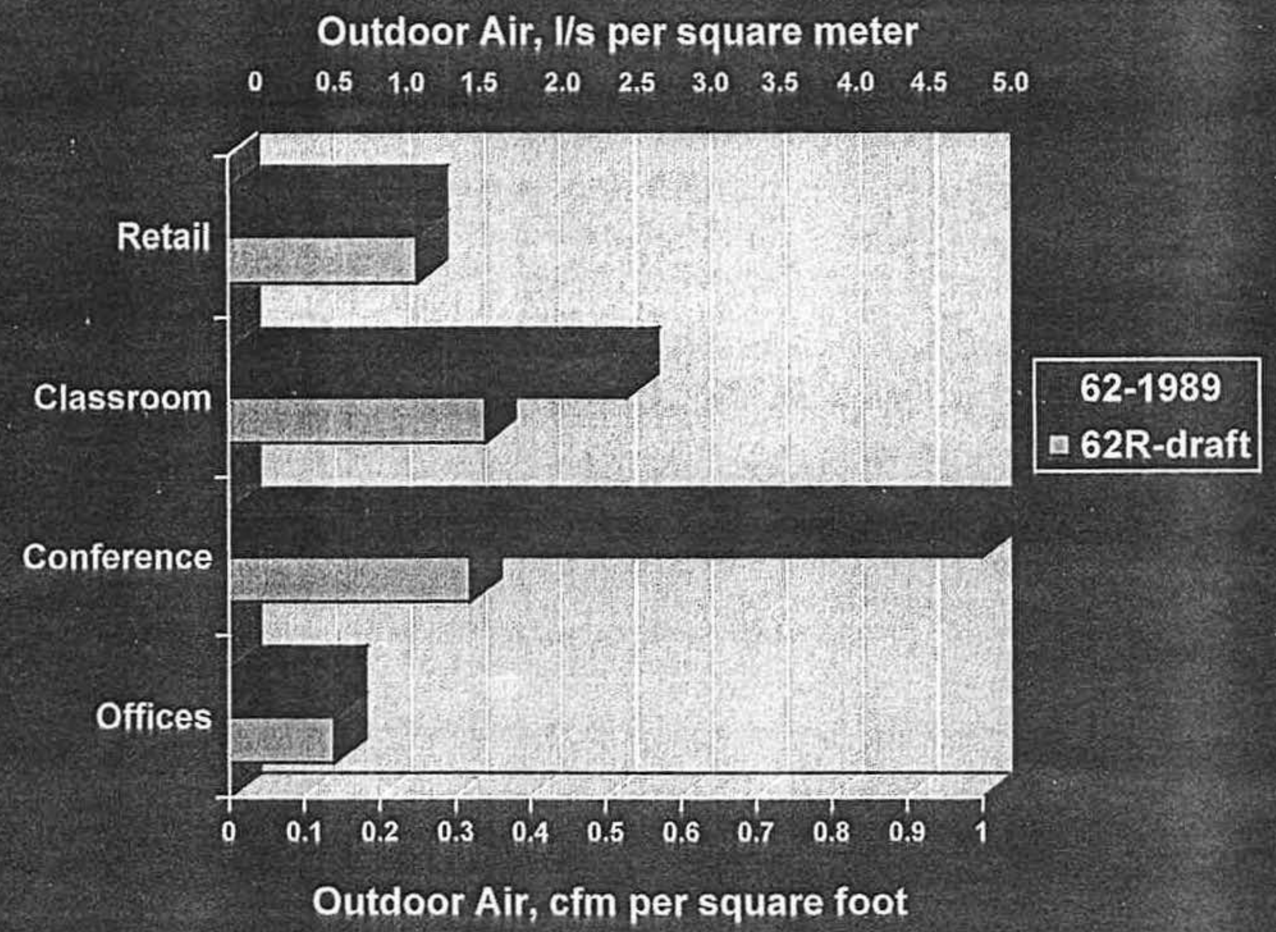
Building Component



- Minimum CFM/Person
- Number of People
- Diversity Factor
- Building Area
- Minimum CFM/sqft

Outdoor Air Requirement Example:

Comparison: 62R and 62-1989



TPS for ASHRAE Standard 62R:

Ventilation for Acceptable Indoor Air Quality

- To define the roles of and requirements for ventilation, source management and air cleaning in providing acceptable indoor air quality
- To specify methods for determining minimum ventilation rates
- To specific ventilation system design, operational, and maintenance requirements for various types of occupied indoor spaces
- *This standard contains requirements for commercial, institutional and residential buildings space intended for human occupancy*
- *This standard considers chemical, physical and biological contaminant as well as factors such as moisture and temperature than can affect human health and perceived air quality*
- *Thermal comfort in not included in this standard (See ASHRAE Standard 55.)*
- *Considering the Diversity of sources and contaminants in indoor air and the range of susceptibility in the population, compliance with the standard will not necessarily ensure acceptable indoor air quality for everyone.*

Standard 62 Definitions:

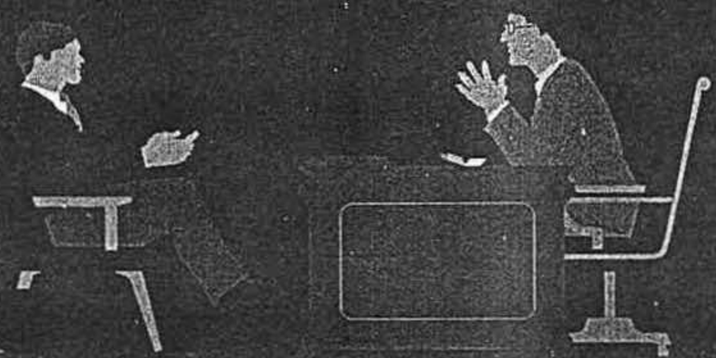
What is "Acceptable IAQ"?

- Standard 62-1989: "Air in which there are no known contaminants at harmful concentrations as determined by cognizant authorities and with which a substantial majority (80% or more) of the people exposed do not express dissatisfaction."
- Standard 62R: "Air in an occupied space toward which a substantial majority of occupants express no dissatisfaction and in which there are not likely to be known contaminants at concentrations leading to exposures that pose a significant health risk."

62 Focus on Commercial Buildings

Your Office: Dollars and Sense

- **Energy Cost: $2**
- **Maintenance: $3**
- **Taxes: $4**
- **Rent: $40**
- **Productivity $300**



Commercial Buildings, 62R Example (SI):

Minimum Supply Rate

If DVR < 15 cfm/person, filtered recirculated air must be added:

V_R = supply of recirculated air to the space

E_{ac} = air change effectiveness

E_F = filter efficiency in 1 to 3 micron range (%)

Commercial Buildings, 62R Example (IP):

Minimum Supply Rate

If DVR < 15 cfm/person, filtered recirculated air must be added:

V_R	=	supply of recirculated air to the space
E_{ac}	=	air change effectiveness
E_F	=	filter efficiency in 1 to 3 micron range (%)

Commercial Buildings, 62R Example:

Ventilation System Efficiency

DVR = Design ventilation (outdoor air) rate to space

V_{ot} = Total outdoor air at ventilation system intake

E_V = System ventilation efficiency (combination of air change effectiveness with other system effects)

Commercial Buildings, 62R Example (SI):

Proposed Ventilation Rates

Occupancy Category	Ventilation Requirement		Guideline Occupancy Assumptions		Ventilation Requirements at Guideline Occupancy and Typical System Efficiency		
	People R_P l/s/person	Building R_B l/s/m^2	Density people/ 100 m^2	Diversity Factor	System Efficiency	Outdoor air l/s/person	Outdoor air l/s/m^2
Office space	3.0	0.35	7	1	0.80	10.0	0.7
Retail sales floor	3.5	0.85	15	0.75	1.00	11.1	1.25
General classrooms	3.0	0.55	35	1	0.90	4.9	1.8
Conference rooms	2.5	0.35	50	1	1.00	3.2	1.6

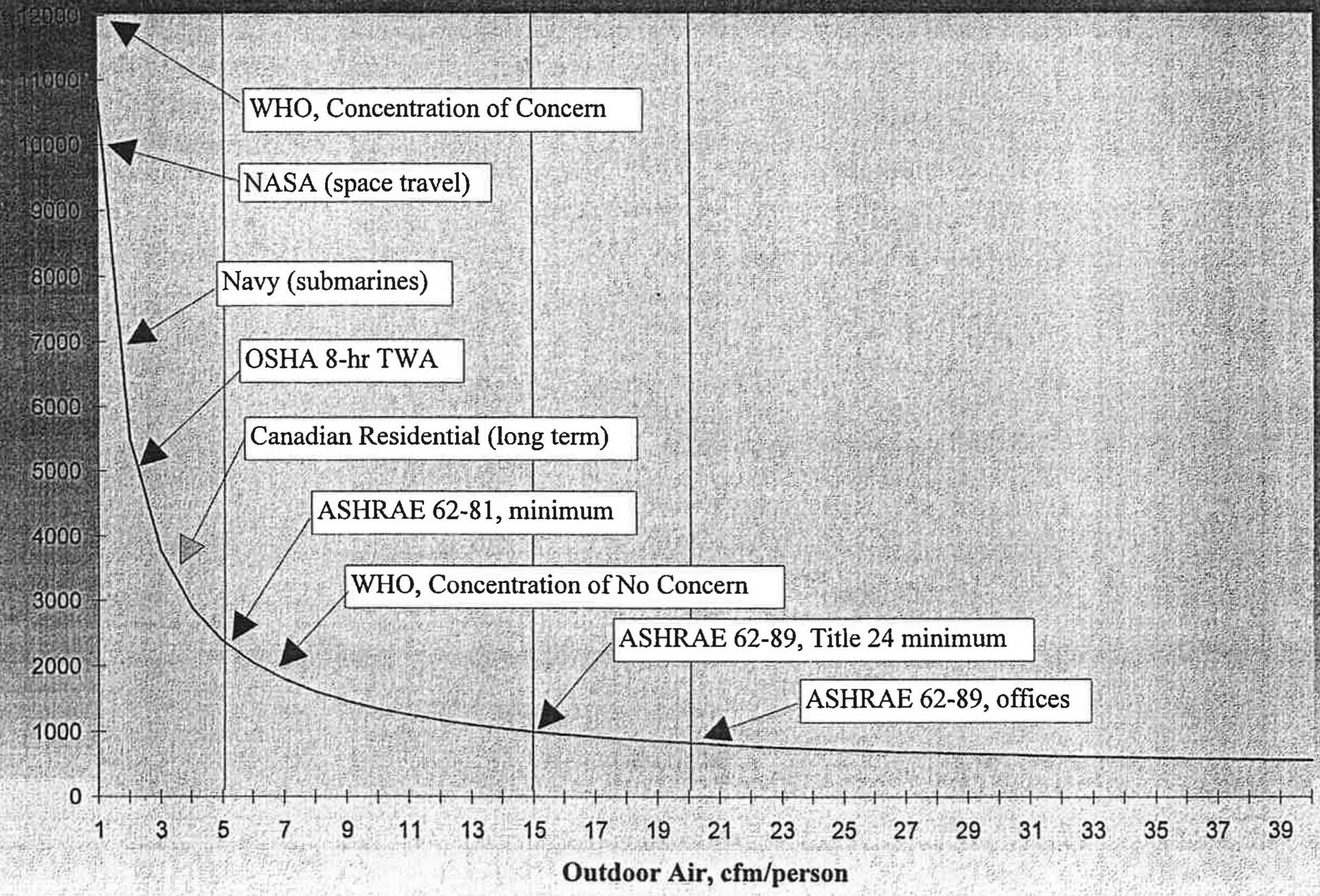
Commercial Buildings, 62R Example (IP):

Proposed Ventilation Rates

	Prescriptive Ventilation Requirement		Guideline Occupancy Assumptions		Ventilation Requirements at Guideline Occupancy and Typical System Efficiency		
Occupancy Category	People R_P cfm/person	Building R_B cfm/ft ^{2}	Density people/ 1000 ft ^{2}	Diversity Factor	System Efficiency	Outdoor air cfm/person	Outdoor air cfm/ft ^{2}
Office space	6.0	0.07	7	1	0.80	20.0	0.14
Retail sales floor	7.0	0.17	15	0.75	1.00	22.2	0.25
General classrooms	6.0	0.11	35	1	0.90	9.7	0.35
Conference rooms	5.0	0.07	50	1	1.00	6.4	0.32

Acceptable Indoor Air Quality:

What about CO_2?



European ventilation standards being developed by CEN TC 156

Mr Peter Jackman, BSRIA, Chairman CEN TC 156 Committee

The European Union wishes to encourage free trade within the Union and as part of this role created a Construction Products Directive to enable the member countries to harmonise standards. The European Committee for Standardisation (CEN) set up a Technical Committee on Ventilation for buildings (CEN TC 156) in 1989. The scope was 'Standardisation in the field of ventilation and air conditioning systems for buildings subject to human occupancy'. Each country is invited to have a representative on the Technical Committee and the British Standards Institution represents the United Kingdom. The Technical Committee has nine groups of experts who are preparing the draft standards and the technical guidelines. The Groups submit their reports to the Technical Committee for approval.

The nine working groups are

1. Terminology
2. Residential ventilation
3. Ductwork
4. Terminal units and air terminal devices
5. Air handling units
6. Design criteria
7. System performance
8. Installation (including commissioning)
9. Fire and smoke protection (for the ventilation system)

Working Group 6 Design Criteria, convened by Professor Ole Fanger, prepared a draft document in 1993 which the Technical Committee agreed should be developed as a CEN Prestandard prENV 1752. Prestandards are publicly available for three years and then reviewed to determine whether or notthey should beadopted as full standards. In the meantime individuals can choose to usethemt if they wish. This preENV 1752 is in the process of being modified and will be resubmitted to the Technical Committee Meeting in September 1996.

The content of the prestandard is a short main body explaining the philosophy of the criteria in terms of health and comfort giving recommended tabulated values of the main parameters, followed by seven Annexes:-

WG6 Design Criteria for ventilation

Main body
Annex A - Development of design criteria
B - Step by step design method
C - Practical examples
D - Thermal data
E - Summary of World Health Organisation guidelines
F - Ventilation effectiveness
G - Bibliography

The indoor climate is classified into three grades, A, B and C. For example, the ventilation rate for these three grades is given in Fig 1, for landscaped offices together with suggestions for noise limits. The current CIBSE guidelines is 1+3 $l/m^2/s$ minimum for such offices which equates to class B. The proposed ventilation rates for occupants depends upon the % of the occupants who are cigarette smokers. The current CIBSE guidelines suggest values from 8 to 32 litres/p/second. Permissible mean air velocities inside the room are specified too. Thermal comfort is measured in terms of operative temperature and quality is ranked in relation to the degree of control. Class A conditions permit ± 0+50C in summer and ± 1+00C in winter, Class C are designed for ± 2+5 in summer and ± 3+00C in winter.

Annex A describes the development of the design criteria for thermal comfort, indoor air quality and the acoustic environment. The thermal conditions can be described in the general terms of predicted mean vote (PMV) which depends upon the activity and clothing, and the percentage of the population dissatisfied (PPD). Local conditions include draught, vertical temperature gradients, radiant asymmetrics and floor temperatures. The three quality classes A, B and C represent less than 6% dissatisfied, less than 10% or less than 15% respectively (Fig 1).

The air quality section deals first with health aspects. This is brief and mainly based on chemical criteria because there is little equivalent medical data available. The perceived air quality, odours, is dealt with by the concepts of olf and decipol. An olf is the odour emitted by a seated adult who bathes every 1+4 days. The smells from other objects is said to be equated to that of multiples of people. The decipol is defined as perceived odour (the total smelliness) which results from supplying ten litres of clean air per second to dilute the body odour of one person. Category A air quality is a 1 decipol odour level and this perceived air quality is expected to create dissatisfaction in 15% of the occupants. Dissatisfaction levels in classes B and C are 20% and 30% respectively.

Humidity is not considered a sensitive parameter and the guidelines permit the range 30 - 70% r.h. indoors.

Ventilation effectiveness is assessed on the air quality at the breathing level. It is defined as the ratio of contaminant elevation for the room as a whole compared with that elevation of contamination at breathing level. This is illustrated in Fig 2.

The required ventilation rate for health is calculated using the known contamination sources and the permitted level in the breathing zone (Fig 3). The ventilation rate for comfort is derived similarly, using olfs as the source strength and decipols as the contaminant concentration (Fig 4).

Annex B introduces the design method step by step. The ventilation rate required for health first identifies the pollutant load of critical chemicals, and the permissible indoor concentration from health and safety guidelines and from these calculates the required ventilation rate. The ventilation rate required for comfort requires identification of the number of occupants and the olf burden within the building from the building itself. These two kinds of odour source are then added and the required indoor level of decipol odour level specified. The decipol level of outdoor air is assessed and, from a knowledge of the ventilation effectiveness, the required outdoor ventilation rate is calculated. The design ventilation rate is the higher one of the two, health and comfort.

Annex C gives practical examples for eight kinds of building uses such as a small office, a landscape office, a department store etc. It suggests typical olf values and decipol criteria which would be suitable for each type and illustrates example calculations.

Annex D is an analysis of thermal comfort showing how the activity level and clothing insulation influence the optimum temperature.

Annex E outlines the World Health Organisations guidelines on air quality for Europe. This Annex is particularly valuable in providing information of specific pollutants and their effect on health.

Annex F explains the importance of ventilation effectiveness and lists useful references.

The revised draft document will be submitted to the September 1996 meeting of the CEN 156 Technical Meeting, when national delegates will have the opportunity to vote on whether or not it should be adopted as a prestandard.

[Footnote: The CEN 156 Meeting took place at the British Standards Office in London on the 30' September.The Chairman requested the voting be deferred to a postal vote because not all countries were represented]

Developments in International Ventilation Standards

Dr Martin Liddament, Director, Air Infiltration and Ventilation Centre

Organisations

The International Standards Organisation (ISO) is a federation of national standards bodies comprising ninety countries. The objective is to promote the development of standardisation and related activities with a view to facilitating international exchange. The organisation involves producers, users, consumers, scientists and engineers. Current and planned standards cover air permeability, air leakage testing and indoor air quality.

The World Health Organisation tackles health related issues by forming an hoc groups of international experts to address particular topics. Air quality guidelines for Europe are based on the best medical knowledge to date and which is used to review the maximum threshold values for exposure to a limited number of pollutants. These values are based on

1. Carcinogenic risk.
2. Toxicity levels
3. Odour and comfort
4. Ecological effects

The European Committee for the Normalisation of Standards (CEN) prepares standards specifically in a European context. CEN often adopts ISO Standards.

Within the European Union ventilation Standards are being developed by Task Group ISG 156, described more fully in the previous paper.

In 1992 the European union introduced the 'CEC European concerted action programme in air quality and its impact on man' to provide guidelines on ventilation and air quality in buildings. This guide introduced the concept that odours could come from the building components and services as well as from body odours and cigarette smoke. The World Health Organisation's guidelines were supported and reproduced as an Appendix.

The health aspects of indoor pollution were emphasised. These included

1. Radon gas, usually from ground leakage from radioactive rock strata underneath the building.
2. Landfill gases such as methane which develops from rotting material dumped in landfill.
3. Environmental tobacco smoke, particularly to the non smoking 'passive' smoker in the room.
4. Formaldehyde gas leaking from adhesives or insulants within the building or furniture structure.
5. Volatile organic compounds from solvents, polishes and adhesives.
6. Metabolic gases from humans.
7. Humidity and the ability of mould spores to develop and germinate in profusion at high humidities.
8. Microorganisms which can thrive indoors.

The perceived air quality aspects considered the odour pollution from all sources and therefore treats the building furnishings and fabric as pollution sources as well as the occupants. This was achieved by introducing the olf as the strength of odour source equivalent to that of an adult and the decipol as the odour intensity equivalent to that when diluting the body odour of an adult (an olf) with a clean air supply of 10 l/s/p.

Some European countries have adopted aspects of the CEC Guidelines.

The five Nordic countries of Denmark, Finland, Iceland, Norway and Sweden each have Building Regulations of their own with the Nordic Committee on Building Regulations representing the coordinating agency. The Nordic Committee has an Indoor Climate Air Quality Committee "to safeguard the health and safety of citizens, to safeguard a good environment and to achieve economical energy management". This Committee considers nine actions regarding the air quality

1. Planning, which involves site location, the outdoor environment , the presence of radon etc.

2. Design, which includes the extent of polluting material within the building and the cleanability of materials.

3. Requirements for ventilation, which in part adopts the European Guidelines.

4. Documentation for the operator.

5. Management of the air quality.

6. Operation of the equipment in a satisfactory manner.

7. Maintenance of the equipment to maintain the air quality.

8. Quality assurance of the air quality.

9. Inspection to check that designed procedures are followed.

This has resulted in Regulations for the Nordic countries which include fundamental design principles
1. Controls shall be easy to reach.
2. Components must be accessible.
3. The system must be cleanable.
4. The components must be durable.
5. Installations must have the required air tightness.
6. Ventilation performance must be demonstrated.
7. All information must be documented.

These Nordic Regulations are supported by SCANVAC which is the joint coordinating body for the professional institutions practising building services engineering within these countries. Corresponding societies in the Baltic states of Estonia, Latvia and Lithuania are associated members. SCANVAC helps to translate the Nordic Regulations into practice.

Mechanical ventilation designs can only be successful if the unplanned infiltration is small in comparison. This requires a standard for air tightness and many countries have evolved an appropriate air tightness specification which depends upon the ventilation system, much higher air tightnesses being specified when the buildings are designed for balanced ventilation systems. Air leakage is assessed in terms of air changes per hour (ACH) when the building is pressured to 50 Pascals. Various standards also cover the air tightness, durability and performance of the components used in the building construction (e.g. the performance of windows, doors, sealants and sealing components.

Some countries specify minimum ventilation requirements for dwellings. Scandinavia, the Netherlands and France specify stack ventilation if mechanical ventilation is not installed. Sweden requires mechanical ventilation with heat recovery when the space heating energy reqirements exceed 2 MWh/year and Canadian regulations require less than 5 Pascals under pressure in buildings with unforced combustion stacks.

Sweden is unusual in requiring compulsory system checks under the Swedish Work Environment Act and the Swedish Planning and Building Act. The inspection interval varies from 9 years for single family homes with balanced ventilation to every two years for day centres, schools and health care premises.

Factors influencing air quality
The means of securing optimum indoor air quality depends upon control of the polluting source, the ventilation system itself and the designed performance of the ventilation system within the building envelope.

Clean outdoor air is essential for achieving good indoor air quality. Although air cleaning is possible, it is costly and not effective in the many offices and dwellings that are either naturally ventilated, leaky or are ventilated by mechanical extract systems.

Pollutants emitted inside buildings are derived from metabolism, the activities of occupants and emissions from equipment, furnishings and building materials.

Achieving optimum indoor air quality relies on an integrated approach to the removal and control of pollutants based on source control, filtration, enclosing pollutant sources and ventilating the occupied space. All these mechanisms are governed by Standards, Codes of Practice and Regulations.

To fulfill the needs of best practice, it is important that these requirements and recommendations are followed. Comprehensive ventilation, health and indoor air quality guidance is regularly produced and updated as part of ASHRAE Standard 62 in the United States. Within the European Union, ventilation related Standards are being developed by Task Group 156, while in Scandinavia, the Nordic Committee on Building Regulations has published comprehensive ventilation guidelines.

Requirements are often "prescriptive" in the sense that the minimum rate of ventilation or the minimum size of ventilation openings is specified. Air flow rates are typically indicated for different types of room, occupant density or activity. Additional "air quality" requirements relate the amount of extra ventilation needed to deal with individual contaminant sources that may be present. Sometimes a choice may be given to select either a "prescriptive" or an "air quality" approach to estimating ventilation need. In general there is a strong linkage between Standards covering the requirements for ventilation and those associated with other aspects of energy efficiency and comfort within buildings. Adherence to this linkage is vital for securing reliable ventilation.

Linked topics include:
Health: Health related air quality Standards are typically based on risk assessment and are either specified in terms of a maximum permitted concentration or a maximum permitted dose. Higher concentrations of pollutants are normally permitted for short term exposure than are permitted for long term exposure. Typical examples include 1-hour and 8-hour "threshold Limit Values" or TLV's. Requirements cover the minimum ventilation needed to avoid injury to health. Values are largely prescribed according to building type, nature of pollutants, emission rates and acceptable exposure levels.

Energy Efficiency: Standards cover the avoidance of excessive energy waste. In some cases there may be a requirement for ventilation heat recovery.

Comfort: Air quality needs for comfort are highly subjective and dependent on circumstances. In the industrial arena, for example, higher levels of odour and heat may be tolerated than would be acceptable in the office or home. As a rule, health related air quality Standards, such as TLV's, set the minimum requirements for safety; these may not necessarily provide for comfort or efficiency at work or in the home. Requirements or recommendations may cover thermal comfort and odour intensity and the absence of draughts.

Ventilation Strategies: Standards often cover the type of ventilation appropriate to specific applications (e.g. enclosing polluting processes, extracting from kitchens and bathrooms, provision of fresh air supply to occupied spaces and the sizing of ventilation systems).

Air tightness: Energy efficient ventilation performance can be destroyed if the air-tightness of the structure is not compatible with ventilation strategy. Several countries have now introduced standards or recommendations covering the air-tightness performance of buildings. Similarly, various Standards cover the air-tightness durability and performance of the components used in building construction (e.g. the performance windows, doors, sealants and sealing components).

Conclusions

- Ventilation is just one component of the "Air Quality" process. Standards must consider related issues.
- An understanding is being reached on how ventilation performance is coupled to other fields.
- There is a good collaboration between Countries through CEN, ASHRAE, ISO and other groups.
- The Standards of some Countries, especially in relation to systems and air-tightness is more advanced than the UK.
- Information on Standards is regularly updated by the AIVC and is published in the AIVC Technical Note 43 "Ventilation and Building Airtightness: an International Comparison of Standards, Codes of Practice and Regulations".

Naturally ventilating UK non-domestic buildings: current status and future policy

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Summary
Increased concern over the adverse environmental impact of energy use has encouraged the design and construction of energy efficient buildings, and many are suited to natural ventilation. In the temperate UK climate, naturally ventilated buildings can provide year round comfort, with good user control, at minimum capital cost and with negligible maintenance.

The principle of good ventilation design is to `build tight - ventilate right'. That is, to minimise uncontrolled (and, usually unwanted) infiltration by making the building envelope airtight, while providing adequate `fresh' air ventilation in a controlled manner. It is necessary to emphasise that a building cannot be `too tight' - but it can be underventilated.

This paper shows that there is considerable scope for making UK buildings tighter and indicates the level of benefits that will accrue. UK activity in this area is identified, including proposed statutory control in the form of revised Building Regulations for England and Wales, which will address issues of tightness for the first time.

Information is available on ventilation requirements necessary to satisfy safety and health criteria. However, criteria relating to comfort, especially those associated with odour, metabolic CO_2, and summer overheating are still being investigated. This paper sets out current thinking in this area, including policies relating to minimising effects of tobacco smoking in public and commercial buildings.

The paper concludes by identifying currently available UK design guidance on natural ventilation. Various instruments which are underpinning these changes, such as revisions to the Building Regulations for England and Wales, codes and standards, professional guidance and support for policy-interests are identified.

This paper was presented at the 2nd International Conference on IAQ, Ventilation and Energy Conservation in Buildings, Montreal, Canada, May 10-12, 1995.

Introduction
At the 1992 Earth Summit in Rio de Janeiro, the UK Government committed itself to limiting emissions of the main greenhouse gas - carbon dioxide (CO_2) - by signing the Climate Change Convention. Buildings-related emissions, as a by-product of energy consumption, contribute about half (over 260 million tonnes) of the UK's release of CO_2. Of this, nearly 90 million tonnes can be ascribed to usage in commercial and public buildings corresponding to a delivered energy consumption of 812 PJ [1].

Natural ventilation is firmly on the UK design agenda because of the potential impact that mechanically serviced buildings can have on environmental issues such as global warming (through emission of CO_2) and ozone depletion (through the use of CFCs and HCFCs). Natural ventilation also offers the potential bonus of providing greater occupant control and avoids the perceived health risks associated with some air conditioned buildings. As a result of these concerns, there are signs that, increasingly, UK clients and developers are seeking naturally ventilated solutions to building 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. In a naturally ventilated building, air enters a building either by design (e.g. openable windows) or adventitiously from uncontrolled leakage (infiltration) through cracks and gaps in the building fabric.

The aim of good design is therefore 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;

have to be considered together in an integrated manner.

Minimising infiltration

Field measurements show that there is considerable scope for making UK buildings tighter [2]. The average UK office building is twice as leaky as an average North American or Swedish. Buildings where staff dissatisfaction has been strongly expressed, and where internal areas are either too hot or too cold (depending on the outside air temperature) have been found to be four times as leaky.

Studies [3,4] have shown that infiltration in a (medium-sized) office with a leaky envelope can be three times that of an equivalent building with a tighter envelope. In terms of space-heating requirements during the heating season, this infiltration represents a loss of about 220 GJ (third of total) compared with 70 GJ (seventh of total) for the tight building.

Approximately three-quarters of the air leakage may be through background hidden paths (Fig 2) rather than through identifiable gaps and cracks in the envelope. Some benefits can be obtained by tightening existing buildings, but often post-constructional remedial measures may have only a minimal effect on an already leaky building. It is therefore more effective to design and construct tighter buildings than to carry out post-construction tightening.

The revised 1995 Edition of Approved Document Part L (Conservation of Fuel and Power) [5] of the Building Regulations for England and Wales contains new provisions for reducing air leakage at windows and doors and through the building fabric. To support this, BRE has produced a report [6] to give guidance on methods of reducing air infiltration in large, complex buildings like offices.

Unlike countries such as Canada, Netherlands and Sweden, the UK has no mandatory requirements for post-construction compliance testing. However, there are indications that some elements of the UK industry are setting voluntary standards as part of the commissioning process before `hand-over'. The simplest form of standard is that for a `tight' building, the whole-building leakage should not exceed 5 m^3/h (per m^2 of permeable envelope area) for an imposed pressure differential of 25 Pa across the envelope.

Good constructional practice, emphasised in the BRE guidance document [6], is the key to a tighter building. In the UK, there are good examples of tight buildings constructed according to these principles; eg. the purpose-built BRE Low Energy Office [7] and the low-energy housing development in Orkney [8].

Ventilation requirements

With tighter buildings, greater attention has to be paid to providing adequate ventilation and a correct balance has to be struck with energy efficiency. To do this, it is necessary to identify the role played by ventilation with respect to the following criteria:

- Safety;
- Health;
- Comfort.

Associated with each is an energy cost, either for space heating in the winter or, in certain instances, for cooling in the summer. The basis of good design is to identify the requirements that need to be satisfied, and to provide the necessary `fresh' air ventilation in an appropriate and controlled manner, i.e. in an optimum manner.

Safety criteria relate mainly to eliminating or minimising the risk of explosion resulting from airborne contaminants. The risk levels are set by the higher and lower explosive limits; values for gases and vapours are published by the UK Fire Protection Association when such guidance is necessary.

Ventilation necessary to satisfy health criteria is mainly set by the requirements for:
- Human respiration; and
- Dilution and removal of contaminants generated within the occupied space.

Common pollutants generated within buildings can include the naturally occurring gases (eg. CO_2, ozone, water vapour, methane), products of combustion (eg. carbon monoxide, oxides of nitrogen and sulphur), volatile organic compounds (eg. formaldehyde) and particulates and fibres. Within this, environmental tobacco smoke (ETS) could be considered another pollutant.

An over-riding principle in 'ventilating right' is that ventilation should be for people - not for the building. A common misconception is that dilution ventilation is the only way to remove harmful contaminants from within the occupied space. The UK Committee on Substances Hazardous to Health (COSHH) Regulations lists [9] the following methods (in order of preference) to ensure maintenance of good indoor air quality:
- Eliminate the substance;
- Substitute the substance for another less hazardous;
- Enclose the process;
- Partially enclose the process and provide local extract ventilation;
- Provide general (dilution) ventilation; and
- Provide personal protection.

In the office environment, generation of internal pollution should either be avoided (eg. low-emitting furnishing and carpeting) or controlled locally (eg. by local extract ventilation near photocopying machines). If this strategy is carried out, ventilation through fresh air is then only needed to:
- Provide sufficient oxygen for breathing;
- Dilute body odours to acceptable levels; and
- Dilute to acceptable levels the concentration of CO_2 produced by occupants and combustion.

Consequently, the following fresh air levels (per person) of ventilation are required:
- 0.3 l/s as the minimum necessary to provide oxygen for life;
- 5 l/s to satisfy the current CIBSE (Chartered Institution of Building Services Engineers) recommended minimum ventilation rate;
- 8 l/s as identified in the new 1995 edition of Building Regulations Approved Document (AD) Part F (Ventilation) for England and Wales [10] provision for 'rapid' ventilation (ie. to rapidly dilute when necessary, pollutants produced in habitable rooms); and
- 16 l/s in the same Regulation's provision for rooms designed for 'light' smoking.

Depending on the proportion of occupants smoking, ventilation requirements can not only be doubled, but can be quadrupled. A no-smoking policy or smoking in a restricted zone (ventilated separately) may be appropriate in these instances. The UK government's Code of Practice on smoking in public place [11] contains suggestions on ventilating smoking areas and rooms.

Design for natural ventilation

Natural ventilation is the movement of air through a building driven by wind and buoyancy induced pressures. Wind-induced pressures on a building depends on wind direction, itsspeed 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.

Some simplified guidance on designing for natural ventilation is given in the revised AD Part F. This provides guidance on the use of permanent background ventilators with an openable area of 400 mm2 per m^2 (of floor area) to meet occupant health requirements (of 5 l/s per person), usually in winter. Similarly, guidance is given on the sizing of windows - the most obvious controllable opening for natural ventilation, especially in summer. The recommendation is for an openable area of at least 1/20th of the floor area for 'rapid' ventilation.

Until now, Building Regulations only dealt with provision for ventilation in domestic buildings. The revised AD Part F now addresses ventilation in non-domestic buildings as well. As a result, and because there was no authoritative guidance on providing natural ventilation in non-domestic buildings, BRE joined with the CIBSE Natural Ventilation Group to produce a new BRE digest [12] on 'Natural Ventilation in non-domestic building'. The digest is the precursor of a more detailed and comprehensive joint CIBSE/BRECSU (Building Research Energy Conservation Support Unit) Applications Manual to be published next year. These two guidance documents are intended to make existing knowledge more widely available.

Research is under way in the UK to address many of the technical issues that currently limit the use of natural ventilation in buildings. In particular, the Department of the Environment's Construction Sponsorship Directorate, in collaboration with BRE, has launched the Energy-Related Environmental Issues (EnREI) research programme to address a range of key issues in the design and management of non-domestic buildings and their services. It includes some 20 different research projects such as:

- Energy-efficient ventilation of large buildings;
- Design and control of night cooling; and
- Energy-targeting strategies for non-domestic buildings, with many of them in collaboration with industry.

An important aim of the UK research programme is to ensure that all the findings and new technologies are absorbed into practice as soon as possible. This is done in a variety of ways:

- Technical input into revisions of the Building Regulations, especially into Approved Document Part F (Ventilation) and Part L (Conservation of Fuel and Power);
- Influence on the developments of national and international codes and standards (eg. CEN and British Standards);
- Input into consensus professional guidance such as CIBSE Guides and Codes; and
- Dissemination via technical authorities of national standing; eg. through BRE Reports and Digests and Energy Efficiency Office Best Practice Guides.

Dissemination through articles in technical and professional journals,seminars and demonstration projects for:

- developers of new buildings;
- owners of existing buildings;
- their professional advisers;
- property agents and managers;

- helping market mechanisms to bring about improved environmental performance; eg. through initiatives such as the BRE Environmental Assessment Method (BREEAM) for assessing the environmental quality of buildings; and
- providing input to ENBRI (European Network of Building Research Institutions) and CIB (Construction du Batiment Internationale) initiatives on environmental issues.

Conclusions

Ventilation is of fundamental importance in securing a healthy environment within buildings. However, ventilation air must often be conditioned by space heating or cooling. This is an energy intensive process which is estimated to account for between a third and a half of all energy consumed in buildings. Excessive or uncontrolled ventilation, therefore, can be a major contribution to general global pollution.

This paper has emphasised that a strategy of designing for natural ventilation needs to go hand-in-hand with that of 'build tight - ventilate right'. The issue of providing ventilation for occupants rather than for buildings was emphasised.

Building design must be appropriate and sympathetic to the client's needs. Good design techniques and practice are essential key factors to a wide and successful uptake of natural ventilation buildings. It is therefore essential that an overall strategy be developed to ensure that the appropriate research is targeted and disseminated within various instruments which underpin this uptake. This includes legislation, codes and standards, professional guidance as well as good-practice initiatives providing the 'pull' (through high-profile energy-efficient and environmentally-friendly buildings) to complement any statutory 'push'.

References

1.Moss, S A, Energy consumption in public and commercial buildings, BRE Information Paper IP 16/94, (1994).

2.Perera, M D A E S and Parkins, L M, Airtightness of UK buildings: Status and future possibilities, Environmental Policy and Practice, Vol 2(2), pp 143-160, (1992).

3.Perera, M D A E S, Marshall, S G and Solomon, E W, Controlled background ventilation for large commercial buildings, Proceedings of the 13th AIVC Conference on Ventilation for Energy Efficiency and Optimum Indoor Air Quality, (1992).

4.Perera, M D A E S, Powell, G, Walker, R R and Jones, P J, Ventilation performance of large buildings: Prediction using pressurisation measurements, Building Services Engineering Research and Technology, Vol 12(3), pp 95-102, (1991).

5.Department of the Environment and The Welsh Office, Approved Document L (Conservation of Fuel and Power) 1995 Edition, HMSO, (1994).

6.Perera, M D A E S, Turner, C H C and Scivyer, C R, Minimising air infiltration in office buildings, BRE Report BR 265, Building Research Establishment, Watford, (1994).

7.Crisp, V H, Fisk, D J and Salvidge, A C, The BRE Low-Energy Office, BRE, Garston, (1984).

8.Scivyer, C, Perera, E and Webb, B, Build tight: The Orkney experience, Building Services, pp 32-33, (July 1994).

9.Youle, A, Building services engineering and the control of substances hazardous to health (COSHH) regulations, Proceedings of the CIBSE National conference, (1991).

10.Department of the Environment and The Welsh Office, Approved Document F (Ventilation) 1995 Edition, HMSO, (1994).

11.Government Code of Practice, Smoking in public places: Guidance for owners and managers of places visited by the public, Department of the Environment, (1991).

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

Fig 1

Design criteria for the indoor environment
Thermal state of the body as a whole

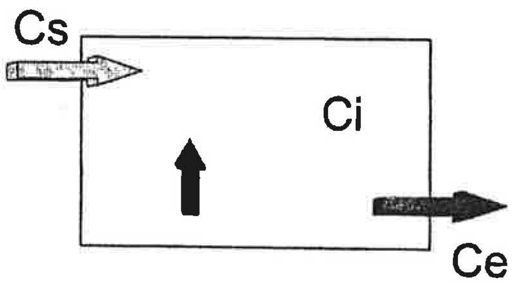
PPD (percentage population dissatisfied

category

category	A	< 6 %
	B	< 10 %
	C	< 15 %

Fig 2

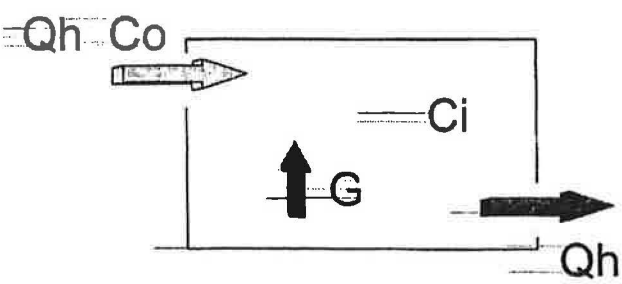
Ventilation effectiveness



$$Ev = \{(Ce - Cs) / (Ci - Cs)\}$$

Fig 3

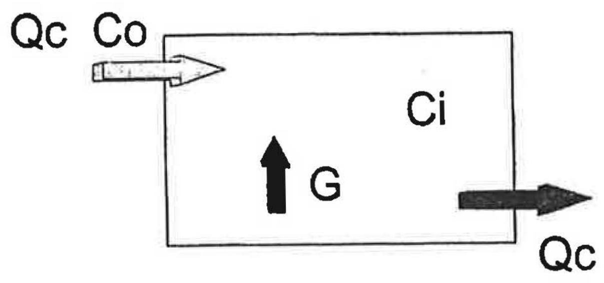
Required ventilation rate - health



$$Qh = G / [(Ci - Co) Ev]$$

Fig 4

Required ventilation rate - comfort



$$Qc = 10\,G / [(Ci - Co)\,Ev]$$

Fig 5

Design criteria for the indoor environment
Landscaped office

		ventilation rate l/s/m.sq	sound pressure dB(A)
category	A	1.7	35
	B	1.2	40
	C	0.7	45

Fig 6

Required ventilation rate per occupant - l/s

	% smokers			
category	0	20	40	100
A	10	20	30	60
B	7	14	21	42
C	4	8	12	24

Fig 7

Design criteria for the indoor environment

Landscaped office

mean air velocity (m/s)

		summer	winter
category	A	0.18	0.15
	B	0.22	0.18
	C	0.25	0.21

Fig 8

Design criteria for the indoor environment

Landscaped office

operative temperature

		summer	winter
category	A	24.5+/-0.5	22.0+/-1.0
	B	24.5+/-1.5	22.0+/-2.0
	C	24.5+/-2.5	22.0+/-3.0