INTERNATIONAL ENERGY AGENCY
energy conservation in buildings and community systems programme

An Annotated Bibliography
Air Intake Positioning to Avoid Contamination of Ventilation Air

Air Infiltration and Ventilation Centre,
University of Warwick Science Park,
Sovereign Court,
Sir William Lyons Road,
Coventry. CV4 7EZ

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Mark J Limb

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The Air Infiltration and Ventilation Centre
University of Warwick Science Park
Sovereign Court
Sir William Lyons Road
Coventry CV4 7EZ
Great Britain

Preface

International Energy Agency

The International Energy Agency (IEA) was established in 1974 within the framework of the Organisation for Economic Co-operation and Development (OECD) to implement an International Energy Programme. A basic aim of the IEA is to foster co-operation among the IEA Participating Countries to increase energy security through energy conservation, development of alternative energy sources and energy

Energy Conservation in Buildings and Community Systems

The IEA sponsors research and development in a number of areas related to energy. In one of these areas, energy conservation in buildings, the IEA is sponsoring various exercises to predict more accurately the energy use of buildings, including comparison of existing computer programs, building monitoring, comparison of calculation

The Executive Committee

Overall control of the programme is maintained by an Executive Committee, which not only monitors existing projects but identifies new areas where collaborative effort may be beneficial.

To date the following projects have been initiated by the Executive Committee (completed projects are identified by *):

I Load Energy Determination of Buildings*
II Ekistics and Advanced Community Energy Systems*
III Energy Conservation in Residential Buildings*
IV Glasgow Commercial Building Monitoring*
V Air Infiltration and Ventilation Centre
VI Energy Systems and Design of Communities*
VII Local Government Energy Planning*
VIII Inhabitant Behaviour with Regard to Ventilation*
IX Minimum Ventilation Rates*
X Building HVAC Systems Simulation*
XI Energy Auditing*
XII Windows and Fenestration*
XIII Energy Management in Hospitals*
XIV Condensation*
XV Energy Efficiency in Schools*
XVI BEMS - 1: Energy Management Procedures*
XVII BEMS - 2: Evaluation and Emulation Techniques
XVIII Demand Controlled Ventilating Systems*
XIX Low Slope Roof Systems
XX Air Flow Patterns within Buildings*
XXI Thermal Modelling
XXII Energy Efficient Communities
XXIII Multizone Air Flow Modelling (COMIS)
XXIV Heat Air and Moisture Transfer in Envelopes
XXV Real Time HEVAC Simulation
XXVI Energy Efficient Ventilation of Large Enclosures
XXVII Evaluation and Demonstration of Domestic Ventilation Systems
XXVIII Low Energy Cooling Systems

Annex V Air Infiltration and Ventilation Centre

The Air Infiltration and Ventilation Centre was established by the Executive Committee following unanimous agreement that more needed to be understood about the impact of air change on energy use and indoor air quality. The purpose of the Centre is to promote an understanding of the complex behaviour of air flow in buildings and to advance the effective application of associated energy saving measures in both the design of new buildings and the improvement of the existing building stock.

The Participants in this task are Belgium, Canada, Denmark, Germany, Finland, France, Netherlands, New Zealand, Norway, Sweden, Switzerland, United Kingdom and the United States of America.

CONTENTS **PAGE**

Other Bibliographies in this series:

1. *Ventilation and Infiltration Characteristics of Liftshafts and Stairwells (1994)*
2. *Garage Ventilation (1994)*
3. *Natural Ventilation (1995)*

Air Intake Positioning to Avoid Contamination of Ventilation Air - An Annotated Bibliography

SCOPE

This bibliography summarises research into the positioning of air intakes to avoid contamination of ventilation air. It is aimed at researchers, designers and engineers who would benefit from an introductory overview of research into this subject. References quoted in this document are available, to participating countries, from the AIVC's Bibliographic Database, "AIRBASE".

1.0 INTRODUCTION

The position of the fresh air intake is a vital element in the design and installation of ventilation systems. It is from this point that outside air is drawn into a building for ventilation. In the literature outdoor air is often termed "fresh air". However, while this air may not have been previously circulated throughout the building, it may already have been contaminated by other sources. Pollutants can become entrained in this air because of the airflow characteristics around the building or intake, or indeed may simply be drawn in through the choice of intake location. Despite the fact that guidelines for the positioning of air intake, to avoid such pollution incidents, have been put forward by CIBSE and ASHRAE, several references discuss buildings where, for one reason or another, such guidance has not always been followed. This bibliography based on current research, attempts to demonstrate various ways in which the pollution at air intakes can be minimised at the design stage. Also for those buildings which have become polluted, it discusses what actions are then available, to reduce the contamination of the indoor environment.

2.0 POSSIBLE CAUSES OF AIR INTAKE CONTAMINATION.

Short-circuiting, badly chosen fresh air intake locations and poor HVAC maintenance have been cited as the most common causes of ventilation air contamination (Ferahian, #3569, 1989). Similar problems have been highlighted throughout a wide variety of buildings by a number of other authors, including Walkinshaw (#7291, 1993), Gorman (#8441, 1984) and Solberg et al (#3777, 1990). The aim of this section is to focus specifically on causes of fresh air contamination and outline research aimed at improving the siting of intakes at the design or retrofit stage.

2.1 Environmental Wind Flows Around Buildings.

Several authors discuss the prediction of dispersal patterns of gaseous pollutants in the outdoor air around buildings. A number of analytical and wind tunnel models have been developed to predict such contaminant dispersal. According to Aynsley et al (1977) chimney stacks should be sufficiently high to ensure the exhaust plume clears the immediate buildings and also care should be taken in the wake regions of buildings, where pollutants are exhausted. These represent the

two main problems associated with outdoor air pollution around buildings. It is necessary to determine the resultant concentrations which will occur at air conditioning intakes and at street level. Such problems are often site specific and thus it is difficult to give any generalised guidance. Aynsley suggests that even the old rule-of-thumb that to be really effective a stack should be twice as high as adjacent buildings cannot be quoted as a certain way to avoid problems.

A jet plume model for short stacks is described by Halitsky (#8762, 1989) which contains a realistic initial jet region merged with a subsequent gaussian plume region. According to the author, the model brings together three experimentally verified elements; the initial jet region, the subsequent simple plume region and a curved plume centreline. He concludes, the jet plume model can be expected to produce meaningful predictions only if the assumed and actual wind fields are in general agreement. Large roof cavity regions on buildings in normal orientation, and edge vortex regions on buildings in diagonal orientation are excluded.

Wilson (#8451, 1977) discusses the effect of changing a building's exhaust stack height or its exit velocity in terms of the reduction of pollutant concentration measured at a receptor point. Experiments and the development of a simple theoretical model are outlined and it is shown that both the stack height and vertical exit velocity can be combined to determine an effective stack height. This, according to the author allows the designer to determine a trade-off between increasing the physical height of the stack, or increasing the vertical velocity from the stack. Wilson finds that, because of the non-linear nature of the dilution process, the designer must be cautious when compromising the optimum stack height with any architectural constraint. This makes the concept of effective stack height both a useful parameter in estimating dilution from vent stacks. Wilson considers that because the fan power necessary to exhaust a given quantity of vent gas is proportional to the square of the vent gas velocity, the key question is whether there is any significant reduction in roof receptor concentrations for reasonable vent velocities, which do not require excessive fan power. If large values of exit velocity are required the necessary stack fan power may make it much more attractive to simply raise the height of the stack. He summarises his investigation by stating, stacks extending less than about 25% of the building height above the roof are probably not worth considering.

A study to develop simple quantitative stack design procedures is discussed by Wilson and Winkel (#8440, 1982). Using a wind tunnel model, different stack heights were tested to determine their effect on the pollution diffusion patterns on a number of building models. Wilson suggests that the design procedure for estimating the reduction in roof intake contamination from an increase in stack height, will give unreliable results if the stack is in, or near, the flow recirculation cavity, or near a roof edge vortex when the wind is not perpendicular to a building wall. It is further stated that the design equations developed in this paper are useful in predicting the effect of remedial stack height changes on existing exhaust vents. Wilson concludes that for original design the best procedure is to provide sufficient stack height to avoid contact of the plume with the roof. In particular the stack must never terminate inside the roof recirculation cavity. These design methods are outlined in Chapter 14 of the ASHRAE Fundamentals Handbook.

Wilson (#2914, 1982) also considered the design and location of exhaust stacks and presents an equation to predict the minimum exhaust to intake dilution factors. This includes the capability of being able to account for the intake dilution due to exhaust jet momentum, turbulent entrainment of ambient air with downwind distance, and the effect of averaging time over which the intake is exposed. The author states that wind tunnel experiments were used to validate the equation, within a factor of 2, over a wide range of exhaust to intake spacing distances. Wilson suggests three factors that should be considered to minimise intake air contamination. Exhausts should be designed to; (i) maintain a minimum distance from intakes in order to take advantage

of distance dilution; (ii) have uncapped exhausts that produce a strong exhaust jet perpendicular to the building surface. It is suggested avoiding louvres and rain caps and maintaining the exhaust velocity at least as high as the local average airport windspeed; (iii) exhausts should be located on the upper two thirds of the building, and always above the level of intakes to take advantage of exhaust buoyancy and to avoid being trapped in flow recirculation regions near the ground. If these points are considered by the designer it should be possible to avoid having more than 1% of exhaust gas contamination in intake air, when averaged over an exposure time of several hours.

An analytical design procedure for estimating air intake contamination from nearby exhaust vents is described by Wilson (#8438, 1983). A simple design procedure is given for determining the necessary height of an exhaust stack to produce a specified level of dilution at a nearby air intake. The effects of internal system dilution, wind dilution and that from stack height are considered separately. The three effects are then combined to determine the available dilution at a critical windspeed which produces minimum dilution. The empirical constants were derived from wind tunnel and full scale dilution measurements. The concept of "available dilution" is used to give a ventilation designer better information on the amount of contamination expected at an air intake for a given exhaust intake configuration. This method has been adopted by ASHRAE.

Schuyler and Turner (#3617, 1989) compared wind tunnel test results with empirical exhaust dilution factors, such as those outlined in Chapter 14 of the ASHRAE Fundamentals handbook. They concluded that, in simple cases, the empirical exhaust calculations can be used to check stack design. However, the margin of error associated with these results must be carefully considered when making final design decisions. The authors emphasise the importance of building geometry as a major source of variability and in their study they show that small upwind obstructions can greatly alter the dilution. Therefore, to make decisions based on these results they found that more information is needed regarding wind climate and the particular chemicals being used. Such information is freely available and can be used when making any decisions. The authors consider the empirical calculations useful in identifying a potential problem condition, before a more detailed wind tunnel study is undertaken. They also stress that, when using the calculations on their own as a design tool, one should maintain a healthy level of conservatism in setting stack heights or intake locations.

Analytical and wind tunnel methods used to determine concentrations due to laboratory exhaust are also compared by Petersen and Wilson (#3533, 1989). They conclude, that for a low exit velocity stack with a small exit diameter and zero stack height, the wind tunnel and analytical estimates compare within a factor of two to six, with the ASHRAE estimates tending to be conservative. For a high exit velocity stack, with a large diameter and zero stack height, the wind tunnel intake dilutions were generally an order of magnitude greater than those obtained using the analytical equations. Furthermore, the authors also state that the paper provides evidence that the equations in Chapter 14 of the ASHRAE fundamentals Handbook do provide conservative estimates of the expected dilution for laboratory stacks, even for the non-idealised building shape considered. However, the estimates may be overly conservative and may result in added design expense (unnecessarily tall stacks or emission control devices). If a designer wishes to optimise the stack design with respect to cost, aesthetics, and safety, the authors suggest that obtaining the added accuracy provided by the wind tunnel may be necessary.

Wilson and Lamb (#8761,1994) conducted a study of six roof exhaust locations to test and refine a minimum dilution model. The model, designed to predict dilution for exhausts and intakes located on the same flat roof surface, gave very good results for roof and ground level receptors with the six different exhaust locations tested. The study suggested that the theoretical model for initial dilution tended to slightly underpredict the initial dilution term. A further conclusion, was

the dilution parameter (B1) is dominated by upwind rather that building-generated turbulence for 1-h averages. The study found this strong dependence on upwind-generated roof-level turbulence, which the authors consider surprising, as it was expected that ground level receptors in the near wake should be dominated by turbulence from the nearest building and not from upwind turbulence. The results of this study show that the minimum dilution model can be confidently applied over a wide range of building exhaust and receptor locations within a group of buildings.

The second problem highlighted by Aynsley et al (1977) concerns pollutants exhausted into the wake regions of buildings. Huber and Snyder (#8455, 1982) undertook a wind tunnel study to investigate the influence of the highly turbulent region found in the lee of a model building upon plumes emitted from short stacks. A rectangular shaped building with its length equal to twice its height and width was orientated with long side perpendicular to the approach wind. The stack was placed midway along the lee side of the building. Both smoke and tracer gas were released with no building present and then with it in place. This allowed for a demonstration of the building wake effects. An analytical model was then developed that provided good estimation of concentrations in the building wake. The building influence was found to be reduced with increases in the effective source height. The application of the "2.5 times rule" ie, an effective source height at 2.5 times the height of the building, resulted in maximum ground level concentrations in the wake being approximately 20% higher than those found in the absence of the building. A stack 1.5 times the height of the building resulted in maximum ground level concentrations in the wake being 250% higher, a far more significant effect.

Melbourne and Garsthore (#8446, 1975) describe an experimental study of the concentration of flue gas ingested into the air conditioning intake of a tall isolated building, with both the emitting stack and the air intake located on the flat roof of the building. Using a wind tunnel model of the 170m high building, and using pure helium as a tracer gas emitted from the model stack, concentrations in the intake air were measured to estimate the percentage contamination. Results showed that this contamination appeared to be independent of the volume flow rate of the air conditioning gas, directly dependent on the mass flow rate of the flue gas and varying between 0.25 and 0.4% for various wind speeds and directions at a flue emission rate equivalent to $1.7m^3/s$. Further model tests showed that, when the air inlets were located on the face of the building rather then the roof, the contamination from the flue gas was roughly halved if the intake was on the lee side, or eliminated if the intake was out of the building wake.

A wind tunnel model was also used by Ratcliff et al (#7914, 1994) to predict the dispersion of diesel exhaust fumes around four different building layouts; (i) a U-shaped building with a loading dock located near a large air intake; (ii) an L-shaped industrial building, with a diesel generator exhaust orientated horizontally; (iii) a loading dock on the side of a building; (iv) a diesel generator located in an alley with a new air intake around the corner. The authors suggest that diesel trucks idling at loading docks and the testing of emergency diesel generators were often responsible for a number of complaints. These complaints are worsened by badly designed building layout, diesel source locations and the building fresh air intake locations. Using wind tunnel modelling the authors found that the open face of a building (layoutiii) is a preferred location for loading docks. However, U and L shaped building enclosures were found to have problems due to the air recirculation zone downwind of the large buildings; counter intuitive flow directions were also found between closely spaced large buildings (layout iv), which may lead to odour problems.

Similar boundary-layer wind tunnel studies using scale models to provide visual and quantitative information with which to develop properly designed exhaust vents and intake louvres, were conducted by Lepage and Schuyler (#4484, 1990). The tests highlighted some unexpected exhaust

re-ingestion problems. For example, it was shown that the placement of fresh air intakes upwind of exhaust vents for the prevailing wind does not guarantee minimal re-ingestion and in fact, can worsen it. Large separation distances between exhausts and intakes also do not ensure minimal re-ingestion. Other factors which must also be taken into account are, building shape, surrounding terrain, stack height, exhaust air velocity and exhaust flow rate. These conclusions are based on a series of wind tunnel scale model studies.

Perera et al (#5264, 1991) describes the results of a wind tunnel study undertaken on two adjacent laboratory buildings, (approximately 30m high) located in a suburban environment. As part of the study, the impact and distribution of fume cupboard exhaust (by two 4m high stacks on the roof of one building) was studied on the adjacent building. Measurements, over a range of wind speeds and directions, were made in order to show how the concentration levels varied as the parameters changed. These measurements also enabled the identification of the wind parameters that would result in maximum contaminant levels at these locations. The maximum concentration levels were compared with an ASHRAE prediction procedure for the case of isolated buildings (Wilson #8438, 1983). The authors found that the two methods provided similar results, although they were considerably improved depending upon the choice of the distance-dilution parameter used in the prediction procedure. They conclude that, in absence of the wind tunnel test, this prediction method could be used to provide guidance as to expected maximum contaminate levels at intake locations. However, wind tunnel tests provide more detailed and accurate estimates, for example, where there is the possibility of airflow interactions with neighbouring building, or when it is necessary to consider the specific effects of local wind speeds and directions.

Wilson (#8450, 1977) addresses the question of whether the dilution factors for vents located on the vertical sides of a building can be estimated using the same equation developed for flat roofs. Although vents located on the front, sides or rear of the building are less common than the roof vents, they are used on medium and high rise buildings, most of which have exhaust vents located on their vertical sides near ground level, mid way up the building or close to the roof line. Using wind tunnel studies it was found that for front facing vents, the pronounced up and downwash patterns on the front of buildings indicate that it would be good design practice to locate vents on the upper 1/3 of the building surface and intakes on the lower 2/3, or vise versa. This would prevent the natural flow patterns on the front face of the building contributing to intake contamination from exhaust air. For side vents, it was found that receptor points which are equidistant from the vent and a vent located on the lower portion of the side, will generate higher levels of concentration than one located closer to the roof. This occurs for two reasons, firstly the wind speed near ground level is less than that near the roof and this prevents rapid dilution of the gas for vents closer the ground. Secondly, the ground acts as a reflecting plane to push contaminated gas back into the separated flow near the building. In the case of rear vents, these are subjected to high levels of turbulence which help to diffuse the gas at a much more uniform pattern than vents located on other faces. However, Wilson suggests that the results of this study should only be used as a guide and any increase in vent face velocity will tend to blow the vented gas away from the building, decreasing the surface concentration.

A method for estimating critical windspeed at which maximum air intake contamination occurs is further presented by Wilson (#8439, 1982). This involves the combination of plume rise and diffusion models. The "Worst Case" is also considered. Wilson finds that that the critical speed is typically 20% of the vent exit velocity, and that for variations in wind speed of a factor of six (from one-half to three times the critical value), the exhaust gas concentration at the air intake will only vary by a factor of about two. The overall conclusion is that these worst case conditions will be a common occurrence, and that critical speeds are responsible criteria to use for design purposes.

Equations, originally proposed by Halitsky in 1963, for the prediction of minimum atmospheric dilution for use in exhaust system design, and outlined in Chapter 14 of the ASHRAE Fundamentals Handbook, are re-examined by the author (#3707, 1990). He considers the equations lack the terms representing the larger dilutions in the plume below the centreline, and therefore yield conservative estimates of dilution at receptors at the lower edges of elevated plumes. The equations also contain empirical constants that could be adjusted to provide more realistic dilution estimates, but no guidelines are offered in the handbook for such adjustment. This paper, therefore, describes an alternative approach using the Halitsky (#8762, 1989) jet plume model. It represents a physically realistic model that has the capability of predicting off-centre dilutions. However, the author stresses that judgment is needed in the selection of a wind parameter, placement of the ground plane, and estimation of the possibility of building generated flow separation and vortices. Model predictions were then favourably compared with dilution observations in a wind tunnel model test of a laboratory building described by Petersen and Wilson (#3533, 1989).

Further work by Halitsky (#8456, 1991) describes a mathematical procedure for correcting a horizontal wind stack plume centreline for wind field curvature over a building. It employs exact solutions for potential flow over idealised bodies that resemble the envelopes enclosing buildings and their zones of separated flow. The correction is made progressively over small increments of downwind distance, starting at the stack top and following the local streamline in each increment. The procedure is applied to a simple block building and stack used in a wind tunnel test, and the corrected plume centreline, together with plume boundaries calculated using the Halitsky jet plume model (#3707, 1990) are shown superimposed on a smoke photograph for comparison. In conclusion, the author notes that the proposed procedure creates a deflected plume that is in reasonable agreement with a smoke plume in a wind tunnel test. The validity of the procedure for a variety of building shapes has not been established, but the principle of using exact potential flow solutions and empirically based potential flow body proportions for the purpose of stack design to avoid plume entrainment in the building cavity, appears to be supported in this case. Further experimentation, focusing on near-field plume behaviour with a variety of building shapes and stack arrangements, is needed for further validation.

Recent developments in Computational Fluid Dynamics (CFD) have meant that this type of modelling can now be undertaken without wind tunnel tests. An example of such a study is Ong (#8447, 1991), in which the wind flow over a factory roof was analysed. A number a VOC's and by-products of manufacturing processes were being discharged via roof mounted stacks. Concern was shown as to the possible re-entrainment of these exhaust gases into the roof mounted air handling units. Results using CFD, supplemented with empirical based calculations, showed that the dilution levels are sufficiently high to ensure that concentrations of stack emissions at air handling unit intakes are within acceptable limits.

2.2 The Problem of Short Circuiting.

Contamination of the wake regions of buildings described above can lead to Short Circuiting. Ferahian (#3569, 1989; #8442, 1986; #1462, 1984) suggests this as a major cause of contamination of fresh air intakes which can result from the natural airflow around the building, or simply by poor design, which has led to the building ventilation intake and exhaust being in the same vicinity. Ferahian (1985, #8452) suggests that, despite all codes warning against short circuiting of the fresh air intakes with building exhausts, it is still a common problem. The author cites seven case studies were such pollution has been exhibited, and concludes that, unless designers

and building inspectors adhere to the scientifically based building codes, such research is of little or no use to the building occupants themselves.

Gorman (#8441, 1984), considers cross contamination and entrainment and suggests possible situations where these are most likely to occur. Cross contamination is possible in multi-use buildings; (i) where an office area and contaminant generating area are serviced by the same HVAC system; (ii) separate HVAC system serving adjacent areas, one of which is a contaminant generating area; (iii) a change in space usage relative to original design and heat wheel recovery device (See Dehli et al, #7034, 1993). Entrainment occurs when contaminants are brought into the building from the outside. For example, when fresh air intakes that are located too close to upwind exhaust stacks, or exhaust stacks discharge inside the turbulent wake that is caused by the airflow over and around the building.

Marchant et al (#8427, 1990), reports on a study that investigated the occupant complaints in a new hospital kitchen. A 100% fresh air intake served the kitchen and air was brought in at ground level in a courtyard. The supply intake was located in front of an eight foot high brick wall, midway between two buildings on either side and facing an open park area. The dishroom exhaust, including the exhaust from the dishwasher, was also located in the same courtyard, on the wall of one of the buildings, 20 feet (6m) above the ground and about 100 feet (30.5m) away from the supply intake. TVOC concentration near to the intake were found to be $0.3mg/m^3$, well above the $0.1\ mg/m^3$ normally associated with outdoor air. Evidence, obtained by using a tracer gas and identifying common pollutants between the exhaust air and intake air, confirmed that short circuiting was occurring. The authors recommended that the kitchen exhaust be re-routed and all duct work and affected areas be cleaned.

Another similar scencario was discussed Bahnfleth and Govan (#4026, 1987) concerning the consequences of a hamburger restaurant placing a grill exhaust system in a downtown ground floor location. Grease fumes were discharged horizontally into an alleyway and entered the air intake of an office complex situated across the street. This particular type of situation could represent a significant source of indoor air quality problems as well as creating economic loss in office buildings in city centre locations. They emphasize that careful attention must be given to how wind forces cause air to move over and around buildings and to use such movements to advantage in avoiding re entry and IAQ problems. The authors conclude by suggesting that, in these locations exhaust fumes should be released from the highest point of the building in which the source is located. These systems should end with vertical discharge through drain type stack hoods and although outside air may be taken from various levels without IAQ problems developing, good engineering practice should be followed to avoid bringing contaminated air into a building.

Arens and Williams (#17, 1977) in considering the effect of wind on energy consumption in buildings, noted that the airflow around a building alters the pressure at intakes and outlets, resulting in short-circuiting of these vents. In an attempt to avoid this problem, designers have spaced exhaust and inlets far apart, which has a resultant impact on ductwork and plumbing costs. The authors suggest that a knowledge of wind influences might be used to minimise the distance between the inlets and exhausts, thereby reducing costs and increasing the feasibility of waste heat retrieval equipment. Solberg (#3777, 1990) also found that when the wind is blowing at right angles to the intake louvre face, there could be a loss of pressure at the air intake, due to the presence of a cross wind or slipstream condition. This could lead to short-circuiting from the slipstream, and possible indoor contamination from outside pollution sources.

Ludwig et al (#6992, 1993), undertook a tracer gas study to evaluate the dilution of exhaust stack emissions from chemical fume hood stacks on the rooftop of a laboratory building. Results should that, under normal operating conditions, exhausts from the laboratories emitted through the stacks, would not be expected to reach the outside air intakes in concentrations high enough to have a detrimental impact on the health of building occupants. However, odours of certain chemicals could be detected at the outside air intake and therefore it could be assumed to be the cause of indoor air quality complaints. The author concludes that the occurrence of these odours will be intermittent and of short duration, having no direct health effects on the building occupants. However, the sensing of an odour could have a long term impact on the occupant. The paper suggests no remedial action to limit the odours in this building. Tracer gas studies to quantitatively evaluate the performance of an HVAC system are discussed by Olesen (#5945, 1992) and Kvisgaard and Collet (#2685, 1987). Using this method, sources and paths of odours and pollutants can be traced and in particular the amount of short-circuiting can be evaluated.

Plotnikova (#7622, 1994) briefly describes an experiment using flume and wind tunnel modelling to show how aerodynamic circulation zones occur and their resultant impact on pollutant re-entry into buildings. The paper, however, gives no clear conclusions or design guidance.

Poor atmospheric conditions can lead to the air flow around a building becoming stagnant, or altered. The problems of unfavourable atmospheric conditions were highlighted by Ferahian (#3569, 1989). Such conditions were believed to be responsible for indoor air quality complaints at the McGill Medical Building in Canada. The author notes that this building occasionally suffers from air inversions, principally caused because of its location next to the mountain near Montreal, and downward wind around the building can bring exhausted air back through he air intakes. The possibility of extending the height of the exhaust stacks was being considered as a possible remedial measure. The Author emphasises the importance of wind tunnel models in such designs. Segal (#3503, 1989) also discusses thermal stratification with regard to air intakes. He suggests, in particular instances, an option for ventable lower and upper air intake is needed to provide the capability for ventilation thermal optimisation. In such situations a dual option of the air intake/air outlet could be considered. Outdoor temperature sensors near the air intakes will control their optimal utilization. If this is not a feasible option, an optimised single height inlet above ground (at ground level, building roof or any intermediate height) can be determined, based on the annual thermal characteristics of the surface layer in the specific area. The author considers that, in large buildings were several air intakes are installed, optimisation of their heights can be determined based on the specific cooling/heating requirement of the building.

Similarly, Trepte (#3118, 1988) also looks at the measures designed to counteract the adverse effects of polluted outdoor air situations. He identifies four categories of pollution incident; (i) the normal case, where regional differences in outdoor air composition have only a minor effect on the outdoor rate required for ventilation; (ii) meteorological incidents, such as the temporary inversions discussed above (Ferahian (#3569, 1989); (iii) accidents, such as a release of chemical substances during a traffic accident; (iv) increased emissions limited to a time and region, for example higher traffic volumes in the centre of cities. The author notes that categories (ii) and (iii) are more common than categories (i) and (iv) and identifies a number of counter measures that could be employed should such occurrences happen. For example, Trepte suggests that the air change between inside and outside should be minimised to reduce the build-up of pollutants indoors; filtering or catalytic oxidation could be used to reduce harmful pollutants and infiltration should be minimised. After outdoor air concentrations have dropped, ventilation should be increased to flush the system and to prevent pollution build-up indoors.

The development of a dispersion model is described by Wilson and Chui (#8448, 1985). The aim was to separate the atmospheric and building generated turbulence, thereby enabling a designer to determine the absolute minimum dilution that might occur under low atmospheric conditions. The authors note that under low wind night-time conditions, much of the turbulence generated by upwind buildings may be damped by atmospheric temperature stability. The authors focused on the effect of upwind turbulence by comparing wind tunnel simulations with varying upwind conditions. Their results indicated that the turbulence carried from upwind buildings increases dilution from building turbulence by factors of 2 to 10.

Wilson (#8449, 1979) also outlines a method for estimating the height and extent of high turbulence zones above a roof, to prevent short circuiting. Simple equations are used to estimate the recirculation cavity, high turbulence region and wake boundaries over the modelled roof. These are then used to provide an estimate of the required stack height (in relation to roof height) to avoid recirculation of exhaust gases by any air intakes which are located nearby. The author considers that the procedure represents only a first approximation to accounting for the complex flow patterns over building roofs and their influence on exhaust stack design. However, the principles outlined in the paper do give an insight into the many factors which influence flow patterns over flat roofed buildings.

2.3 Location of Air Intake Adjacent to Sources of Pollution.

The outdoor air in a particular location must meet the required outdoor air quality standards. The National Ambient Air Quality standards for the United States are outlined by the US Environmental Protection Agency (1990). European air quality standards are delt with in a number of EC Directives, such as EC Directive 80/779/EC which outlines the air quality standards for sulphur dioxide and suspended particulates. The requirements for Nitrogen Dioxide are outlined in 85/203/EEC and other guidelines are given by the World Health Organisation (WHO) (NSCA 1994) The design options available depend upon the nature of the pollutant and of course their location. Pollutants are classified in Chapter 11 of the ASHRAE Fundamentals Handbook as either dusts, fumes and smokes; mists and fogs or vapours and gases. More specifically they include naturally occuring pollens, moulds, dust mites, volcanic dust, eroded soil particles, spores and microbes and wind blown sea salt. Man made pollutants derived from combustion for heating, incineration, and internal combustion engines include carbon monoxide, sulphur oxides, nitrogen oxides, hydrocarbons and particulates.

Available guidelines actively discourage the location of air intakes adjacent to such sources of pollution. However, many examples exist which demonstrate that such problems do still frequently occur. Kruger (#8344, 1994) studied the location of air inlets of buildings in relation to streets with heavy traffic flow. Results, based on the measurements of carbon monoxide (CO) inside and outside the building over a week, found that several parameters were of vital importance when considering traffic related pollutants. These included the distance between the traffic and the building, the traffic intensity (both during the day and during peak hours), wind direction and velocity, street geometry and building construction. Five different multifamily houses in urban areas were studied, although Kruger points out that the measurements are equally applicable to other types of buildings. The study found that in the buildings with heavy traffic close by on one side, the locations of air intakes were significant. Similarly located buildings should not use ventilation systems where the supply air intakes are situated on the street side. If streets with heavy traffic are some distance away, then both mechanical exhaust systems and balanced systems could be used to supply the building with outdoor air. In the latter case, the

choice of ventilation system is more dependent on thermal comfort aspects than on outdoor air quality aspects. Thus the outdoor environment should always be studied before choosing ventilation systems. The author also notes that the investigation has shown that measuring periods of at least a week are needed to get sufficient basis to be able to correctly analyse the measurements of traffic related pollutants.

Gebefuegi and Korte (#7439, 1990) also studied vehicular pollutants entering an office building through fresh air intakes. The building being studied contained Environmental Tobacco Smoke (ETS) and a variety of Volatile Organic Compounds (VOC's). It was found that the ventilation system effectively removed the ETS from the 1200 to 1500 cigarettes consumed per day in the office. However, evidence of aromatic hydrocarbons and some natural compounds still remained. Further investigation showed that odours where being drawn in through the "fresh air" intake located near the parking entrance at street level. The study also found that peak levels were experienced at car arrival and departure times. The Sources of other VOC's were found to be from chemicals used to clean the office. The materials used to clean the offices were changed and the fresh air intakes were modified, resulting in an 80% reduction in limonene and a 30% reduction of toluene concentrations of VOC's.

Another building study was undertaken by Armstrong et al (#4036, 1989) in which they describe an epidemiological and environmental investigation into the air quality of a high rise office building with reported SBS symptoms, consistent with an irritative rather than infectious or allergic process. This was further backed-up by elevated Total Suspended Particle (TSP) concentrations on many of the study floors. These high levels of TSP were traced back to soot from vehicular traffic on the adjacent interstate highway which was being drawn into the ventilation system. This polluted air then escaped adequate filtration and was dispersed indoors, especially on the service floor. Recommendations where made, including the improvement of the filtration system to reduce indoor TSP concentrations, Until this could be done, improved levels of office cleaning and a proper HVAC maintenance program was recommended to control mould growth. Another bibliography it this series entitled "Garage Ventilation", outlines a number of other incidents of vehicular pollutants entering a building and the possible consequences.

A hospital, where SBS symptoms were reported was investigated by Hanson et al (#8436, 1992). The problems appeared to be the most severe in the surgical suite and recovery room which are supplied by one air handling system. The affected areas have separate air intakes from the rest of the hospital and the operating room receives 100% fresh air. The air intakes are located on the roof in close proximity to the exhaust vents from the kitchen and the health sciences centre tower. This study was conducted to locate the source of pollutants believed to be introduced through the system. Results indicated that, while the air quality was probably not a major health hazard, there is evidence of an irritative effect. The results are consistent with cross contamination of the 4th floor air supply with trace irritants in the exhaust air from other hospital areas. The identity on any specific physical or chemical factor causing the symptoms, was not determined. In conclusion, individuals employed in an area of the hospital where the air supply could have been contaminated with the exhaust air from other hospital areas had an increased prevalence of certain work related symptoms, though their overall health was not significantly worse than employees from other hospital areas. The effect of the design characteristics of the ventilation systems, particularly those which relate to the potential for contamination of fresh air intake, should be considered in future studies of SBS.

Julian & Dennis (#8431, 1987), Miller (#6227, 1992), Binnie (#6727, 1992) and Yoshizawa et al (#2783, 1987) all emphasise the increase in awareness and appreciation of the importance of

airborne infection. The appearance of humidifier fever caused by thermophilic actinomycetes and amobae and the recognition of Legionnaires' disease and Pontiac Fever has led to an appreciation of the microbiological dangers posed in modern buildings. These conditions originate within building water systems, humidifiers and air conditioning equipment often associated with inadequate maintenance or infrequent usage. The survival of these organisms or their toxins in aerosols produced by water handling equipment can lead to the establishment of disease in susceptible individuals who inhale them. For this reason, the location of air intakes is crucial and the positioning of them near potential hazards, such as cooling towers or the inadequate examination of possible short-circuiting paths, needs to be considered. Binnie further emphasises that the fresh air intake is an obvious entry point for a variety of foreign bodies, such as birds, butterflies, moths and other insects. If these living remains are allowed to putrefy, he states that, the numbers of microbes present may increase many times and may include species more pathogenic than might normally be found. Therefore such air intakes should be adequately protected by wire mesh or guards.

A ventilation model has been developed by Meckler and Janssen (#4032, 1989) that allows a calculation of the effect of outdoor pollution on indoor air quality. This model is outlined in Chapter 40 of the ASHRAE Applications Handbook. If the pollutant is evident in the outdoor air the most effective method of cleaning the air is filtration.

2.4 Poor HVAC Maintenance.

The hazards and dangers of poor HVAC maintenance and design, including short-circuiting of intakes and exhausts, the reduction in ventilation air to achieve greater energy conservation, and the interruption of fan operation to achieve greater energy conservation, have been highlighted by a number of researchers including Ferahian (#8442, 1986; #1462, 1984), Holness (#4596, 1990) and Jaquet (#2849, 1987). Ferahian advocates the need for mandatory good maintenance of the HVAC system as part of law, a point often reiterated.

Poor maintenance can cause the HVAC system itself to become a source of pollution. However, it has been stated that the occurrence of dust in ventilation ductwork does not necessarily mean that the ventilation air is contaminated (Valbjorn et al, #8429, 1990). Although, dirt in the ductwork can allow the generation of microbes, fungi and pathogens, Valbjorn's investigation did not show whether the dust itself may be of any importance in the way that it adsorbs gasses and vapours. They noted however that, depending on the amount and composition of the dust, it could in some systems be a potential risk, especially if the growing conditions are changed. Such changes could occur by the use of humidification or cooling equipment, which will create wet surfaces inside the system. If this bacteria then becomes airborne and subsequently part of the ventilation air, it could lead to widespread illness within the building. Dirty ductwork has been one topic discussed by Robertson (#3018, 1988) who points out that excessive amounts of dirt can accumulate in ductwork, often being built into the system during construction in the form of construction dusts, wood shavings, lunch packets, and even drink cans and bottles. Also during the life of the building more dirt will enter the system with the supply and return air. Dirty ductwork is a perfect breeding ground for germs, providing an enclosed space, constant temperature, humidity, and food. This point is illustrated in a case study of a bank where employees were reporting SBS symptoms (Anon #6647, 1992). Following an excessive survey it was found that the problems in the building stemmed from a variety of causes and fed each other. Once again, dirt in the ductwork provided a breeding ground for microbes and an combination of dirt and poor

maintainence resulted in an overall system imbalance which added to the discomfort experienced by occupants.

A recent review of duct cleaning literature (Luoma et al (#7896, 1993) concludes that periodical cleaning of HVAC systems is recommended. In order to avoid frequent duct cleaning, facility managers would welcome guidelines concerning that amount and content of debris which is acceptable. Such recommendations however, are rarely given because forecasting re-suspension and microbial life cycles in HVAC systems is complex. The first industry standard on mechanical cleaning of non porous air conveyance system components has been published by National Air Duct Cleaners Association in the US. The standard recommends that surface density of dust should not exceed 1 mg/100cm^2. A guideline for dust surface densities on floors and the microbiological content of the dust on floors is given for low risk, medium risk and high risk categories by a Nordic group of Scientists. The dust surface densities of dust measured from 13 Danish and 8 Finnish buildings ranged between 0.7 to 3.5 g/m^2. Loyd (#7722, 1994) has also conducted a review of duct cleaning literature, and emphasises its importance, especially as many of todays buildings are refurbished wereas the ventilation and air conditioning systems are largely unaltered. This is compounded by the fact that little is known about the true nature of the direct accumulations in these ducts and on their effect on indoor air quality and therefore very few guidelines exist for procedures to inspect, maintain and clean these systems. Loyd outlines the current legislation surrounding duct cleaning. Also included in the review is an overview of typical pollutants and their effect on health, together with a guide on how to limit the introduction of dirt into the system and how to inspect and clean systems that are already contaminated.

The provision of wire guards over the air entry points and the regular inspection of intake drains to remove any collected rain or snow water is vital. The ductwork itself should be inspected and if necessary cleaned at regular intervals in-line with the relevant regulations and codes of practice (for example ASHRAE/CIBSE guides). Collet and Ross (#8426, 1990) investigated two office buildings in Ecuador, and identified a potential source of intake air contamination as being microbial growth in the intake duct around a spray water humidification system. The authors also studied a building which illustrated a potential for problems due to the relative location of outside air intakes adjacent to exhaust vents and cooling towers. These locations resulted in short circuiting and re-entrainment of contaminated air, further leading to insufficient fresh outdoor air to dilute the build-ups of contamination within the building.

Poor maintenance or design can lead to the entry of animals and insects. Their faeces also could be responsible for the growth and subsequent introduction of harmful bacteria into a building. The location of the air intake should be designed to minimise as far as possible the level of contamination from these sources. The condition of fans should also be monitored, as fans designed to draw air into a system if dirty and clogged may become less efficient, be running in reverse or even have stopped.

In certain urban or industrial areas some filtration of the outdoor air is essential, while in other regions it may simply be desirable. A variety of different filters and air cleaners, with applications are readily available. A comprehensive review of these devices has been undertaken by several researchers including, Meckler and Janssen (#4032,1988), Gibbs (ED) (#5913, 1992), Hoppitt (#8453, 1976), Langenborg (#656, 1979) and Holcombe and Kalika (#8437, 1971).

MacDonald (#4955, 1991) is of the opinion that air filters are typically specified and selected not from any consideration for indoor air quality, but to protect the heat exchangers and fans of the heating or air conditioning units. As the filters are basically designed to remove fibres and large dirt particles from the incoming air to prevent clogging of the equipment, their efficiency

requirement is therefore low. High efficiency filters, which are capable of removing pollens, bacteria, viruses, tobacco smoke and other allergens present in the air, are often ignored because of cost. Apart from the cost factor, even high efficiency filters can make a negative contribution to the indoor air quality as they can also be a source of bacteria build up and propagation in the ventilation system. For these reasons regular maintainence and replacement is essential. McDonald also discusses the short comings in design of several other components of the HVAC system which could lead to reduced levels of IAQ, such as mixing boxes, humidifiers and heat exchangers.

3.0 DESIGN GUIDANCE

The design guidance outlined by CIBSE (B3-40, 1989) and ASHRAE (1991) on the location of air intakes is essentially the same. Each vent should be protected against the weather by the fitting of louvres, cowls or similar devices. Drains should be included behind or under these louvres or cowls to allow the removal of any rain or snow that may penetrate. These drains also prevent the accumulation of stagnated water which would result in unpleasant odours within the building. Birdscreens should also be used to prevent the entry of birds or other large objects into the inlet. Intake points should be located away from possible sources of pollution, such as cooling towers, boiler flues, fume cupboards and other discharges of contaminated air, vapours and gases (refineries, power plants etc) and places where vehicle exhaust may be drawn in. Care should be taken to ensure that any planned developments are also considered. If air inlets are located adjacent to discharge points then "short-circuiting" can occur. However, the airflow characteristic of the building will also determine whether Short-Circuiting is a major problem.

The Quebec government have issued a document outlining practical maintenance for good indoor air quality (#4266, 1989) in which prevention, verification and maintenance of components are discussed. It is suggested, the main source of problems in a ventilation system is the outdoor air intake, and that such problems are related to its location and its capacity to eliminate rain water and snow. An outdoor air intake, according to this document, should allow fresh outdoor air of good quality to enter. It is important to avoid recycling the air, inducing air contaminated by carbon monoxide (CO) (from combustion), and foul smelling air (from waste bins etc). Positioning an outdoor air intake at street level, or too close to stagnant puddles of water, should also be avioded. The document gives several alternative solutions to obstructed or polluted outdoor air intakes. For example, it recommendeds the prohibiting of cars parking near such inlets and the installation of CO detectors inside the outdoor air intake, linked to an audible alarm to alert the warehouseman. Other preventative measures include the elimination of the contaminate source, or moving the exhaust vent to prevent re-entrainment into the supply air. Care should also be taken to ensure that the outdoor air intake is free of any obstructions and that bird screens are fitted to prevent the entry of animals and leaves etc.

Spry (#8435, 1989) discusses a number of ventilation issues, and suggests that two most common practical problems a ventilation designer faces are the location of fresh air intakes and the distribution of fresh air. Spry quotes AS1668 (Australian Standard 1668 Part 2 1980 Ventilation Requirements) which requires air dischargers to be not less than 6 metres from air intakes. It also requires air intakes to be "so located and arranged that..contamination from ...other adjacent sources of pollution ...does not reduce the quality of outdoor air entering the ..intake below that of outdoor air in the locality". Spry suggests that this places considerable responsibility on designers as their duty of care requires them to do more than rely on arbitrary minimum distances between air intakes and sources of pollution.

Ferahian (#2704, 1988;#3569, 1989) emphasises the need for research findings to be translated into codes and standards for building design, construction and maintenance professionals. He also recommends a number of improvements in building codes to ensure good indoor air quality and considers factors, such as ensuring the good quality of the air intake (the outdoor air should at least be of acceptable quality as defined by the relevant ventilation standard such as ASHRAE 62-89). Further consideration should also be given to the possibility of ensuring against contamination by the building's exhausts and that of adjacent buildings (i.e., limit Short-Circuiting), and to avoiding energy conservation measures that compromise the quality and quantity of the required ventilation air. Once again the conclusion was drawn that the quality of the ventilation air throughout the lifetime of the building is vital for the health of the tenants.

These views are echoed by Levin (#7339, 1991) who mentions the need for considering sources of indoor air contaminants in the ambient air. These sources may originate locally or at a distance from the site. Levin identifies several control measures used by designers to control indoor air quality by site planning and design, including the evaluation of sites prior to acquisition. Project planning, to minimise pollutant concentrations etc and avoid problem sites and inefficient vehicular circulation, are also important.

Levin also notes that several questions exist regarding the suitability of outdoor air, for example, in the case of dilution, the proper approach for strong contaminant sources, the contamination from the ventilation system itself, and the distribution of ventilation air within the building should be considered. He further states that before the wide spread adoption of ASHRAE 62-81 and 89 virtually no designers thoroughly evaluated outdoor air quality and devised means to control contaminants required to provide acceptable air quality for supply air used for ventilation. However, with greater use of this standard more attention has been shown to this requirement. Levin goes on to review the main areas of importance in the design of dilution ventilation systems to tackle pollutants generated within the indoor environment. Several authors discuss ways of implementing the Indoor Air Quality Procedure outlined in ASHRAE 62-1989, for example, Yu and Raber (#5636, 1992), by mathematical analysis, determine what filter efficiencies are needed (particulate to gas) to account for source capture efficiency, reduced outdoor air flow and poor ventilation effectiveness, all under VAV conditions. More guidance on how to agree with ASHRAE 62 with pure and non pure air is given by Meckler and Janssen (#4032, 1988).

Sterling and Sterling (#2219, 1985) note that while increased ventilation may well reduce the level of carbon dioxide in a building, other contaminants including carbon monoxide and particulates, respond more to outdoor levels than to indoor sources. In specific buildings with large occupancy levels and small volumes, increased ventilation may be an effective means of reducing carbon dioxide and other indoor-generated contaminants to acceptable levels. However, a better means of controlling carbon monoxide and particulates would be by way of control or filtration of outdoor air. Higher volumes of air may be required if the quality of the outdoor air is poor. The amount of outdoor air required to dilute indoor pollutants therefore, may be higher than the standards recommend. This leads to larger air volumes and more expense. To provide adequate dilution of air to maintain the contaminant level within acceptable levels of a ventilation system with variable occupancy, outdoor air quantity should be adjusted by dampers or stopping and restarting ventilation. However, when the contamination level is due to occupancy only, it is dissipated during unoccupied periods and the supply of outdoor air may lag occupancy. If the contaminant level in a zone is independent of occupancy, then outdoor air being supplied must lead occupancy in order to attain an acceptable level when reoccupied.

4.0 CONCLUSIONS

The location of ventilation air intakes is of vital importance to the quality of the air that is circulated throughout a building. Contamination of this air, even before it becomes fully ingested into the buildings' ventilation system can occur for a number of reasons. The most important and far reaching of these, are those relating to the complex nature of environmental airflow around buildings. The site specific nature of these problems make it difficult to produce generalised guidance. In response therefore, a number of analytical and wind tunnel models have been used to evaluate the effective height of nearby exhaust stacks, the contamination of wake regions of buildings (which can lead to short circuiting problems), and to provide ways of predicting levels of pollution from other nearby sources. In some cases inadequate thought for these problems has led to poor design, where the ventilation air intake is located nearby an otherwise avoidable pollutant source, for example adjacent to a buildings exhaust , be it its own or that of another building, or at street level, where vehicular pollutants can occur a specific times during the day. A further consideration is that of poor maintenance, which can result in air intakes becoming clogged, or themselves a source of pollution. The decomposition of animals, vegetation and other waste products can lead to the production of fungi, microbes and pathogens, which can then become entrained in the ventilation air and distributed throughout the building. Although these problems, can be avoided, or at least minimised if considered at the design stage, the quality of intake air ultimately depends upon the nature of the outdoor air in the first place.

5.0 REFERENCES

#NO 17 The effect of wind on energy consumption in buildings.
AUTHOR Arens E.A. Williams P.B.
BIBINF Energy & Bldgs. May 1977, 1, (1), 77-84, 7 figs, 13 refs. #DATE 01:05:1977 in English
ABSTRACT Treats 4 mechanisms of building heat exchange with the environment and their effect on overall energy consumption: 1) air infiltration and exfiltration, pressure distributions and gradients and resulting mass transfer at building surfaces; 2) influence on surface heat transmission of turbulent mixing of air close to building surface and mechanisms causing this mixing; 3) how air circulation around buildings strongly affects air conditioning cooling towers and how incorrect location of ventilation inlets and exhausts can reduce thermal efficiencies of cooling equipment and increase fan power requirements; 4) results of enclosing spaces such as shopping centres.
KEYWORDS heat transfer, air infiltration, pressure distribution, air flow, turbulence.

#NO 656 Contaminant control in the built environment: state of the art summary.
AUTHOR Langenborg R.G.
BIBINF Lawrence Berkeley Laboratory LBID-085, July 1979 4p. #DATE 01:07:1979 in English #AIC 316
ABSTRACT The reduction of ventilation in buildings as an energy saving measure may result in a deterioration in indoor air quality. Suggests use of contaminant control devices and summarises devices available. These are filters, electrostatic precipitators, mechanical dust collectors, scrubbers, and contaminant combustors Suggests five areas where further research is necessary.
KEYWORDS air quality, filter, electrostatic precipitator,

#NO 1462 Indoor air pollution - Some Canadian experiences
AUTHOR Ferahian R H.
BIBINF Indoor Air. Vol.1 Recent Advances in the Health Sciences and Technology edited by B. Berglund, T. Lindvall and J. Sundell. Swedish Council for Building Research. Stockholm. 20-24 August 1984, 207-212, 6 refs. in English #DATE 20:08:1984 AIC bk,
ABSTRACT It is only recently that indoor air pollution has begun to attract the attention it deserves in Canadian Governmental and Building code circles. Two main events have been catalytic towards this increased emphasis. First, the ban on the use of urea formaldehyde foam insulation by the *Federal Government in 1980. The second was the continued complaints since 1979 by some federal employees supported by their Union about the quality of the air and its effect on their health in one of the major office complexes, Les Terrasses de la Chaudiere, in the National Capital Region. Gives a short review of the problems encountered therein, the corrections undertaken, together with the research they sparked and the precedential concessions granted to these employees. It also deals with indoor air pollution caused by the contamination of the fresh air intakes by short-circuiting with the exhausts of the building, code infractions and bad maintenance of the building services based on examples from the author's experience. Research needs and code changes are recommended.
KEYWORDS formaldehyde, insulation, energy conservation, house, health, air quality, office , ventilation, standard, air conditioning, heating, formaldehyde, air change rate, organic compound

#NO 2219 The impact of building ventilation on indoor gaseous and particulate pollution in office and institutional buildings.
AUTHOR Sterling E M, Sterling T D
BIBINF Ventilation '85. (Chemical Engineering Monographs 24). Edited by H D Goodfellow. Amsterdam, Elsevier, 1986. p297-305. 15 refs. #DATE 00:00:1986 in English AIVC bk
ABSTRACT Effectiveness of ventilation as a major means of controlling indoor air quality was evaluated by correlating concentrations of gaseous (CO and CO2) and particulate (total) pollutants with two ventilation parameters. Pollutants are differently affected by ventilation parameters depending on their source and a complex of building and filter factors. Concen- trations of CO2 are decreased by increases in ventilation but not of CO that appear to depend primarily on infiltration from outdoors. Concentration of particulates may be determined primarily by duct and filter properties and their maintenance. Some buildings appear to maintain higher base levels of pollutants than others regardless of changes in ventilation. This background level very likely is the result of an equilibrium established for gases and particles that are entrapped in enclosed spaces under normal operating conditions. The extent to which this equilibrium is modified by ventilation parameters may be significantly influenced by building design features. But it appears that reliance on ventilation parameters alone may not be sufficient to control indoor pollutants.
KEYWORDS ventilation efficiency, air quality, carbon monoxide, carbon dioxide, mechanical ventilation, office building

#NO 2704 Building codes designed for ensuring good indoor air quality.
AUTHOR Ferahian R H
BIBINF 8th AIVC conference, 'Ventilation Technology - Research and Application', 21-24 September 1987, Proceedings, Ueberlingen, West Germany, AIVC 1987, p23.1-23.6, 8 refs. #DATE 00:09:1987 in English
ABSTRACT All the findings about indoor air quality are of little use to the average citizen, if they are not applied and translated into rules incorporated in our building codes for the design, construction, and last but certainly not least, maintenance of our buildings. And scientifically based up-to-date codes are not much use if they are not backed by strict, honest, and competent building inspectors. Recommendations are made for improvements in building codes to ensure good indoor air quality by concentrating, but not exclusively, on ventilation. Among the factors considered are: ensuring the good quality of the air intake, ensuring against its contamination by exhausts of the building or adjacent buildings, ensuring that energy conservation measures do not compromise the quality of the required ventilation air, and ensuring good maintenance of the building services that determine the quality of the ventilation air throughout the lifetime of the building necessary for the health of the tenants. Our laws must ensure good air quality in our living and working habitat as an environmental human right with right of access to information necessary for citizens to determine the quality of their indoor air environment.
KEYWORDS building codes, indoor air quality

#NO 2685 Tracer gas used to evaluate HVAC equipment.
AUTHOR Kvisgaard B, Collet P F
BIBINF 8th AIVC conference, 'Ventilation Technology - Research and Application', 21-24 September 1987, Ueberlingen, West Germany, AIVC 1987, p4.1-4.7, 2 figs. #DATE 00:09:1987 in English
ABSTRACT When controlling the performance of a ventilation system it is important to investigate how the system works together with the building it ventilates. It is the performance of the complete system which is of interest, not its individual components. This paper describes the use of a computer-controlled, tracer-gas measuring system for controlling ventilation systems. By means of 4 measuring probes the condition of the air at the intake, room injection, room extraction and exhaust are registered. On the basis of these results, the computer can calculate the efficiency coefficients for the heat exchange, the percentage of air being recirculated, the outdoor short-circuit from exhaust to air intake and the percentage of extracted air resulting from room injection. On the basis of field measurements with the equipment, the experience gained is discussed. In particular, it is interesting to see how large a percentage of the air blown through the ventilation system into the building is refound in the extracted air. Percentages of 60-80% are quite normal. If only, for instance, 60% of the injected air is returned, the building will have an air change which is at least 1.66 times the performance of the ventilation system. @abstract = KEYWORDS computer, tracer gas, ventilation system, air change rate

#NO 2783 Microbiological contamination from air conditioning systems in Japanese buildings,
AUTHOR Yoshizawa S, Irie T, et al
BIBINF in: Indoor Air'87, Proceedings of the 4th International Conference on Indoor Air Quality and Climate, Berlin (West), 17-21 August 1987, Vol 1, Institute for Water, Soil and Air Hygiene, 1987, p627-631, 2 figs, 3 tabs. #DATE 00:00:1987 in English
ABSTRACT Fungal and bacterial particle contamination in air conditioning systems and supply air were investigated in four buildings in Tokyo area. At the steady state operation the concentration was very low but the turbulence such as starting the system, opening the service door or changing filters during operation of system caused significant increase. Fungi and bacteria were of human and earth origin.
KEYWORDS air conditioning, particle, organic compound, bacteria

#NO 2849 Indoor air quality.
AUTHOR Jaquet J
BIBINF #DATE 00:00:1987 in English
ABSTRACT Describes the problems of indoor air quality: causes of contamination; control methods; ventilation effectiveness; improving air quality; and lists several major sources of indoor air pollution.
KEYWORDS indoor air quality, pollutant, mechanical ventilation, ventilation effectiveness

#NO 2914 Ventilation intake air contamination by nearby exhausts.
AUTHOR Wilson D J
BIBINF in: Indoor air quality in cold climates: hazards and abatement measures. APCA Specialty Conference 1986, p 335-347, 6 figs, 11 refs. #DATE 00:00:1986 in English
ABSTRACT Buildings with mechanical ventilation systems often place air intakes and exhausts close to each other to make the most efficient use of space.

This is particularly true for direct air-to-air exchangers for exhaust heat recovery. The greatest hazards occur for exhausts on laboratories, hospitals and industrial buildings where concentrated emissions of solvents, toxic gases and pathogens are carried by the wind or their own momentum from exhaust to intakes. Tracer gas studies in wind tunnel simulations are reviewed, and correlated to show the contributions of exhaust jet plume rise, building induced turbulence, and large scale atmospheric turbulence on dilution between an exhaust and an intake. Measurements show that the two major factors that influence dilution are distance between exhaust and intake, and the ratio of exhaust jet velocity to windspeed. The location of the exhaust intake pair on the building is also important, with good design placing the intake on the lower third of the building and the exhaust on the upper two thirds. Flow visualization tests show the reason for this. A simple theory for exhaust to intake dilution is presented. The theory, which accounts for dilution close to the exhaust, is in good agreement with wind tunnel data, and with full scale tracer gas tests on large buildings. The implications for hood design of closely spaced exhausts and intakes are discussed. It is shown that the fraction of recirculated exhaust in intake air can change by a factor of five with only minor changes in design, such as the removal of a rain cap.
KEYWORDS mechanical ventilation, laboratory, hospital, industrial building, toxic gas, tracer gas, wind tunnel

#NO 3018 Source, nature and symptomology of indoor air pollutants: "sick building syndrome".
AUTHOR Robertson J
BIBINF in: Symposium on air infiltration, ventilation and moisture transfer, Fort Worth, Texas, USA, Building Envelope Coordinating Council, 1988, p243-250, 4 tabs. #DATE 00:00:1988 in English
ABSTRACT The accumulation of indoor air pollutants inside many buildings has been seriously exacerbated by the current design and operating practices, primarily aimed at saving energy dollars. Two common denominators in many sick buildings are inadequate ventilation, specifically insufficient fresh air intake, and poor filtration. The latter is frequently a major contributor to a third common problem, namely the accummulation of dirt, dusts, and microbes inside the air handling units and their associated ductwork. Future building designs must address these faults. If the prime factor in the design of a building's ventilation system was the health of the employees rather than the maintenance of a specific temperature, far more emphasis would be given to minimum fresh air intake levels. Higher standards of filtration efficiency would be introduced and greater awareness of the hygiene of the air handling systems would be essential. Since carbon dioxide levels are widely recognised as one of the best indicators of ventilation efficiency, a ceiling of 1,000 ppm of carbon dioxide in the indoor environment would mandate the use of a minimum of 15 to 20 cfm per person at all times, a value to which ASHRAE has reverted in its current proposed standards ANSI/ASHRAE 62-1981R. Many VAV systems would have to be altered to maintain these levels. Furthermore, VAV systems, with recirculation loops where return air is recycled, would need to be refined, especially if higher infiltration standards were also introduced for all the air supply to occupied areas. Well tempered air is not necessarily healthy air, but the requirements of comfort and health are very compatible. However, the practice of improving a system's design is only as good as the ongoing standards of maintenance and operation, i.e., legislation should be introduced mandating the continous operation of a building's ventilation system at or above the minimum ASHRAE make-up air levels.
KEYWORDS sick building syndrome, indoor air quality, pollutant

#NO 3118 Ventilation strategies in the case of polluted outdoor air situations.
AUTHOR Trepte L
BIBINF in: "Effective Ventilation", 9th AIVC Conference, Gent, Belgium, 12-15 September, 1988. #DATE 00:09:1988 in English
ABSTRACT Outdoor air pollution can have a bearing on the effectiveness of indoor air and the quality of ventilation. There is a pressing need to reflect on the potential type and effect of occurrences (e.g. smog, or chemical accidents) and to develop technical, operational and organisational measures which must be taken with mechanical ventilation units in the case of polluted outdoor air situations. A polluted outdoor air situation is present when a ventilation process leads to the intake of pollutants in the interior and to the enrichment of these pollutants to an unacceptably high concentration. The measures to recommend will primarily depend on the specific outdoor air situation, type and quality (leaks) of the building and the type of mechanical ventilation unit in use.
KEYWORDS ventilation system, ventilation strategy, outdoor air, pollution

#NO 3503 Atmospheric thermal stratification and the position of mechanical ventilation air intakes.
AUTHOR Segal M

BIBINF Building and Environment, Vol 24, No 3, 1989, pp.239-243, 5 figs, 22 refs. #DATE 00:00:1989 in English
ABSTRACT The specific characteristics of the thermal structure in the atmospheric surface layer can be utilized for thermal optimization of ventilation of buildings. General description of these characteristics, as well as procedures for their evaluations are presented. Illustrative observations are given, which imply that thermal energy gains can be obtained under appropriate ventilation procedures. The applicability and significance of the suggested procedures are discussed.
KEYWORDS ventilation, buildings, energy

#NO 3533 Analytical versus wind tunnel determined concentrations due to laboratory exhaust.
AUTHOR Peterson R L, Wilson D J
BIBINF Preprint, Ashrae Trans, Vol 95, Pt 2, 1989, 8pp, 4 figs, 3 tabs, 16 refs. #DATE 00:00:1989 in English
ABSTRACT This paper presents a determination of the expected concentrations for an actual building using the analytical and wind-tunnel modelling procedures presented in Chapter 14 of ASHRAE Fundamentals. A comparison of the estimated concentrations using the two methods is presented as well as a description of the calculation methodologies. The results of the comparison showed that for a low exit velocity stack with a small exit diameter and zero stack height, the wind tunnel and analytical estimates compare within a factor of two to six, with the ASHRAE estimates tending to be conservative. For a high exit velocity stack with a large diameter and zero stack height, the wind tunnel intake dilutions were generally an order of magnitude greater than those obtained using the analytical equations. The paper provides further evidence that the equations in Chapter 14 do provide conservative estimates of the expected dilution for laboratory stacks, even for the non-idealized building shape considered. However, estimates may be overly conservative and may result in the added design expense (unnecessarily tall stacks or emission control devices). If a designer wishes to optimize the stack design with respect to cost, aesthetics, and safety, the added accuracy provided by the wind tunnel may be necessary.
KEYWORDS wind tunnel, modelling

#NO 3569 Building design and maintenance and indoor air pollution.
AUTHOR Ferahian R H
BIBINF in:UK, AIVC, 10th AIVC Conference, held at Espoo, Finland, 25-28 September 1989, Volume 1, February 1990, pp429-442, 21 refs. #DATE 00:02:1990 in English
ABSTRACT This paper examines some designs which lead to indoor air pollution and exhorts mandatory maintenance of all building services which determine the health and safety of the building occupants as an integral part of our city bylaws. Effect of poor maintenance of some of these systems on the indoor air quality is examined together with the effect of the interruption of the ventilation fans for energy conservation purposes, not always done legally. Among the examples considered are the effect of underground parking and its ventilation system, proximity of the fresh air intakes to exhausts of the building and/or adjacent buildings and the drains of the plumbing system. The author's denied appeals to ASHRAE committees regarding adoption of ASHRAE STandard 62-1981R, done to ensure that the ventilation fans are not turned off when such buildings are occupied are discussed together with the City of Westmount's maintenance bylaw for apartment buildings adopted June 1989 which incorporates such a requirement. Our laws must ensure good air quality in our habitat as an environmental human right with the citizens' right of access to the information necessary to determine the quality of their indoor air environment for their health and safety. Examples from present Quebec legislation are presented.
KEYWORDS maintenance, design, indoor climate, pollution

#NO 3617 Comparison of wind tunnel test results with empirical exhaust dilution factors.
AUTHOR Schuyler G D, Turner G G
BIBINF Preprint, Ashrae Transactions, Vol 95, Pt 2, 1989, 8 pp, 8 figs, 5 tabs, 4 refs. #DATE 00:00:1989 in English
ABSTRACT Dilution factors obtained from scale-model tests in a boundary layer wind tunnel, were compared to empirical dilution factors obtained using the equations presented in the new (1989) chapter 14 of the ASHRAE Fundamentals Handbook. The use of this information in making design decisions is also discussed. The comparison illustrates the fact that while the empirical equations are useful in identifying a potential problem condition, building geometry can greatly alter the dilution. Consequently, a healthy level of conservation should be maintained in setting stack heights or intake locations.
KEYWORDS wind tunnel, model, boundary layer

#NO 3707 Calculation of minimum available atmospheric dilution downwind of building exhausts.
AUTHOR Halitsky J

BIBINF USA, preprint, ASHRAE Transactions, Vol 96, Part 1, 1990, 6 pp, 8 figs, 8 refs. #DATE 00:00:1990 in English
ABSTRACT Equations recommended in the ASHRAE Handbook - 1989 Fundamentals, chapter 14 (ASHRAE 1989) for prediction of minimum atmospheric dilution for use in exhaust system design are examined. The equations have no terms representing the large dilutions in the plume below the centerline; therefore, they yield overly conservative estimates of dilution at receptors at the lower edges of elevated plumes. The equations contain empirical constants that could be adjusted to provide more realistic dilution estimates, but no guidelines are offered in the Handbook for such adjustment. An alternative approach using a jet plume model is described, and model predictions are compared with dilution observations taken in a wind tunnel model test of a laboratory building.
KEYWORDS calculation techniques, exhaust, wind tunnel

#NO 3777 Measurements for the control of fresh air intake.
AUTHOR Solberg P W, Dougan D S, Damiano L A
BIBINF USA, Ashrae Journal, January 1990, pp46-51, 8 figs, 14 refs. #DATE 00:01:1990 in English
ABSTRACT This article documents the key reasons why Ashrae Standard 62-1989, "Ventilation for acceptable indoor air quality" recommends the measurement and documentation of outdoor air intake flow on constant volume and variable air volume (VAV) systems. The article also analyzes the most critical portion of the fan system control algorithm, the control of minimum outdoor air during mechanical refrigeration (cooling coil operation).
KEYWORDS mechanical ventilation, outdoor air

#NO 4026 Effect of building airflow on re-entry and IAQ.
AUTHOR Bahnfleth D R, Govan F A
BIBINF in: Practical Control of Indoor Air Problems, proceedings IAQ 87, ASHRAE 1987, pp185-194, 7 figs, 1 tab. #DATE 00:00:1987 in English
ABSTRACT Obtaining clean outdoor air for ventilation and "free-cooling" in economizer air-handling systems is at best difficult and sometimes nearly impossible. This is especially true in ground floor offices or commercial space nestled among multistory buildings. Knowledge of the effect of airflow over buildings on pressure gradients and air movement around buildings is essential for engineers and architects seeking to avoid or minimize re-entry of contaminated air into occupied building spaces and related indoor air quality (IAQ) problems. Remodelling of the ground floor of an eight-story building across the alley from a single-story office element attached to a ten-story tower led to significant economic loss when re-entry was not considered. A mushroom-type exhaust fan installed in the exterior wall of the remodeled space to serve a steak and hamburger grill exhausted grease fumes, smoke and odours into the alley at the ceiling of the first floor that were taken in by the outside air intake of the ground floor office. Although limited "whiffs" of cooking steak may whet one's appetite, continuous exposure to heavy hydrocarbon fumes and odours has a negative impact upon absenteeism and lost time. Comparison of lost time for the first eight months of the year during the year before and the year after installation of the grill exhaust showed lost time of 543 manhours before and 1271 manhours after, respectively. Value of the lost time was estimated to be approximately $32,000. Losses of productivity among those who remained on the job could not be measured but lost time was evident.
KEYWORDS indoor air quality, air flow, air conditioning, outdoor air

#NO 4032 Use of air cleaners to reduce outdoor air requirements.
AUTHOR Meckler M, Janssen J E
BIBINF in: Engineering solutions to indoor air problems, proceedings IAQ 88, ASHRAE 1988, pp130-147, 6 figs, 3 tabs, refs. #DATE 00: 00:1988 in English
ABSTRACT The proposed revision to ASHRAE Standard 62-1981, "Ventilation for Acceptable Indoor Air Quality", recommends a minimum of 15 cfm of outdoor air per person. This amount is needed to control occupant odours and guarantee that the concentration of carbon dioxide will not exceed 1000 ppm. Additionally, other recognised contaminants, including formaldehyde, office products, building materials, and tobacco smoke, will be maintained at acceptable levels. Most applications (i.e. offices) where the above contaminants can be expected to be found generally require more outdoor air. Air-cleaning systems that effectively remove the major contaminants can reduce the amount of outdoor air required. However, this generally requires an increase in the amount of recirculated air. A model is developed and equations are presented for calculating the amount of outdoor air required, space concentration of filtered contaminants, or the amount of recirculation needed. These parameters are dependent on the type of air distribution system (VAV or constant volume), supply temperature (constant or variable), and the use of outdoor air (constant or proportional). Also required are the air cleaner efficiency, ventilation efficiency, recirculation factor, and the flow reduction factor (with VAV

systems). Sufficient design of air cleaning systems can reduce the amount of outdoor air required.
KEYWORDS outdoor air, air cleaning, model

#NO 4036 Sick building syndrome traced to excessive total suspended particulates (TSP).
AUTHOR Armstrong C W, Sherertz P C, Llewellyn G C
BIBINF in: The human equation: health and comfort, proceedings IAQ 89, pp3-7, 2 tabs, refs. #DATE 00:00:1989 in English
ABSTRACT An epidemiological and environmental investigation into the air quality of a high-rise public office building was conducted in July 1988. A walkthrough inspection revealed particulate (dust) soiling of ceiling and work surfaces in occupied sections of the service floor. Building air samples obtained by high-volume air pumps and cassette filters revealed elevated concentrations of total suspended particulates (TSP) which ranged up to 1.07 mg/m3 (more than 17 times the Building Officials and Code Administrators [BOCA] standard). In 17 (59%) of the 29 areas tested, TSP levels exceeded the BOCA standard of .06 mg/m3 (annual average). Recorded temperatures, relative humidity readings, and supply of outside air were within acceptable limits. Testing for volatile organic compounds, combustion products, formaldehyde, ozone and fungal spores revealed no levels of concern. A survey of occupants in selected units was conducted with 94% participation. Fifty-five percent indicated that they had experienced symptoms that appeared or worsened during their working hours. Of these, 47% indicated that they had missed work because of their symptoms. Common symptoms were headache and sinus/upper respiratory congestion compatible with air contamination by TSP or other irritants. In multivariate analysis, illness was found to be significantly associated with air TSP concentration (P.002), CO2 concentration, average number of hours worked per week, gender, and smoking status. This is one of very few outbreaks of building-related illness where occupant illness has been associated with exposure to elevated levels of an environmental contaminant (TSP).
KEYWORDS sick building syndrome, particulate

#NO 4266 Practical maintenance for good indoor air quality.
AUTHOR AQME
BIBINF Canada, Quebec, Association quebecoise pour la maitrise de l'energie (AQME), 1989, 89pp, loose leaf clip file. #DATE 00:00: 1989 in English
ABSTRACT Covers concept of comfort and indoor air quality; how to handle complaints; problem diagnosis and solutions; prevention; verification and maintenance of components; and energy efficiency and indoor air quality. The manual is written from an energy conservation perspective. It also has numerous handy check-lists and practical hints. This publication systematically goes through the variety of IAQ complaints received by building operators, describes procedures for evaluating the complaints, and provides specific solutions. The appendix contains a listing of air quality standards from Quebec and from ASHRAE.
KEYWORDS maintenance, indoor air quality, energy conservation

#NO 4484 How fresh is fresh air?
AUTHOR Lepage M F, Schuyler G D
BIBINF Canada, Indoor Air '90, Proceedings of the 5th International Conference on Indoor Air Quality and Climate, Toronto, 29 July - 3 August 1990, Volume 4 "Building and System Assessments and Solutions", pp 311-316. #DATE 00:07:1990 in English
ABSTRACT Ventilation designers must take care that make-up air is fresh, and not just reingested exhaust air. A common solution is to place air intakes upwind of exhaust vents for the prevailing winds. Scale model studies in a boundary-layer wind tunnel show that this is often not a solution in its own. Firstly, non-prevailing winds, although less frequent than the prevaling winds, can still occur frequently. Secondly, locally redirected flow can lead to reingestion of exhaust gas at an upwind intake. Scale model test data demonstrate the potential for relatively high levels of exhaust gas to be reingested at intakes located upwind for the prevailing winds, even when the intakes are at large distances from the exhausts.
KEYWORDS outdoor air

#NO 4596 Human comfort and IAQ.
AUTHOR Holness G V R
BIBINF UK, Heating, Piping and Air Conditioning, February 1990, 5 figs, 6 tabs. #DATE 00:02:1990 in English
ABSTRACT Discusses human comfort as the forgotten issue in the design of buildings, including indoor air quality, ventilation rates, humidity, air circulation, air filtration, and maintenance.
KEYWORDS human comfort, indoor air quality

#NO 4955 Impact of air filters, heat exchangers, humidifiers and mixing sections on indoor air quality.
AUTHOR MacDonald P
BIBINF Proceedings of a Workshop held Lausanne, Switzerland, 27-28 May 1991, Brussels-Luxembourg, ECSC-EEC-EAEC, Publication No. EUR 137766 EN of the Commission of the European

Communities, Scientific and Technical Communication Unit, Directorate General Telecommunications, Information Industries and Innovation, Luxembourg, pp 151-160. #DATE 00:05:1991 in English
ABSTRACT Air filters, by controlling the level of particulate contamination, can improve indoor air quality (IAQ), yet the benefits of high efficiency filtration are not fully understood. Research studies are needed to quantify the benefits. Heat exchangers and humidifiers on the other hand are more normally associated with problems for IAQ, so work is required to establish how these problems can be overcome. Much research is currently being focussed on minimum outdoor air ventilation rates, yet no attention is being paid to the device that directly regulates this - the mixing section. The author doubts the effectiveness of mixing sections and feels that there is a very real need to research their performance so that guidelines can be produced and standards drawn up.
KEYWORDS filter, heat exchanger, humidifier

#NO 5264 Assessing intake contamination from atmospheric dispersion of building exhaust.
AUTHOR Perera E, Tull R, White M, Walker R R
BIBINF UK, AIVC 12th Conference, "Air Movement and Ventilation Control within Buildings", held 24-27 September 1991, Ottawa, Canada, proceedings published September 1991, Volume 1, pp 347-358. #DATE 00:09:1991 in English
ABSTRACT The possibility of unacceptable internal air pollution levels can cause concern at the design stage given the potential for cross contamination between building exhausts and ventilation intakes is there. The complexity of airflows around buildings, however, makes it extremely difficult to predict the contamination levels at the intake locations. This paper reports a wind tunnel technique using a model of a proposed building to determine the pollutant levels expected at various inlet locations due to the re-ingestion of noxious emissions from its two stacks. Tests were carried out in the BRE environmental wind tunnel on a 1 in 200 scale model of the proposed building with the approach wind simulated to correspond to the flow over a suburban terrain. Two tracer gases, sulphur hexafluoride and nitrous oxide, were injected separately, and at known concentrations, from the stacks at an efflux velocity corresponding directly to that required at full scale. Tests were carried out over a range of wind directions and speeds expected to occur for over 95% of the time. Air samples were taken at various locations on the model surface through brass tubes fitted from the inside. The concentration of the sampled air was measured using infrared gas analysers and the results presented as pollutant fractions in grams of pollutant measured to a kilogram of emitted pollutant.
KEYWORDS exhaust, air inlets, air outlet, pollutant, wind tunnel

#NO 5636 Air-cleaning strategies for equivalent indoor air quality.
AUTHOR Yu H H S, Raber R R
BIBINF USA, Ashrae, Transactions, Vol 98, Part 1, 1992, 9pp, 13 figs, refs. #DATE 00:00:1992 in English
ABSTRACT ANSI/ASHRAE 62-89, Ventilation for Acceptable Indoor Air Quality (ASHRAE 1989), provides guidelines for achieving acceptable indoor air quality in occupied spaces by either of two methods: a Ventilation Rate Procedure and an Indoor Air Quality procedure. The Ventilation Rate Procedure prescribes ventilation rates (in Table 2 of the standard) that it is assumed will provide adequate indoor air quality when 100% outdoor air is used. This 100% outdoor air value is also the minimum supply airflow per person. The amount of outdoor air in this minimum supply airflow may be reduced below 100% by recirculating adequately cleaned return air if the Indoor Air Quality Procedure is used. The Indoor Air Quality Procedure does not set outdoor air ventilation rates but employs both qualitative and subjective air quality evaluation. By mathematical analysis, this paper helps implement the Indoor Air Quality Procedure by determining what filter efficiencies are needed (particulate and gas) to account for source capture efficiency, reduced outdoor airflow, and poor ventilation effectiveness, all under VAV conditions.
KEYWORDS air cleaning, indoor air quality, mathematical modelling

#NO 5913 The IAQ product and service guide.
AUTHOR Indoor Air Quality Update
BIBINF USA, Cutter Information Corp, 1992, 207pp. #DATE 00:00:1992 in English
ABSTRACT Presents practical, comprehensive information on the technologies and professional services which can be used to detect, mitigate, or prevent indoor air quality problems in nonindustrial environments. Presents detailed descriptions of products and services for IAQ problems including volatile organic compounds, ozone, environmental tobacco smoke, carbon monoxide, atmospheric dust, and bioaerosols such as pollens, mould spores and bacteria. These indoor air pollutants lie at the root of most complaints about sick building syndrome or building related illness.
KEYWORDS indoor air quality, filter, air cleaning, pollutant, instrumentation

#NO 5945 Tracer gas technology for IAQ measurements.
AUTHOR Olesen B W
BIBINF USA, The New York Chapter ASHRAE 1992 Spring All Day Seminar on Indoor Air Quality, 9th May 1992. #DATE 09:05:1992 in English
ABSTRACT Many studies of buildings with reported Sick Building Syndromes (SBS) have shown that the ventilation system is a main contributor to the problems. It is, therefore, of great importance to be able to quantitatively evaluate the performance of a HVAC system. In many systems it is difficult or impossible with existing techniques (Pitot tubes, air velocity sensors) to measure accurately the amount of outside air, air flows, and air exchange rate for a ventilation system. Often it is not possible to find a well developed velocity profile (straight duct), the outside air intake is not ducted at all, and you do not know if exhaust air is coming back through the air intake. By using a tracer gas technique these problems can be taken into account. At the same time it will be possible to measure air flow in ducts, air exchange rate, percentage of outside air, outside circuiting of exhaust air, amount of air infiltration and the overall efficiency of the system. It is also important to be able to verify that the outside air is getting down to the occupants in the occupied zone. The tracer gas technique can also be used to evaluate the air distribution (air change efficiency) and the pollutant removal efficiency (ventilation effectiveness) of a system. The present paper will set off the procedure for doing this type of measurement and show a couple of field measurements.
KEYWORDS tracer gas measurements, indoor air quality, sick building syndrome, ventilation system

#NO 6227 Microbial contamination of indoor air.
AUTHOR Miller J D
BIBINF Indoor air quality, ventilation and energy conservation, 5th International Jacques Cartier Conference, Montreal, Canada, October 7-9, 1992, publisher: Center for Building Studies, Concordia University, Montreal, Canada, pp 1-11. #DATE 00:10:1992 in English/French
ABSTRACT The literature of ca. 10 years ago placed modest emphasis on fungi in relation to bacteria and viruses in indoor air (1,2). Viruses are almost entirely spread by personal contact and no obvious changes in building design or management can alter this (2,3). Many types of bacteria have been reported in indoor air, sometimes in high concentrations. Most of these are normal species associated with skin and nasal-pharyngeal surfaces. There is no direct evidence that the presence of these bacteria in office/residential indoor air contribute to disease (4). However, elevated concentrations of bacteria are normally a sign of poor ventilation (see 5). Indoor air exposure to Legionella and the endotoxin-containing bacteria is hazardous. However, the management of these bioaerosols in indoor air is well-defined and they rarely pose a health risk (6,7,8). In the last five years, fungi have come to be seen as quantitatively the most important bioaerosols with respect to health in indoor air. This paper will briefly review aspects of microbial problems in buildings. Recent findings regarding the biomedical aspects of fungal contamination of indoor air will be considered with a perspective on the normal mycoflora of indoor air.
KEYWORDS biological pollutant, indoor air quality, ventilation rate

#NO 6647 Biological contamination causes SBS symptoms in bank employees.
AUTHOR Anon
BIBINF USA, Indoor Air Quality Update, November 1992, pp 9-11, 2 tabs. #DATE 00:11:1992 in English
ABSTRACT A contaminated HVAC system accounted for an outbreak of allergic symptoms among the twelve employees of a bank building. Out-of-balance equipment added to the problem by causing hot and cold spots, as well as draughts throughout the office. After an IAQ investigation, bank officials followed the investigators' recommendations to alleviate the problems.
KEYWORDS sick building syndrome, bank, biological pollutant

#NO 6727 Biological pollutants in the indoor environment.
AUTHOR Binnie P W H
BIBINF USA, Chelsea MI, Lewis, 1992 "Indoor Air Pollution, Radon, Bioaerosols and VOCs", pp 13-24. #DATE 00:00:1992 in English
ABSTRACT Studies carried out by Healthy Buildings International (HBI) found that in over one third of the more than 400 buildings studied, the major pollutants included allergenic fungi, and in greater than two thirds, air supply systems were contaminated with dust, dirt, and microbes. This paper discusses the recognition of sick building syndrome (SBS) as an accepted malady and the possible association of microbial contaminants with SBS. The different types of microbes are described along with the problems they can produce. Sources and spread of microbes within buildings are discussed along with descriptions of methods for sampling from surfaces, water, and indoor air. Special mention is made of sampling for and identification of Legionella pneumophila, using a new rapid assay technique, and

the importance of correct interpretation of microbial findings against available standards.
KEYWORDS biological pollutant, indoor air quality

#NO 6992 Assessment of hood stack re-entrainment as determined by real-time tracer gas measurements.
AUTHOR Ludwig J F, Bolsaitis P P , McCarthy J F
BIBINF Finland, Helsinki, Proceedings of 'Indoor Air '93', The 6th International Conference on Indoor Air Quality and Climate, July 4-8, 1993, Volume 5, "Ventilation", pp 175-182. #DATE 00:07:1993 in English
ABSTRACT A tracer dispersion study was performed to evaluate the dilution of exhaust stack emissions from chemical fume hood stacks on the rooftop of a laboratory building complex located on a United States midwestern university campus. Tests were designed to (1) experimentally verify dilution ratios at outdoor air intakes for emissions from existing chemical fume hood stacks on the building complex; (2) evaluate potential exposures to rooftop service personnel; (3) further characterize the airflow on the rooftop and effect that turbulence might have on the dispersion of stack pollutants both instantaneously and averaged over time; and (4) evaluate the effects of increased stack heights as they relate to minimum and time weighted median stack dilution. Study results indicate that under normal operating conditions, vapors generated in the laboratories and emitted from the stacks were not expected to reach the outside air intakes in concentrations high enough to detrimentally impact the health of building occupants. However, odors of certain chemicals could be detected in some instances at the outside air intake and therefore could be sensed by occupants of the building and cause complaints about air quality.
KEYWORDS exhaust hood, tracer gas, laboratory

#NO 7034 A New Development for Total Heat Recovery Wheels
AUTHOR Dehli F, Kuma T, Shirahama N
BIBINF UK, Air Infiltration and Ventilation Centre, 14th AIVC Conference, "Energy Impact of Ventilation and Air Infiltration", held Copenhagen, Denmark, 21-23 September 1993, proceedings, pp 261-268. #DATE 21:09:1993 in English
ABSTRACT Total energy exchangers with a rotating heat storing matrix have been applied to airconditioning systems for more than 25 years with very good results for saving both heating and cooling energy. The efficiency of the hygroscopic coating of the rotors is very important to recover the latent energy, but there is the risk of cross contamination. To prevent odour transfer, the mechanism of the sorption and desorption process has to be investigated in detail. Selecting the adsorbant accordingly, the rotating heat exchanger can meet the new ventilation requirements in buildings for a high indoor air quality.
KEYWORDS heat recovery, odour

#NO 7291 Designing building for improved indoor air quality: ventilation systems and contaminant migration.
AUTHOR Walkinshaw D S.
BIBINF USA, Ashrae, 1993 "Building design technology and occupant will-being in temperate climates". International conference, held February 17-19, 1993, Brussels, Belgium, pp 186-196, 6 figs, 9 tabs, refs. #DATE 00:02:1993 in English
ABSTRACT This paper describes ways in which ventilation systems can be used to eliminate undesirable migration of contaminants. Addressed are contaminant flows from rooms of high to low concentrations, spillage and reingestion of exhaust, and infiltration of contaminated air from the building envelope. Blower-induced depressurization measurements are included for a few houses to illustrate some of the variables involved. Performance data are provided for a ventilation system for preventing the migration of basement enclosure contaminants into the living space. Two case studies of exhaust reingestion are included to demonstrate the cost benefits of having ventilation system designs that prevent contaminant migration problems in the first place.
KEYWORDS indoor air quality, pollutant, building envelope, depressurisation.

#NO 7339 Critical building design factors for indoor air quality and climate : current status and predicted trends.
AUTHOR Levin H.
BIBINF Denmark, Indoor Air, No 1, 1991, pp 79-j92, 3 tabs, refs. #DATE 00:00:1991 in English
ABSTRACT In recent years, some building design professionals have become more aware of the indoor air quality concerns of owners and occupants and as a result, they have made some important changes to improve indoor air quality climate. These changes include improvements in site planning and design; overall building design; ventilation and climate control systems; and materials selection and specifications. In addition, changes that limit the chemical contamination of building air during the construction process and during occupancy of buildings are also occurring ; some of these changes are specified or controlled by design professionals. However, the majority of design professional have little or no awareness of indoor air quality considerations. There is inadequate dissemination of building science re-

search results to design professionals. There is a need for a useful general body of knowledge, theory, and practice regarding building-environment-occupant interactions. The lack of such knowledge, theory, and practice is an impediment to developing the necessary professional design tools and practices to address effectively indoor environmental quality and energy conservation issues.
KEYWORDS design, indoor air quality, building material, energy conservation.

#NO 7439 Source of organics in the air of an office building.
AUTHOR Gebefuegi I L, Korte F.
BIBINF in: proceedings of Indoor Air '90, the fifth international conference on indoor air quality and climate, Toronto, Canada, July 29-August 3, 1990, pp 701-706, 2 tabs, 6 refs. #DATE 00:00:1990 in English
ABSTRACT The inventory of organics in the air of a ten year old office building show a wide variety of natural and synthetical volatile organic compounds (VOCs). Although 240 employees consume 1200 - 1500 cigarettes per day, the effective ventilation system reduces the ETS rapidly, however, aromatic hydrocarbons and some natural compounds still remain in the air in the higher g/m3-range. Systematic analyses of volatile compounds of all cleansers used show that they are sources of high limonene amounts. Aromatics entered by way of "fresh air" intake near the parking entrance at street level. The time depending concentration of the indoor air clearly showed maximums during the main arrival and departure times of cars (without catalytic converters). The substitution of the cleansers and modifying the fresh air intake reduced the indoor concentration of VOCs significantly.
KEYWORDS organic compound, office building, garage.

#NO 7622 The effect of streamlines of wind flow in calculation of pollution re-entry into buildings.
AUTHOR Plotnikova L V
BIBINF Finland, FINVAC, 1994, proceedings of the Cold Climate HVAC '94 Conference, held March 15-18, 1994, Rovaniemi, Finland,Edited by J Sateri and E Kainlauri, pp 245-247.#DATE 00:03:1994 in English
ABSTRACT The existing procedures of calculating the atmospheric pollution in the places of air intake devices of the ventilation and air conditioning systems do not take into account the diversity of peculiarities of streamlining the buildings with complex configuration, the formation of circulation zones that to a greater degree determine the pollution level at a given point, the quality of incoming air and respectively the efficiency of the ventilation systems functioning.
KEYWORDS Wind effect, calculation techniques, outdoor air, ventilation system.

#NO 7722 Ventilation system hygiene - a review
AUTHOR Loyd S
BIBINF UK, Building Services Research and Information Association (BSRIA) Technical Note TW 18/92.5, 6th edition, May 1994, 48 pp, 10 figs, 4 tabs, #DATE 00:05:1994 in English
ABSTRACT Reviews published literature on the hygiene of ventilation systems. Aims to provide designers with information to limit contamination as well as aiding building owners in procedures to help mitigate the effects on the occupants of a building
KEYWORDS ventilation system, hygiene, health

#NO 7896 Duct cleaning - a literature survey.
AUTHOR Luoma M, Pasanen A-L, Pasanen P, Fan Y
BIBINF UK, Air Infiltration Review, Vol 14, No 4, 1993, pp 1-5, 1 fig, 2 tabs, 28 refs. #DATE 00:09:1993 in English
ABSTRACT An effort has been made to gather the information available about duct cleaning. The emphasis in the survey was on the hygienic aspect of the cleaning of supply air ducts. Most of the literature deals with cleaning of exhaust ducts. Guidelines for the cleanness of duct surfaces have been given by some organizations, but the scientific basis for such guidelines needs more research.
KEYWORDS duct, maintenance, review, hygiene

#NO 7914 Wind tunnel modeling of diesel odors for fresh air intake design
AUTHOR Ratcliff M A, Petersen R L, Cochran B C
BIBINF USA, ASHRAE Transactions, Vol 100, Pt 2, 1994, (preprint), 9pp, 11 figs, refs. #DATE 00:00:1994 in English
ABSTRACT Odors from idling diesel tanks at loading docks and from emergency diesel generators often lead to complaints. Improper layout of the buildings the diesel source locations and the building fresh air intake locations add to the situation. To evaluate odor problems and possible alternative air intake locations, wind tunnel modeling is used to predict the dispersion of the diesel exhaust within the complex airflow patterns around buildings. Standard numerical models do not work in the immediate vicinity of buildings especially for ground-level sources. The wind climate of the site and odor objection data from the literature are also used. Four case studies are presented that illustrate the analytical

procedure and typical results. The open face of a building is preferred location for diesel sources rather than within U-shaped and L-shaped building enclosures
KEYWORDS wind tunnel, odour, outdoor air

#NO 8103 Changing requirements for air filtration test standards.
AUTHOR Ensor D S, Krafthefer B C, Ottney T C
BIBINF USA, Ashrae J, June 1994, pp 52-60, 3 figs, 1 tab, 12 refs.
ABSTRACT Proposes that new standards incorporating new test methods are needed to determine particle-size-dependent efficiencies of air filters and cleansers. A review of the standards used to rate filters for the removal of particulate matter is discussed. Also the requirements of new test standards currently being developed by ASHRAE Standards Project Committee (SPC) 52.2p, Particle Size Efficiency Procedure for Testing Air Cleaning Devices are presented.
KEYWORDS (filtration, standard)

#NO 8344 Location of air intakes to buildings situated in urban environments.
AUTHOR Krueger Ulf.
BIBINF Poland, Silesian Technical University, 1994, proceedings of Roomvent '94: Air Distribution in Rooms, Fourth International Conference, held Krakow, Poland, June 15-17, 1994, Volume 2, pp 373-388.
ABSTRACT In urban environments the locations of air intakes in relation to outdoor pollutant sources are important. A significant parameter is where the building is situated in relation to streets with heavy traffic. The wind direction and velocity, street geometry and building construction are also of importance for the concentrations of traffic-related pollutants at street side and backyard of a building, especially when the building is located adjacent to a street on one side. In this study carbon monoxide, CO was used as an indicator of traffic related sources. The measurements show that monitoring periods of at least one week are needed to get reliable results and that climatic conditions influence the concentration difference of traffic related pollutants between street side and backyard of a building. When a mechanical exhaust system is used, the outdoor air is normally supplied to the rooms through the facades. The result of this arrangement could be that the indoor air will be more contaminated than when using a balanced system with the air intakes placed at the back of the building or on the roof. However, if the building is not close to busy streets, the mechanical exhaust system could be a good solution from the air quality point of view.
KEYWORDS air inlets, wind direction, carbon monoxide, outdoor air

#NO 8426 Indoor air quality in two buildings in Ecuador
AUTHOR Collett C W, Ross J A
BIBINF Indoor Air 90, Vol 3, Building and system assessments and solutions, Toronto, 29 July - 3 August 1990, pp 395-400, 2 tabs, 5 refs.
ABSTRACT Investigations of two office buildings in Ecuador were undertaken to assess the impact of sealed building technology on indoor air quality and occupant comfort. Several design and operational inadequacies were identified which created the potential for indoor pollution, including microbial contamination of outside air intakes, infiltration of automobile exhaust, re-entry of exhausted air and mechanical malfunction of outside air dampers.
KEYWORDS office building, sealing, indoor air quality, occupant reaction

#NO 8427 Skin irritation and dyspnea in kitchen workers: sodium hydroxide.
AUTHOR Marchant R E, Yoshida K, Walkinshaw D, Ross J B, et al
BIBINF Indoor Air '90, proceedings of the 5th International Conference on Indoor Air Quality and Climate, Vol 4, Toronto, 29 July - 3 August 1990, pp 653-657, 9 refs.
ABSTRACT Workers in a new hospital kitchen experienced skin problems, eye irritation, headaches, and dyspnea, at an attack rate of 26 - 42%, depending on the work area. Symptoms were relieved within minutes to hours of leaving the kitchen environment. The kitchen air was sampled for fungi and volatile organic compounds (VOCs), and the outdoor ventilation system make-up air for VOCs. Concentrations of a tracer gas were measured at the dishwasher exhaust and kitchen intake, and surface contamination of various sites in the kitchen were determined by wipe tests. The kitchen and dishroom each has a dedicated 100% fresh-air supply, with kitchen intake and dishroom exhaust located in the same ground-level courtyard. Cross contamination from the dishroom exhaust to the kitchen supply air was confirmed. The offending agent was found to be sodium hydroxide in the dishwashing detergent.
KEYWORDS allergies, kitchen, pollutant

#NO 8429 Dust in ventilation ducts.
AUTHOR Valbjorn O, Nielsen J B, Gravesen S, Molhave L
BIBINF Indoor Air '90, proceedings of the 5th International conference on Indoor Air Quality and Climate, Vol 3, Building and system assessments

and solutions, International Conference, Toronto 29 July - 3 August, 1990, pp 361-364, 6 refs.
ABSTRACT Several epidemiological studies have shown that the prevalence of SBS generally is high in mechanically ventilated building, especially when equipped with supply air systems and humidification. Other studies have indicated that the indoor air may be deteriorated by the ventilation plant. Cleaning of ducts is now recommended, but a rationale does not exist. The paper presents results from investigating 13 plants in schools and offices. Some had recirculation, but none had humidification or cooling coils. The amount of dust per duct area, concentration of fungi, bacteria and potential antigenic material, as well as the release of odour and VOC were analysed. The results showed low contents of sedimented dust. It was found that the dust did not differ from dust generally found on floors in offices in Denmark concerning the microbial and antigenic load. The odour and the release of VOC were negligible.
KEYWORDS dust, duct, disease, sick building syndrome

#NO 8431 Airborne bacteria and the indoor climate.
AUTHOR Dennis P J L
BIBINF Indoor Air '87, proceedings of 4th International Conference on Indoor Air Quality and Climate, Berlin West, 17-21 August, Volume 4, Institute for Water Soil and Air Hygiene, 1987, pp 69-78, 2 tabs, 33 refs.
ABSTRACT Since the 1940's there has been an increase in the awareness and appreciation of the importance of airborne infection. The importance of particle size and the concept of droplet nuclei which remain suspended in air for considerable periods have been seen as important determinants of infectivity. The appearance of humidifier fever caused by thermophilic actinomycetes and amoebae and the recognition of Legionnaires' disease has led to an appreciation of the microbiological dangers posed to individuals in modern building. These microorganisms like the legionellaceae are aquatic in nature and are able to colonise building water services probably gaining access via the public water supply. Proliferation of these organisms within building water systems, humidifiers and air conditioning equipment is associated with inadequate maintenance or infrequent usage. These factors provide the ideal conditions for settlement and growth of organisms in water handling equipment. The survival of these organisms or their toxins in aerosols produced by water handling equipment can lead to the establishment of disease in susceptible individuals who inhale them.
KEYWORDS bacteria, indoor climate, aerosol

#NO 8435 An overview of the theory and practice of ventilation.
AUTHOR Spry P E
BIBINF Australian Refrigeration Air Conditioning and Heating, April 1989, Vol 43, No 4, pp 26-33, 1 tab, 54 refs.
ABSTRACT The purpose of this paper is to present an overview of the theory and practice of ventilation. As ventilation is usually provided for the benefit of people some aspects of human psychophysiology are described. Some criteria, standards and problems of indoor air quality are also addressed. This paper is not simply a literature review; it contains some observations, by its author, on the criteria, standards and practices of ventilation.
KEYWORDS human comfort, review

#NO 8436 Does contamination of fresh air intake cause some cases of building intolerance?
AUTHOR Hanson R L, Dolphin B, Parkinson D K
BIBINF Indoor Environment, January-February 1993, Vol 2, No 1, pp 19-25, 1 fig, 4 tabs, 22 refs.
ABSTRACT A survey of 160 hospital employees, those employed in an area where the air supply was potentially contaminated with the exhaust air from other hospital areas had a higher prevalence of certain work-related symptoms than employees from other areas. There was little difference between the two groups in overall health. These findings have implications for building intolerance, and larger studies are needed to investigate the role of ventilation system design, especially as it relates to the potential for contamination, in the cause of this syndrome.
KEYWORDS outdoor air, sick building syndrome

#NO 8437 The effects of air conditioning components on pollution in intake air.
AUTHOR Holcombe J K, Kalika P W
BIBINF Ashrae Trans, 1971, Vol 77, part 1, pp 33-49, 4 diags, 7 tabs, 33 refs.
ABSTRACT The principal objectives of the study were: (1) to determine the information available concerning the ability of commercial air conditioning equipment to reduce concentrations of pollutants in the outdoor air drawn into a building; (2) to determine the probable effects of various combinations of equipment and compare these predictions with measurements made in selected existing situations. These objectives were accomplished largely by a comprehensive literature search, a survey of equipment manufacturers, and contacts with researchers in industry, government and universities. In addition, data available from an ongoing study with the National Air Pollution Control Administration was combined with theoretical techniques to

assess the value of mathematical modelling in predicting indoor/outdoor pollutant relationships.
KEYWORDS outdoor air, pollutant, air conditioning

#NO 8438 A design procedure for estimating air intake contamination from nearby exhaust vents.
AUTHOR Wilson D J
BIBINF Ashrae Trans, 1983, Vol 89, part 2A, pp 136-152, 5 figs, 12 refs.
ABSTRACT A simple design procedure is developed for determining the necessary height of an exhaust stack to produce a specified level of dilution at a nearby air intake. The contributions of internal system dilution, wind dilution and dilution from stack height are considered separately. The three effects are combined to determine the available dilution at a critical windspeed which produces minimum dilution. Wind tunnel and full scale dilution measurements are used to set the necessary empirical constants, and a sample design calculation is presented.
KEYWORDS pollutant, exhaust, outdoor air

#NO 8439 Critical wind speeds for maximum exhaust gas reentry from flush vents at roof level intakes.
AUTHOR Wilson D J
BIBINF Ashrae Trans, 1982, part 1, pp 503-513, 5 figs, 7 refs.
ABSTRACT In considering the contamination of intake air by gases exhausted from nearby vents, it is usually impractical for a designer to make detailed estimates for all wind speeds and directions. The alternative is to determine the critical wind speed and direction at which the concentration of exhaust gases in the intake air will be highest, then locate the intakes and exhausts so that this highest concentration is less than an acceptable maximum value. Considerable information is available to estimate the minimum vent to intake dilution for the worst case critical wind direction. Here, we will attempt to predict the critical wind speed that would produce the absolute maximum concentration at this critical wind direction. Another important question that must occur to every designer is whether this "worst case" results in excessively conservative design. The analysis will show that the critical wind speed is typically 20% of the vent exit velocity, and that for variations in wind speed of a factor of six (from one-half to three times the critical value), the exhaust gas concentration at the air intake will only vary by a factor of about two. This will lead us to conclude that these worst case conditions will be a common occurrence, and that critical speeds are reasonable criteria to use for design purposes.
KEYWORDS wind speed, exhaust, vent, roof

#NO 8440 The effect of varying exhaust stack height on contaminant concentration at roof level.
AUTHOR Wilson D J, Winkel G
BIBINF Ashrae Trans, 1982, Vol 88, part 1, pp 515-533, 8 figs, 19 refs.
ABSTRACT A two-part study by Wilson was completed in 1979 to develop simple quantitative stack design procedures. The first part of the study used flow visualization to determine the necessary stack height required to avoid all contact between the exhaust gas plume and roof level air intakes. These experiments and the design procedure are described by Wilson and are presented in the ASHRAE Handbook - 1981 Fundamentals. This paper will deal with the second part of the study in which concentration measurements on building models in a wind tunnel were used to predict the effect of varying stack height.
KEYWORDS exhaust, stack, pollutant, roof

#NO 8441 Cross contamination and entrainment
AUTHOR Gorman R W
BIBINF Evaluating office problems, Annals of the USA American Conference of Governmental Industrial Hygienists, Vol 10, Cincinnati, October 1984, pp 115-120, 3 figs, 4 refs.
ABSTRACT Airborne contaminants may be generated within the area of a building, such as sometimes found in new buildings or recently renovated buildings, or outside of the building and brought into the area by either cross contamination or entrainment. Cross contamination and entrainment are two unique ventilation problems either, or both, of which may be contributing to the problem. Cross contamination occurs when a contaminant is present in an area of a building other then where it is generated and finds its way there without leaving the building. Entrainment occurs when contaminants are brought into the building from the outside. Conditions conducive to entrainment are: fresh air intakes that are located close to or down wind of exhaust stacks; exhaust stacks too low to discharge outside the turbulent wake caused by airflow over and around the building; buildings under negative pressure.
KEYWORDS cross contamination, outdoor air

#NO 8442 Contravention of building bylaws for HVAC systems and bad maintenance as causes of indoor air pollution.
AUTHOR Ferahian R H

BIBINF Proceedings of IAQ 86, Managing indoor air for health and energy conservation, USA American Society of Heating Refrigerating and Air Conditioning Engineers, Atlanta, Georgia, 20-23 April, 1986, pp 251-257, 1 fig, 7 refs.
ABSTRACT Bad maintenance and violation of Building Byelaws and Standards for HVAC systems are major contributors to indoor air pollution. Contamination of outdoor air intakes by exhausts due to proximity of the intakes and exhausts, adjacent building and aerodynamic interaction of the building and the winds at the site cause problems not covered by the codes. PCB-cooled transformers and capacitors may produce dioxins and furans in the event of fire or explosion. Examples of PCB contamination caused by fires are presented. The drive towards energy conservation in buildings and the subsequent reduction of outdoor ventilating air are discussed. Interruption of fan operation for energy conservation sometimes cover up malfunctions in the HVAC system. Mandatory good maintenance of the HVAC system is urgently needed as a part of our laws.
KEYWORDS maintenance, indoor air quality

#NO 8446 A wind tunnel model study of air conditioning contamination by intake of flue gas.
AUTHOR Melbourne W H, Gartshore I S
BIBINF ICIASF '75 Record, pp 92-96.
ABSTRACT An experimental study was made of the concentration of flue gas ingested into the air conditioning intake of a tall isolated building of square cross section, with both the emitting stack and the air conditioning intake located on the flat roof of the building. A wind tunnel model of the 170m high State Bank building (Melbourne) was used, injecting pure helium from the model stack; concentrations of helium in the intake air were then measured to estimate the percentage contamination. For the conditions studied, this contamination appeared to be independent of the volume flow rate of air conditioning gas, directly dependent on the mass flow rate of flue gas and varying between 0.25 and 0.4% for various wind speeds and directions at a flue gas emission rate equivalent to 1.7 m3/s. Further model tests showed that when the air conditioning inlets were located on the face of the building, rather than on the roof, the contamination from the flue gas was roughly halved if the intake was on the lee side, or eliminated if the intake was out of the building wake.
KEYWORDS wind tunnel, modelling, air conditioning

#NO 8447 Modelling wind flow over a factory with CFD
AUTHOR Ong I
BIBINF DT (Arup J.) Spring 1991, vol.26. no.1, 15, 4 figs.
ABSTRACT Presents a brief, illustrated description of the application of computational fluid dynamics (CFD) to the study of wind flow over a factory roof for Shimizu UK Ltd. The objective was to determine whether a roof parapet would interfere enough with the wind flow regime over the roof to produce unacceptable concentrations of pollutants in the environment discharged via roof-mounted stacks, with the additional possibility of re-entrainment of exhaust gases into the roof-mounted air-handling units. Explains how CFD techniques were applied which, supplemented by empirically-based calculations, showed that the influence of the roof parapet on wind flow patterns gives no cause for concern and that concentrations of stack emissions at air-handling unit intakes are within acceptable limits.
KEYWORDS Calculating, air flow, factories, case studies, computers, UK, outdoor, air pollution, roofs, air inlets,

#NO 8449 Flow patterns over flat roofed buildings and application to exhaust stack design
AUTHOR Wilson D J
BIBINF ASHRAE Trans. 1979, vol.85, no.2, 284-295, 12 figs, 10 refs. in English.
ABSTRACT It is often necessary to locate both air intake and system exhausts on a roof, particularly for industrial ventilation systems on large, low-rise buildings. Effect of building on wind as it blows of the roof makes it difficult to specify correct height of exhaust stacks to avoid recirculation of vented gases to air intakes. Develops simple equations and shapes for roof recirculation cavity, high turbulence region and the wake boundary which permit approximate estimation of required stack height to avoid recirculation of exhaust gas to roof level and its injection by air intakes located there.
KEYWORDS calculating, chimneys, vents, roofs, factories, airinlets

#NO 8450 Dilution of exhaust gases from building surface vents.
AUTHOR Wilson D J
BIBINF DT (ASHRAE Trans.) 1977, Part 1, 168-176, 10 figs, 5 refs. 697.982
ABSTRACT Notes importance for designer to be able to estimate chance of wind around a building recirculating any toxic or corrosive gases, vapours or odours to an air intake or to ground level. Treats experiments on 2 building models of medium and high-rise structures, using flow visualisation and wind tunnel measurement of exhaust gas dilution to determine whether dilution factors for vents on vertical sides of a building can be estimated using same

equation developed for roof vents. Provides and discusses results. Finds use of equation to be generally satisfactory, regardless of vent location.
KEYWORDS Exhaust gases, buildings, vents, winds, recirculating, toxic gases, gases, corrosion, vapours, odour, wind tunnels, factors, diluting, air flow visualisation

#NO 8451 Effect of vent stack height and exit velocity on exhaust gas dilution.
AUTHOR Wilson D J
BIBINF ASHRAE Trans., 1977, Part 1, 157-167.
ABSTRACT The purpose of the present investigation was to determine if a simple design procedure could be developed to predict the reduction in concentration at a receptor point which would occur if either the vent stack height or its exit velocity were changed. The emphasis was on the development of a simple theory, rather than attempting more general and accurate formulations which would apply to a wide variety of situations. This emphasis on simplicity is justified because the variability of the dilution process around a building introduces levels of uncertainty of two or more in predicting concentrations, and any theory of stack height effects which improves on this uncertainty is an exercise in self-delusion on the part of the designer. The results of the experiments and the simple theory will demonstrate that both the stack height and the vertical exit velocity can be combined to determine an effective stack height. This is an important concept because it allows a designer to determine a trade-off between increasing the physical height of the stack, or increasing the vertical velocity from the stack. Because the fan power necessary to exhaust a given quantity of vent gas is proportional to the square of the vent gas velocity, the key question which must be answered is whether there is any significant reduction in roof receptor concentrations for reasonable vent velocities, which do not require excessive fan power. If large values of exit velocity are required, the necessary fan power may make it much more attractive to simply raise the height of the stack.
KEYWORDS vents, height, exhaust gases, speed, pollution, air pollution, chimneys,

#NO 8452 Indoor air pollution caused by short-circuiting of fresh air intakes with exhausts of buildings.
AUTHOR Ferahian R H
BIBINF Clima 2000 proceedings, Vol 4, Copenhagen 25-30 August 1985, VVS Kongres-VVS Messe, pp 307-312
ABSTRACT This paper deals with indoor air pollution mainly due to a part of design characteristics of the HVAC system, namely that of the ventilation system, and of this only with the air before it is supplied to the ventilation's circulation system. Although just a component cause of the indoor air pollution, it is nevertheless a very important one because the air that reaches the tenants in most if not almost all apartment and office buildings can never be cleaner than this supply air, in chemical composition and odours at least. It deals with cases from the author's experience and those gleaned from published records where indoor air pollution was caused by short-circuiting of the fresh air intakes with the exhausts of the building or adjacent building or contamination of the fresh air intakes due to their badly chosen locations. Other cases are presented where the aerodynamic interaction of the building with the winds at the site caused such a contamination under unfavourable atmospheric conditions.
KEYWORDS pollutant, indoor air quality, air intakes

#NO 8453 Filtration for the HVAC industries.
AUTHOR Hoppitt H B
BIBINF Heat. Vent. Engr, May 1976, vol. 50, no. 586, 6-8, 6 figs, 697.942
ABSTRACT Notes insufficient attention paid to correct filter selection in planning stage of major air conditioning projects with considerable costs incurred by user or occupier of building due to discolouration of decorations and furnishings and stock losses in stores, ambient contamination adversely affecting operation of other components of air conditioning installation etc. Covers selection of throw-away filters and their various subdivisions. panel filters, automatic filters, bag filters and absolute filters. Treats standards and performance. Mentions grease filters in kitchens and special filters for low-level air intakes, coastal sites, induction unit systems. Stresses need to buy from reputable manufacturers.
KEYWORDS Building services, industrial, filtration properties, filters, air conditioning, panels, automatic, standards, performance, kitchens, manufacturers

#NO 8455 Wind tunnel investigation of the effects of a rectangular-shaped building on dispersion of effluents from short adjacent stacks.
AUTHOR Huber A H, Snyder W H
BIBINF BHRA Industrial Aerodynamics Abstracts, December 1984, Vol. 15, no. 12, p.258.
ABSTRACT In a wind tunnel, study, the influence of the highly turbulent region found in the lee of a model building upon plumes emitted from short stacks was examined through smoke visualization and tracer gas concentration mappings. A simple mathematical model was developed that provided

good estimates of concentrations in the building wake.
KEYWORDS models, jets, chimneys, chimneys, experiment, calculating, turbulent flow, buildings, air pollution,

#NO 8456 Plume centerline warpage in the wind field surrounding a building.
AUTHOR Halitsky J
BIBINF Unpublished report, February 25, 1991, 34pp.
ABSTRACT A mathematical procedure for correcting a horizontal-wind stack plume centerline for wind field curvature over a building is described. It employs exact solutions for potential flow over idealized bodies that resemble the envelopes enclosing buildings and their zones of separated flow. The correction is made progressively over small increments of downwind distance, starting at the stack top and following the local streamline in each increment. The procedure is applied to a simple block building and stack used in a wind tunnel test, and the corrected plume centerline, together with plume boundaries calculated by the Halitsky jet plume model, are shown superposed on a smoke photograph for comparison.
KEYWORDS wind effects, mathematical modelling

#NO 8761 Dispersion of Exhaust Gases from Roof-level Stacks and Vents on a Laboratory Building.
AUTHOR Wilson D J, Lamb B K

#NO 8762 A Jet Plume Model For Short Stacks
AUTHOR Halitsky J

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Air Intake Positioning to Avoid Contamination of Ventilation Air
Bibliography Update
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#NO 8455 Wind tunnel investigation of the effects of a rectangular-shaped building on dispersion of effluents from short adjacent stacks.
AUTHOR Huber A H, Snyder W H
BIBINF BHRA Industrial Aerodynamics Abstracts, December 1984, vol. 15, no. 12, p.258.
ABSTRACT In a wind tunnel, study, the influence of the highly turbulent region found in the lee of a model building upon plumes emitted from short stacks was examined through smoke visualization and tracer gas concentration mappings. A simple mathematical model was developed that provided good estimates of concentrations in the building wake.
KEYWORDS models, jets, chimneys, chimneys, experiment, calculating, turbulent flow, buildings, air pollution,

#NO 8500 Dispersion in jets from short stacks.
AUTHOR Hallitsky J.
BIBINF USA, Ashrae Winter Meeting, January 1995, 21 pp, 19 figs, refs.
ABSTRACT When a building exhaust stack and a fresh air intake are located on the same roof and the stack has sufficient volume flow and emission velocity to create a free jet in a crosswind, an accurate calculation of the exhaust concentration at the intake requires a model of the initial plume region. EPA models provide no guidance in this regard since they apply to receptors located at distances greater than several building heights downwind of the stack, for which a crude virtual source approximation is adequate. The Halitsky Transverse Jet Plume model fills this gap. It was developed in two stages, referred to herein as the 1966 model and the 1989 model. The 1966 model employed empirical equations based on wind tunnel test observations to describe the growth of the plume from its origin at the stack top, through the jet region where plume velocities differ from the free wind velocity, and then in the simple plume region where dispersion is controlled by wind properties alone. This radially symmetric model used a longitudinal coordinate distance s measured along the plume centreline, a radial coordinate distance r perpendicular to the centreline, and different plume boundary expansion rates in three plume regimes. The curvilinear coordinate s was used because no plume rise equation had yet gained general acceptance, and conversion to an x,y,z system was dependent on the centreline shape. The 1989 model is an updated, simplified version of the 1966 model. It uses x,y,z coordinates, the Briggs neutrally buoyant plume rise equation, and a wind turbulence factor based on the Pasquill-Gifford stability classification scheme. The jet region is not modeled explicitly because it was found from experience that fresh air intakes would rarely be exposed to it. The characteristics of the jet region may be retrieved by use of the equations in the 1966 model. A key point of the 1989 model is the specification of the plume properties at Station 2 located at the end of the jet region (start of the simple plume region). Here, the radial concentration distribution is converted from triangular in the jet region to Gaussian in the simple plume region. The values of x2, z2, and o2 may be used to calculate a virtual source location or to serve as a starting cross section for downwind expansion of the simple plume.
KEYWORDS Stack, air inlets, wind effects, air flow.

#NO 8517 Feasibility of passive ventilation by constant area vents to maintain indoor air quality in houses.
AUTHOR Wilson D J.
BIBINF USA, Ashrae, from proceedings of IAQ 92 Environments for people, pp 273-290, 9 tabs, refs.
ABSTRACT Measurements of air infiltration in five test houses, with and without passive ventilation inlets and exhausts, were used to refine and validate a computer model for wind- and stack-effect flow through a sheltered single-zone building. The model was then used to test various passive vent locations on three house types; a single-storey bungalow, a large two-storey house, and a townhouse with its side walls common with adjacent buildings. It was found that even with several ground-level intake openings and exhaust through a roof-level furnace flue, houses cannot be adequately ventilated in spring and fall (?T = 10 degrees C) in light winds (3.6 km/h) without using large flow areas that cause considerable over ventilation in windy weather. Some supplementary form of mechanical ventilation is required in spring and fall during periods of light to moderate winds.

KEYWORDS passive ventilation, vent, indoor air quality, residential building

#NO 8531 Accuracy and realism of ASHRAE handbook estimates of exhaust gas contamination of nearby air intakes.
AUTHOR Wilson D.
BIBINF USA, Ashrae Winter Meeting, January 1995, 13 pp.
ABSTRACT The 1993 ASHRAE Handbook procedure fails to account for two important factors. These are: 1. The plume is assumed to be conical with equal crosswind and vertical spreads. Plumes dispersing in atmospheric turbulence typically have vertical spreads only half as large as the crosswind spread. Neglecting the difference between plume height and width produces required stack heights that are conservative (too high) using the 1993 ASHRAE handbook method. 2. The single atmospheric turbulence level used in the 1993 ASHRAE calculation procedure fails to account for changing plume spread with varying atmospheric stability. Because atmospheric turbulence accounts for about half the total dilution from a building exhaust to an air intake, the use of a single average atmospheric turbulence level makes it difficult to estimate the range of real dilutions that occur. Using field data from a full scale tracer gas study of dispersion from roof level vents and stack on a large building, Wilson and Lamb developed a new model for dispersion. This model is based on the functional forms of the 1993 ASHRAE handbook calculation procedure but accounts for varying levels of atmospheric turbulence. The new model was validated by an independent data set on nuclear reactor buildings in a 1994 study by Ramsdell and Fosmire. This improved model adds a new element of realism to the ASHRAE calculation procedure, and will be incorporated in the 1996 ASHRAE handbook of Fundamentals. The most important feature of this revised calculation procedure is a more realistic assumption that the vertical plume spread is about half the horizontal plume spread for the atmospheric turbulence component of dispersion. For typical levels of atmospheric and building-generated turbulence this produces required stack heights that are only two thirds as large as the 1993 ASHRAE Handbook requirement.
KEYWORDS air inlets, air flow, wind effects, outdoor air.

#NO 8728 HVAC Systems as emission sources affecting indoor air quality: a critical review.
AUTHOR Batterman S A, Burge H.
BIBINF HVAC & R Research, Vol 1, No 1, January 1995, PP 61-80 1 tab, refs
ABSTRACT This study evaluates literature on heating, ventilating and air conditioning (HVAC) systems as contaminant emission sources that affect indoor air quality (IAQ). The various literature sources and methods for characterizing HVAC emission sources are reviewed. Characterization methods include in situ test, longitudinal and cross-sectional studies, and laboratory studies. A critique of the literature reveals that few studies are well-controlled, comprehensive and quantitative. Significant gaps in the data are highlighted and procedures are suggested to improve the characterization of bioaerosol and VOC (volatile organic compound) emission sources. Several HVAC components are cited frequently as emission sources, and there is broad agreement regarding their significance. These sources include biological growth and bioaerosol generation in the presence of moisture provided by air washers and other recirculating water systems, or by poor control of humidity, badly designed humidifying systems, and inadequately maintained cooling coils and drip pans. IAQ problems appear exacerbated by dust accumulation, and by the presence of fibrous insulation. Other problems include entrainment, migration, and infiltration of indoor and outdoor contaminants that are distributed to indoor spaces by the HVAC system. The importance of good design and operation of HVAC systems, including the appropriate placement and maintenance of air intakes, building pressurization, and local exhaust in source areas, is well accepted. More limited data implicate dust (resulting from inadequate filtration and maintenance of filters) as a secondary source for VOCs.
KEYWORDS air conditioning, indoor air quality, biological pollutant, humidification, organic compound

#NO 8760 Natural ventilation of car parking buildings. Natuurlijke ventilatie van parkeergarages
AUTHOR Kornaat W.
BIBINF Netherlands, TVVL Magazine, No 4, 1995, pp 28-31, 3 figs, in Dutch.
ABSTRACT Car park buildings have to be properly ventilated to remove exhaust gases. Unjustly natural ventilation often is regarded to be insufficient. This article deals with the advantages of natural ventilation. With air movement modules the effect of a natural ventilation system can be made understandable and the design can be ameliorated. The ventilation and the flow rate of a car park building can be determined, advancing the applicability of natural ventilation.

KEYWORDS garage, motor vehicle, natural ventilation, pollutant

#NO 8761 Dispersion of exhaust gases from roof-level stacks and vents on a laboratory building
AUTHOR Wilson D J, Lamb B K.
Atmospheric Environment Vol 28, No 19 pp3099-3111, 1994
A field study of six roof exhaust locations was carried out to test and refine a minimum dilution model using 44 sequential samplers at roof and ground level locations within a group of buildings located on a university campus. An existing minimum dilution theory was refined to develop a new theroetically based expression for initial dilution in the bent-over momentum jet from a stack, and to express the distance-dependent dispersion directly in terms of turbulence intensity. Predictions from the model were in good agreement with measured maximum concentrations (i.e. minimum dilution) over the 5-270m range of exhaust to receptor distances. The field measurements confirmed wind-tunnel observations that hourly averaged dilution is strongly influenced by upwind-generated turbulence as well as building generated turbulence. The distance-dependent dilution increased as crosswind turbulence in the approach flow increased, indicating that hourly average concentrations on the roof and at ground level are sensitive to upwind turbulence. Constants of proportionality averaged over the nine test periods were within 10% of distance-dilution constants from previous wind tunnel simulations of generic building shapes.
Buildings, dispersion, turbulence, dilution, tracer, field measurements

#NO 8762 A jet plume model for short stacks
AUTHOR Halitsky J.
BIBINF J APLCA, Vol 39, No 6, 1989, pp 856-858.

#NO 8980 Combustion gases in your home.
AUTHOR Anon
BIBINF Canada Mortgage and Housing Corporation, About Your House series, 1995, 8pp, 4 figs.
ABSTRACT Advice to householders on keeping combustion products - visible smoke and invisible gases - out of the house. Describes the symptoms to spot relating to excess combustion spillage and outlines steps that can be taken to reduce the risks. The problems described relate to the chimney, equipment and pressure, and lists are given for simple detection and correction measures.
KEYWORDS combustion product, residential building, combustion appliance

#NO 9249 Re-entrainment and dispersion of exhausts from indoor radon reduction systems: analysis of tracer gas data.
AUTHOR Henschel D B
BIBINF Denmark, Indoor Air, No 5, 1995, pp 270-284, 1 fig, 10 tabs, refs.
ABSTRACT Tracer gas studies were conducted around four model houses in a wind tunnel, and around one house in the field, to quantify re-entrainment and dispersion of exhaust gases released from residential indoor radon reduction systems. Re-entrainment tests in the field suggest that active soil depressurization systems exhausting at grade level can contribute indoor radon concentrations 3 to 9 times greater than systems exhausting at the eave. With a high exhaust concentration of 37,000 Bq/m3, the indoor contribution from eave exhaust re-entrainment may be only 20% to 70% of the national average ambient level in the U.S. (about 14 Bq/m3) while grade-level exhaust may contribute 1.8 times the ambient average. The grade-level contribution would drop to only 0.18 times ambient if the exhaust were 3,700 Bq/m3. Wind tunnel tests of exhaust dispersion outdoors suggest that grade-level exhaust can contribute mean concentrations beside houses averaging 7 times greater than exhaust at the eave, and 25 to 50 times greater than exhaust midway up the roof slope. With 37,000 Bq/m3 in the exhaust, the highest mean concentrations beside the house could be less than or equal to the ambient background level with eave and mid-roof exhausts, and 2 to 7 times greater than ambient with grade exhausts.
KEYWORDS radon, soil, depressurisation

#NO 9277 Flow resistance and wind performance of some common ventilation terminals.
AUTHOR Welsh P A
BIBINF UK, Building Research Establishment, BRE, March 1995, BRE Information Paper 6/95, 3pp, 1 fig, 2 tabs, 1 ref.
ABSTRACT States that terminals are often fitted to chimneys, flues and ventilation exhausts specifically to increase air movement and prevent wind-induced flow reversal. Discusses the performance of several terminal designs. Notes that such information can be used as a basis for system designers to select terminals for particular applications, ensuring terminal behaviour is to system requirements. States this matching should lead to more efficient mechanical ventilation systems, passive stack systems with greater air-moving capabilities and chimneys and flues that are protected against flow reversal. The data may also be used by terminal manufacturers as a comparison test.

KEYWORDS air flow, wind pressure, air movement, mechanical ventilation

#NO 9278 Testing the performance of terminals for ventilation systems, chimneys and flues.
AUTHOR Welsh P A
BIBINF UK, Building Research Establishment, BRE March 1995, BRE Information Paper 5/95, 4pp, 3 figs, 4 refs.
ABSTRACT States that terminals are often fitted to chimneys, flues and ventilation exhausts specifically to increase air movement and prevent wind induced flow reversal.
KEYWORDS chimney, flue, ventilation system, air movement, wind

#NO 9380 Free-standing ventilation terminals: testing and rating.
AUTHOR Welsh P
BIBINF UK, Building Serv Eng Res Technol, Vol 16, No 4, 1995, pp 189-198, 14 figs, 1 tab, 12 refs.
ABSTRACT Terminals on the exhausts of all types of ventilation systems alter system performance as they interact with the exhaust flow and the wind. They cause a pressure loss and the wind may either assist the exhaust flow, cause a resistance or even flow reversal. The precise effects depend on terminal design, exhaust flow rate, wind speed, wind angle and wind direction. This paper discusses a suitable test procedure and rating method which allows terminals to be selected on a basis of performance. The widely varying performance of some popular designs is discussed. The results indicate those terminals that may cause flow reversal, that have good extractive qualities and that have high resistive properties.
KEYWORDS ventilation system, exhaust, wind speed

#NO 9547 Design criteria of ventilation for healthy buildings.
AUTHOR Seppanen O
BIBINF Healthy Buildings 95, edited by M Maroni, proceedings of a conference held Milan, Italy, 10-14 September 1995, pp 215-238, 10 figs, 6 tabs, 38 refs.
ABSTRACT The purpose of ventilation is to maintain and improve air quality in a building by removing polluted air and supplying fresh air. In principle, the required ventilation rates for desired air quality can be calculated if the pollution loads, outdoor air quality and requested indoor air quality are known. This method is often referred to as an air quality method in ventilation design. A European prestandard Ventilation for Buildings - Design Criteria for the Indoor Environment outlines such a method. The data for the application of the standard is rapidly accumulating through extensive measurements and is soon available for the general application in ventilation design. Because the data are not yet completed for practical use, additional prescriptive requirements and criteria have to be used in the design of ventilation systems. These criteria include such aspects as the selection of ventilation strategy, ventilation rates, balancing of airflows, ventilation effectiveness, local exhaust systems, cleaning of intake air, location of air intakes, cleanliness of equipment, air recirculation, air tightness, noise control and demand controlled ventilation. The reasoning behind these requirements is presented and discussed in the paper.
KEYWORDS building design, health

#NO 9583 The impact of outdoor air intake rate on the indoor air quality of office buildings located in metropolitan areas.
AUTHOR Sohn J-Y, Yee J-J, Moon H-J, Song K D
BIBINF Healthy Buildings 95, edited by M Maroni, proceedings of a conference held Milan, Italy, 10-14 September 1995, pp 1401-1406, 6 figs, 3 tabs, 5 refs.
ABSTRACT Recent rapid increases in global atmospheric contamination levels, especially in metropolitan areas, lead to high attention to indoor air qualities in commercial buildings located in the polluted areas. One of the most common methods to provide office workers with a clean and comfortable indoor air environment is ventilation, in which a certain portion of the return air from the interior spaces is replaced by outdoor air in the air handling unit (AHU). Indeed, ventilation is the most effective method of maintaining a high quality indoor air environment when the outdoor air is fresher than the indoor air. However, ventilation usually causes higher energy consumption in HVAC system due to the temperature and humidity controls with the raw outdoor air. Therefore, it is a key objective of this field study to identify the impact of outdoor air intake rates at the air handling units on the indoor air contaminant levels in commercial office buildings especially located in metropolitan areas. A total of four commercial office buildings located in Seoul, Korea and Tokyo, Japan were selected for field measurements. The concentration levels of the indoor air pollutants were monitored at different outdoor intake rates and the odor and discomfort ratings were made by the occupants through questionnaire surveys.
KEYWORDS outdoor air, pollutant

#NO 9804 The design of ventilation systems of large enclosures with unconfined pollutant sources.

AUTHOR Fontaine J R, Rapp R
BIBINF Japan, proceedings of the 5th International Conference on Air Distribution in Rooms, Roomvent '96, held Yokohama, Japan, 17-19 July, 1996, Volume 3, pp 95-102.
ABSTRACT Indoor air quality of large enclosures containing unconfined pollutant sources is a really challenging problem. Local capture ventilation systems cannot be used because the contaminant source is either too large or even moving; available design principles for general ventilation systems are not very often applicable either, because they generally would lead to enormous air flowrates. It is the purpose of this paper to tackle this problem by using computational fluid dynamics methods. Two practical examples chosen in the domain of occupational health are presented. The first case concerns the ventilation of underground building sites of car parks. Here pollution produced by the earth movers is made of dust and diesel engines exhaust gases. In the second example a ventilated tunnel is used to protect the occupied zone of a large workshop from styrene vapours produced by the manufacturing of large fiber glass reinforced plastic pipes. For every example several ventilation strategies are tested, by performing numerical simulations of the resulting air and pollutants flow fields. In the second application a parametric study is carried out to optimise the design of the tunnel. Both cases have already been successfully implemented and tested on sites. All computer simulations are performed with the EOL-3D software developed at INRS. This paper shows that CFD is a real design tool for ventilation systems in complex industrial situations.
KEYWORDS large building, ventilation system, pollutant

#NO 9833 The effect of external atmospheric pollution on indoor air quality.
AUTHOR Kukadia V, Palmer J
BIBINF UK, Air Infiltration and Ventilation Centre (AIVC), 1996, proceedings of 17th AIVC Conference, "Optimum Ventilation and Air Flow Control in Buildings", Volume 1, held 17-20 September 1996, Gothenburg, Sweden, pp 41-53.
ABSTRACT This paper reports the findings of a pilot field study carried out to investigate the internal and external air pollution levels of two adjacent buildings, one naturally-ventilated and the other air-conditioned in an urban area, to investigate their relative attenuation of external pollution levels and to compare internal levels with existing air quality guidelines. Concentration levels of sulphur dioxide, nitrogen oxides, carbon monoxide and carbon dioxide were monitored, Simultaneously, measurements of ventilation rates within the buildings and periodic video recordings of the traffic were also carried out. As expected the concentration of external pollutants in the buildings followed the daily external variation, but at reduced levels. Generally, pollutant levels were higher in the naturally ventilated building than in the air-conditioned building. However, on a number of occasions, combustion products from heating boilers were entrained into the air-conditioned building via the high level air intake of the ventilation system raising the levels of nitrogen oxides, sulphur dioxide and carbon dioxide inside the building to higher than those found externally. A comparison of the results with existing air quality guidelines or standards for exposure showed that in both buildings the level of contamination was less than the relevant standard, except during a limited period at the weekend when combustion products were possibly entrained into the air-conditioned building. There is thus no clear distinction between the two types of ventilation strategies in terms of providing adequate indoor air quality to the occupants of the buildings.
KEYWORDS outdoor air, pollutant, ventilation rate, combustion product

#NO 9842 Modelling the influence of outdoor pollutants on the indoor air quality in buildings with airflow rate control.
AUTHOR Kraenzmer M
BIBINF UK, Air Infiltration and Ventilation Centre (AIVC), 1996, proceedings of 17th AIVC Conference, "Optimum Ventilation and Air Flow Control in Buildings", Volume 1, held 17-20 September 1996, Gothenburg, Sweden, pp 135-143.
ABSTRACT Low emitting building materials have contributed to the reduction of indoor air contaminants, and in many countries gas ranges and gas cookers are rarely used. As a result, in buildings located in urban environments, a considerable part of the contaminants in the indoor air may originate from the outdoor air. In urban areas buildings are exposed to high concentrations of a large number of contaminants, especially during traffic peak hours. Often, the air intakes are located on the facades, and if there are no filters, the supply air will have the same content of contaminants as the outdoor air adjacent to the buildings. Where if possible, it is advantageous to place the air intakes on the roofs of the buildings (1). The higher the air intakes are placed, the better is the air quality in most cases. To avoid exposure to high concentrations indoors due to concentration peaks of contaminants in the outdoor air, it is possible to decrease the airflow rate temporarily (2). This could be done by monitoring the concentration of carbon dioxide (CO) adjacent

to the air intake. When the outdoor concentration of CO exceeds a preset limit, the fans are simply switched off, or the speed of the fans are decreased to a more suitable level.
KEYWORDS modelling, outdoor air, pollutant, air flow, building material

#NO 9882 A control system that prevents air from entering an air-handling unit through the exhaust air.
AUTHOR Seem J E, House J M
BIBINF UK, Air Infiltration and Ventilation Centre, (AIVC), 1996, proceedings of 17th AIVC Conference, "Optimum Ventilation and Air Flow Control in Buildings", Volume 2, held 17-20 September 1996, Gothenburg, Sweden, pp 561-569.
ABSTRACT Traditional air-handling unit (AHU) control systems link the position of the exhaust air damper, recirculation air damper, and outdoor air damper. Tests at the National Institute of Standards and Technology (NIST) on a variable-air-volume (VAV) AHU have shown that air can enter the AHU through the exhaust air damper. This can negatively impact indoor air quality if the exhaust air duct is located near a pollution source. This paper presents a new control system for variable air volume AHU's that use volume matching to control the return fan. The new control system links only the position of the exhaust air damper and recirculation air damper. During occupied times, the outdoor air damper is in the fully open position. Simulation and laboratory results are presented to compare the new control system and a traditional control system. Several cases are simulated to examine the effect of damper sizing and system load on airflow in AHU's. The simulations demonstrate that the new control system can prevent air from entering the AHU through the exhaust air damper for conditions that the traditional control system cannot. A case demonstrating the limits of the new control system to prevent this phenomenon is included in the simulation results. The laboratory results provide further evidence that the new control system prevents air from entering the AHU through the exhaust air damper for conditions that cause the phenomenon with the traditional control system.
KEYWORDS air intake, indoor air quality, outdoor air

#NO 9928 Carbon monoxide dispersion in residential buildings: literature review and technical analysis.
AUTHOR Persily A K
BIBINF USA, National Institute of Standards and Technology, Building and Fire Research Laboratory, October 1996, 71pp, refs.
ABSTRACT Carbon monoxide (CO) detectors are being used increasingly in residential buildings to warn occupants about CO concentrations that could potentially cause acute health effects. While the use of CO detectors can decrease the likelihood of exposure to such CO levels, questions exist concerning the installation of these devices in residential buildings, primarily with regards to the location and number of detectors. Efforts to develop installation guidance and standards have been faced with these questions of location, and the availability of technical information to support the development of installation recommendation has been questions. As the first task of a project to analyze the distribution of CO in residential buildings as it relates to the installation of CO detectors, a literature review and technical analysis was conducted to assess information on CO dispersion in residential buildings that could support the development of guidance on detector installation. The review covered a number of issues including CO concentration measurements in residential buildings, sources of indoor CO, mixing within and between rooms, tracer gas techniques for assessing building airflow, and computer models of air movement and contaminant dispersal in buildings. The material obtained in the literature review is discussed, and a technical analysis of the issues related to CO dispersion in residential buildings is presented.
KEYWORDS carbon monoxide, residential building

#NO 10046 Effect of the external air pollution on indoor air quality and selecting mechanical ventilation system.
AUTHOR Kajtar L, Banhidi L
BIBINF Indoor Air '96, proceedings of the 7th International Conference on Indoor Air Quality and Climate, held July 21-26, 1996, Nagoya, Japan, Volume 2, pp 211-216.
ABSTRACT External air quality has a direct effect on the quality of indoor air in rooms of natural ventilation whereas in air-conditioned rooms it defines the ventilation system (e.g. filter type) to be selected. We have performed on-spot measurements to study the dust pollution of air in the inner city of Budapest of moderate traffic and in walking areas of no motor vehicle traffic. Based on the measurement results we have evaluated air quality and efficiency of the filtering stages to be applied by climate centres in view of the annual filter replacement costs.
KEYWORDS indoor air quality, mechanical ventilation,

#NO 10305 Air pollution levels inside buildings in urban areas: a pilot study.
AUTHOR Kukadia V, Palmer J, Littler J, Woolliscroft R, Watkins R, Ridley I
BIBINF UK, CIBSE, 1996, proceedings of CIBSE/ASHRAE Joint National Conference Part Two, held Harrogate, 29 September - 1 October 1996, Volume 1, pp322-332.
ABSTRACT This paper reports the findings of a pilot field study carried out to investigate the internal and external pollution levels in two buildings, one naturally-ventilated and the other airconditioned and to investigate their relative attenuation of external pollution levels. The study is a precursor to more extensive studies aimed at providing guidelines for the design of energy-efficient buildings with a good indoor environment in urban areas. Concerns about energy usage and CO2 emissions from buildings require that adequate indoor air quality is obtained in an optimal manner within low-energy design criteria. There is thus an increasing number of buildings employing natural ventilation strategies. At present, however, little is known about the interaction between indoor air quality and external air pollution. Therefore, no formal guidelines exist on designing for natural ventilation in nondomestic buildings in urban areas with respect to external air and noise pollution. The buildings investigated were adjacent to one another and located near a major road in a city centre where the local air pollution levels were known to be relatively high. During the study, concentration levels of typical urban pollutants, such as sulphur dioxide, nitrogen oxides and carbon monoxide were monitored. Concurrently, measurements of carbon dioxide, ventilation rates, humidity and temperature within the buildings including some measurements of noise and particles were also carried out. Analysis of the data reveals a number of interesting points. The concentrations of external pollutants in the buildings follow the daily external variation, but at reduced levels. Generally, pollutant levels were higher in the naturally ventilated building than in the mechanically ventilated building. However, on a number of occasions, combustion products from heating boilers were entrained into the air-conditioned building via the high level air intake of the ventilation system. This raised the levels of nitrogen oxides and carbon dioxide inside the building to higher than those found externally.
KEYWORDS outdoor air, pollutant, natural ventilation

#NO 10406 Relationships between indoor and outdoor air quality in four naturally ventilated offices in the United Kingdom.
AUTHOR Phillips J L, Field R, Goldstone M, et al
BIBINF UK, Atmospheric Environment, Vol 27A, No 11, 1993, pp 1743-1753, 4 figs,7 tabs, refs.
ABSTRACT Three offices in central London and one at a rural location were characterized with respect to air quality. All four offices were naturally ventilated. The characterization was supplemented by using a mobile laboratory to monitor the outdoor air quality. Results indicate that indoor pollutant concentrations may be up to 80% of the concentration outdoors but can greatly exceed outdoor concentrations. Additionally, it has been shown that indoor pollutants usually follow outdoor pollutant trends at lower levels, with only a small time delay due to mixing and dilution factors. The interaction between indoor and outdoor air is discussed with respect to ventilation characteristics and pollutant sources. A comparison between actual and modelled carbon dioxide levels may provide a useful indicator of ventilation.
KEYWORDS natural ventilation, outdoor air, indoor air quality

#NO 10409 Particle physics.
AUTHOR Kukadia V, Palmer J
BIBINF UK, Building Services Journal, May 1997, pp 29-31, 5 figs, 1 tab, 11refs.
ABSTRACT Considers whether air conditioned buildings are better at filtering out external pollutants than naturally ventilated buildings, and reports the results of a study carried out by researchers at the UK Building Research Establishment, which ultimately showed that there is no clear distinction between the two ventilation strategies in providing adequate indoor air quality with respect to externally generated air pollutants, other than when combustion products were entrained into the air conditioned building. The study highlighted a real need to address issues related to external air pollution and its sources, and the ways in which they affect the internal environment of buildings in urban areas whatever ventilation strategy is used.
KEYWORDS air conditioning, natural ventilation

#NO 10426 Volatile organic compounds in office buildings. 2. Identification of pollution sources in indoor air.
AUTHOR Lagoudi A, Loizidou M, Asimakopoulos D
BIBINF Indoor and Built Environment, No 5, 1996, pp 348-354, 2 figs, 6 tabs, 25 refs.
ABSTRACT A great number of volatile organic compounds (VOCs) are found in the indoor air of office buildings, emitted mainly by the

building materials, the consumer products used, the furnishing, office equipment, smoking, mechanical ventilation systems and outdoor air pollution. An attempt has been made to identify the strongest sources of VOCs in the indoor and outdoor air of six office buildings in Greece. Analysis of the results showed that the VOCs in the outdoor air were strongly related to the traffic in the area. Correlation of the concentrations found in both the indoor and outdoor air showed that the outdoor air contributes significantly to the chemical pollution load of the indoor air in some of the buildings. Also, a significant intercorrelation was found among the concentration patterns of aromatic and a number of aliphatic compounds, which showed that these compounds were emitted by similar sources. However, since these compounds are not emitted exclusively by car exhausts, the identification of their source is difficult. The dominant indoor sources of VOCs were permanent ones such as building materials and furniture.
KEYWORDS organic compound, office building

#NO 10759 Laboratory ventilation work book.
AUTHOR Burton D J
BIBINF USA, D Jeff Burton, 1994, 350pp.
ABSTRACT Summarizes laboratory ventilation issues. Topics include air behaviour, management of laboratory ventilation systems, chemical laboratory fume hoods, glove box hoods, perchloric acid fume hoods, biosafety cabinets, hazardous chemical materials labs, testing of lab ventilation systems, usefulness of hood static pressure, standards and codes, air supply and HVAC systems, placement of stacks, exhausts and inlets, general exhaust and dilution air equations, design of lab fume hood duct systems, and fans.
KEYWORDS laboratory, ventilation system, fume hood

#NO 10947 Design criteria for air filtration in general industrial ventilation.
AUTHOR Hagstrom K, Hiltunen M, Holmberg R, Lehtimaki M, Niemela R, Railio J, Siitonen E
BIBINF Belgium, Proceedings of Clima 2000 Conference, held Brussels, August 30th to September 2nd 1997, paper 345, 2 figs, 2 tabs, 4 refs.
ABSTRACT There has been lack of fact-based knowledge for design and operation of supply-air filters for general industrial ventilation. A multi-company project within the Industrial Ventilation (INVENT) technology programme was started in 1994 to tackle this problem area which is assumed to be the most problematic one, according to the feedback from end-users in several industries, who also made the initiative to this project. The main objectives of the project were to clarify a methodology for control of particulate contaminants in industrial premises, and to define the basic criteria for design and optimal selection of supply and recirculation air filters. This methodology will take into account outdoor air quality, desired indoor air quality, emissions from the processes and cleaning of ductwork and equipment. The first stage of the project, finalized in the end of 1995, included state-of-art surveys, preliminary case studies and a preliminary proposal for the filter performance classification. The second stage, currently ongoing, will include validation of the existing knowledge by laboratory and field tests, development of an expert system for filter selection, and draft contributions to the international Design Guide Book for Industrial Ventilation (DGB).
KEYWORDS industrial building, filtration

AIVC Air Infiltration and Ventilation Centre

The Air Infiltration and Ventilation Centre provides technical support in air infiltration and ventilation research and application. The aim is to promote an understanding of the complex behaviour of air flow in buildings and to advance the effective application of associated energy saving measures in both the design of new buildings and the improvement of the existing building stock.