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VENTILATION HEAT LOSS OUTSIDE IN

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VENTILATION HEAT LOSS OUTSIDE IN

In this paper we hope to demonstrate the present importance and future implications of ventilation heat loss in domestic premises. Having stated and amplified the problem we will discuss, firstly, the mechanisms and pathways of ventilation, secondly, ways of controlling ventilation, thirdly, ways of measuring ventilation rates by both manual and automated methods.

In conclusion we shall discuss some experimental results obtained in the SEGAS Test House particularly those relating to the impact of mechanical ventilation systems on the house ventilation rate. Along the way relevant literature will be reviewed and the essential minimum number of definitions necessary for mutual understanding will be given.

TERMINOLOGY

To assess ventilation heat loss it is essential to know the ventilation rate. Throughout this paper ventilation rate means - THE RATE AT WHICH AIR ENTERS THE DWELLING FROM OUTSIDE this is sometimes known as the Fresh Air Infiltration rate. Some confusion arises over the term Air Change Rate. Ventilation Rate and Air Change Rate are synonymous in a single celled dwelling. In a multi-celled dwelling the air in any cell may change because of its interaction with another part of the dwelling in addition to or to the exclusion of its interaction with the outside air.

We designate as natural ventilation - ventilation induced by natural forces, wind effect, stack effect etc. Mechanical ventilation is that produced by mechanical means.

The IHVE Guide (1) in common with the ASHRAE handbook of fundamentals (2) defines infiltration to be ventilation through gaps and cracks in the structure and natural ventilation to be the change of air within an enclosure without the interference of the inhabitants, or inhabitant induced air infiltration. These varying definitions can cause confusion in the literature of the subject.

Having defined ventilation, heat loss remains misleading. The heat lost is determined by the volume of air that leaves the dwelling multiplied by the average internal-external temperature differential and the specific heat of air. The manifestation of the heat loss is as the increased loading placed upon the central boiler or the individual emitters in a heating system, which must supply heat to warm the air which enters the dwelling to replace or eject that which was lost. Locally concentrated air infiltrations, draughts, or excessively ventilated rooms may affect heating system controls.

Paraphrasing Newton and ignoring volume corrections we can say "what goes out comes in". Ventilation heat loss is better appreciated as ventilation heat loading. We shall see later that most common methods of measuring ventilation rate involve determining "What comes in". We shall see later too that air often enters the lower floor of a two-storey dwelling and leaves by the upper floor. The incoming air needs to be heated to average downstairs temperature. The positive factor is that in leaving by the generally cooler upper rooms the heat demand from the upstairs emitters is lessened. The negative aspect is that should the control system not be able to benefit from this, the upper rooms may overheat.

A knowledge of ventilation rates is essential in designing a heating system since if design temperatures cannot be maintained due to excessive ventilation then ventilation heat loss becomes uncomfortably understandable.

THE IMPORTANCE OF VENTILATION HEAT LOSS

We are concerned here with houses rather than flats or tower blocks. Houses constitute about 80% of the total dwellings. The heating of houses consumes roughly one eighth of the Nation's annual energy output. It is instructive to consider the magnitude of ventilation heat loss using as our guide the Building Research Establishment figures in Digest 190, "Heat Loss from Dwellings". This calculation assumes a typical detached house with typical U values for floors, walls and ceiling and assumes average prevailing weather conditions. The mean outside/inside temperature differential is taken to be 7°C.

With these assumptions the total fabric heat loss, FHL, is 55 GJ. Assuming a ventilation rate of 2 per hour, the ventilation heat loss, VHL, is 21 GJ. This represents a probable worst case of an exposed house since ventilation rates are more normally around 1 h^{-1}. In most parts of the country the sun, though not always clearly visible, does aid the heating process. An average heating season solar gain is 15 GJ. Under these circumstances VHL constitutes 34% of the total.

Insulation of the loft space brings a reduction in FHL of 9 GJ and so raises VHL to 40% of the total. Cavity insulation can save 17 GJ per season and raise VHL to 60% of the total. Lastly, double glazing throughout our typical house further reduces FHL by 7GJ and elevates VHL to 75% of the total heat loss of the dwelling. Even if we reduce the ventilation rate to 1 h^{-1} in our super insulated typical house VHL is still 59% of total heat loss.

As energy consciousness grows and standards of insulation improve ventilation heat loss assumes an ever greater importance.

Because VHL is such a large contributor to the total energy demand for low energy houses then any assessment of its magnitude depends on a secure knowledge of the ventilation rate. This can be obtained by guess work, prediction or measurement. Prediction techniques need measurements for validation and measurements need predictions for guidance. Our work at SEGAS is concerned with assessment of ventilation, whilst at Watson House our values along with others are used to refine predictive techniques (3).

To understand ventilation heat loss an important pre-requisite is to understand ventilation rate. The rest of this paper illustrates attempts to do this.

NOT THE PROBLEM

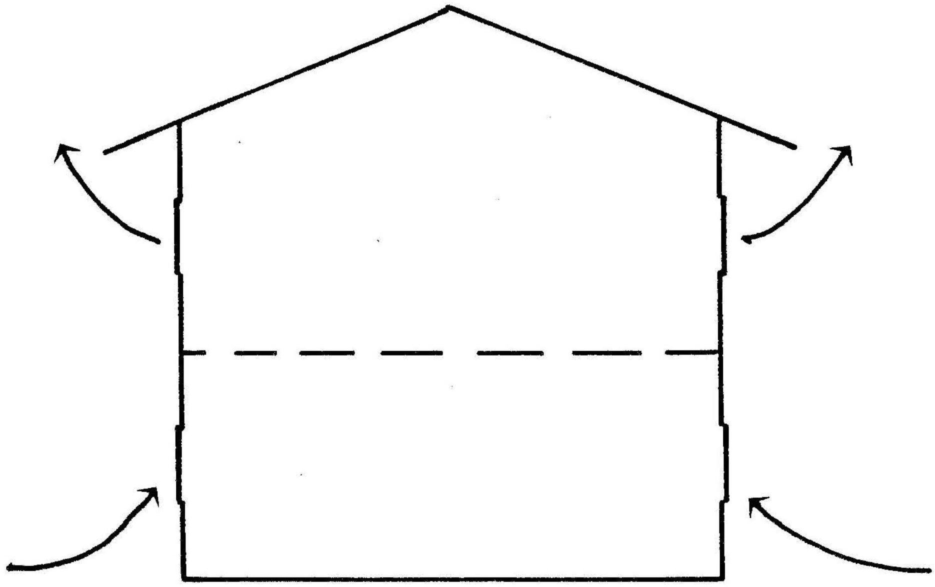
Ventilation is necessary for the quality of the indoor environment. Fresh air ensures the safe operation of gas burning appliances and contributes to the health, safety and comfort of the building occupants. In Sweden ventilation is needed to reduce the level of radio-activity from concrete used in buildings (4). Ventilation controls the level of indoor pollutants, bodily odours, cigarette smoke, water vapour. We are not concerned, in this paper, with ventilation to meet these needs or with Regulations or Recommendations regarding the provision of ventilators.

MECHANISMS OF VENTILATION

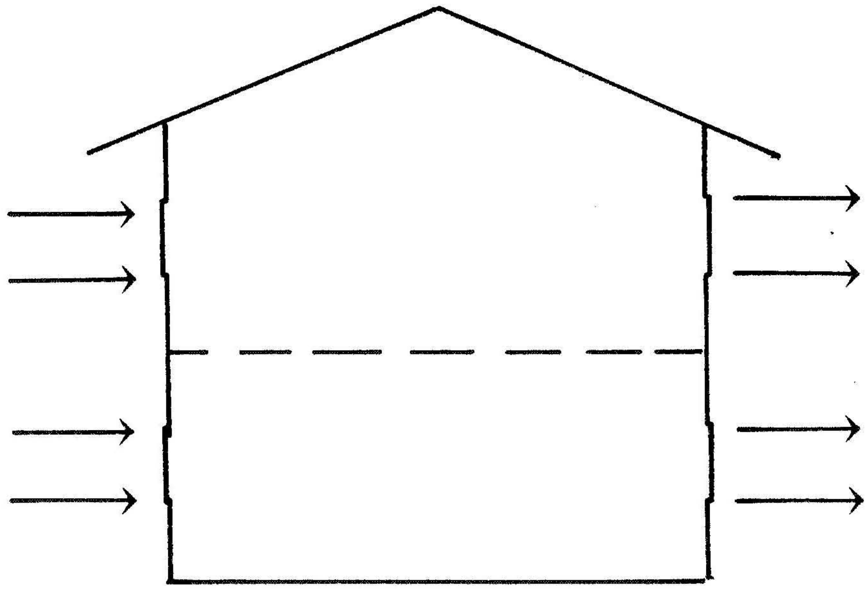
Flow results from pressure differences and these arise from 2 principal causes. Firstly, the stack effect, bouyancy effect or temperature differential effect which is due to the mass difference of an equivalent column of air at the mean internal temperature and the external temperature. The generated pressure is a function of the temperature difference and the vertical height of air column between lower and upper openings. The stack effect may operate within a room if openings exist near floor and ceiling level. Stack effect causes air to enter the lower floor and leave the upper floor. This is illustrated in Figure 1.

Secondly, the wind effect. The pressure in this case arises from the mean velocity of air impinging on the building surface. The pressure is proportional to the squared velocity. The flow of air around a building is complex but reasonably similar for all wind speeds so the pressure can be expressed in the form of a coefficient, Cp. The value of Cp depends on the

VENTILATION MECHANICS - SCHEMATIC REPRESENTATION

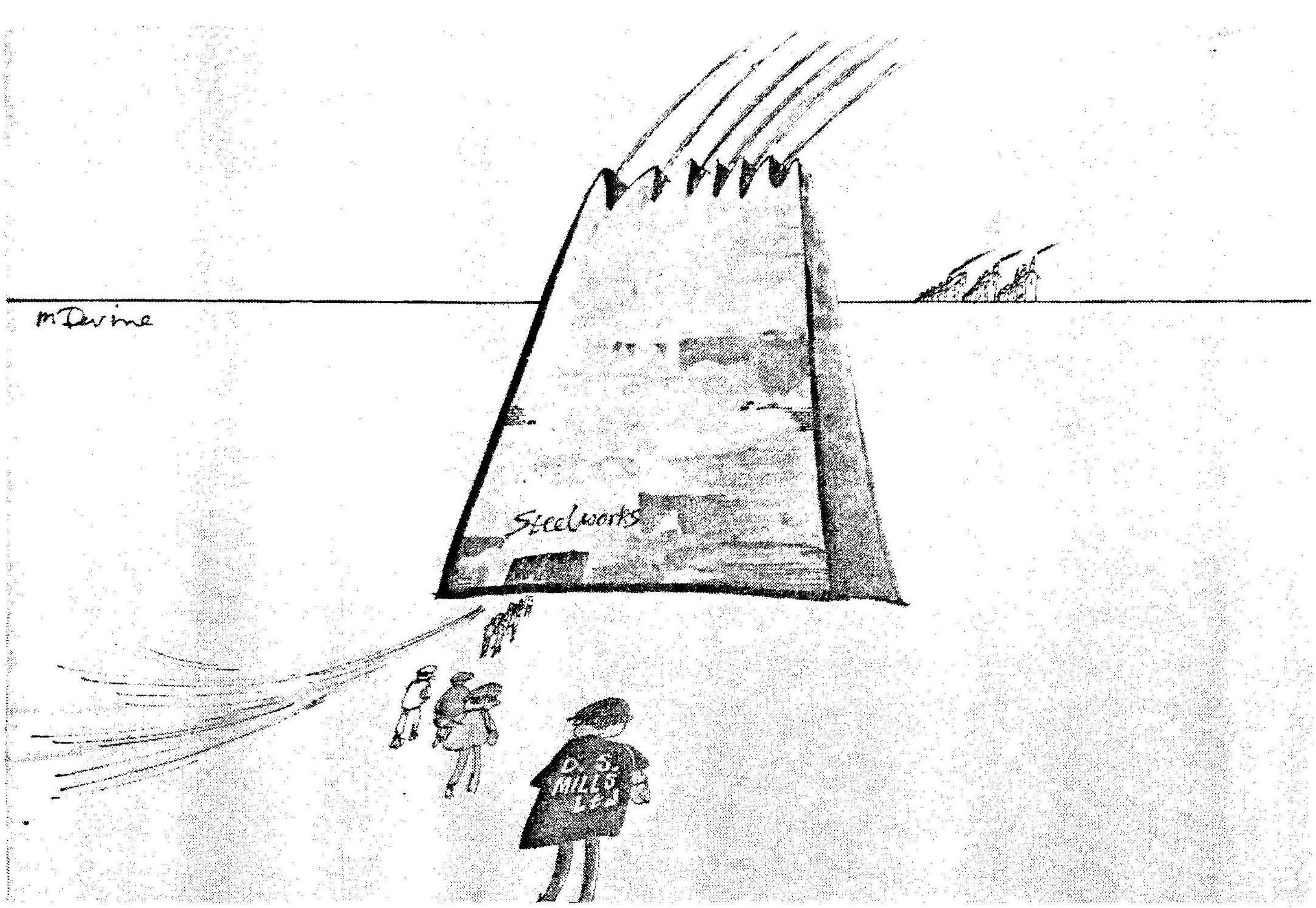


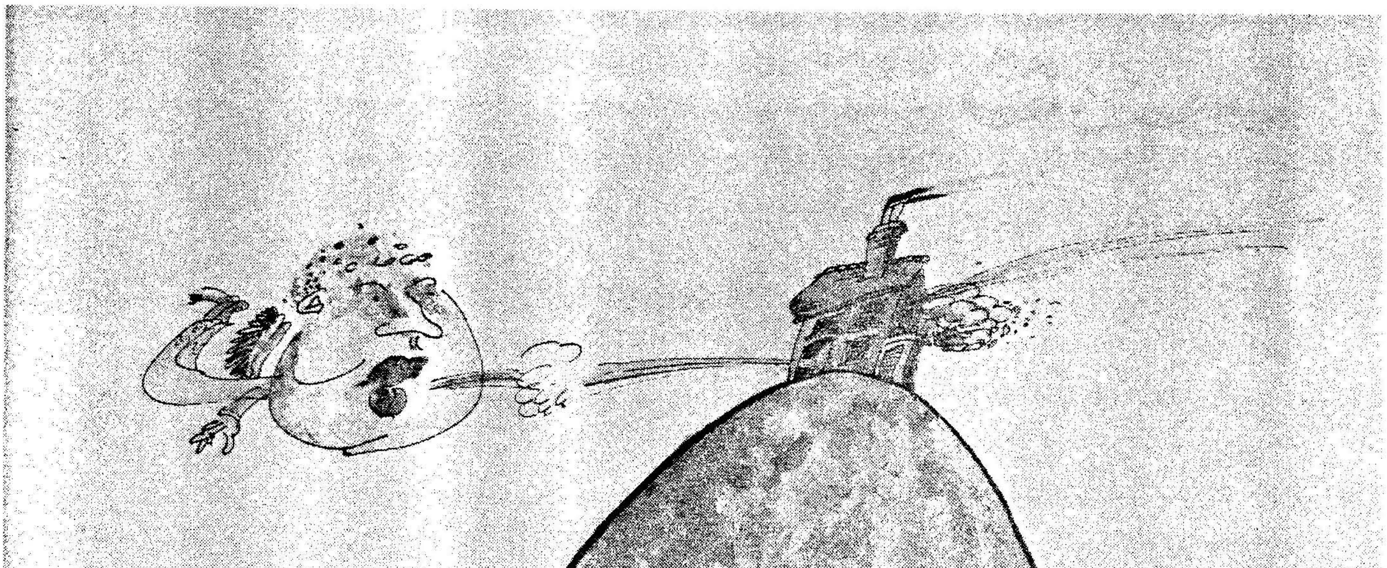
THE STACK EFFECT



THE WIND EFFECT

FIGURE 1


Steelworks



wind direction and the degree of shelter or exposure of the site. The wind effect causes air to enter the house through openings on the windward side and to leave through openings on the leeward. Any obstructions between, such as internal doors will only interfere with this process if the openings around them are small compared with the external ones. In general internal doors fit loosely.

In reality the wind and stack effects act in concert and tend to enhance and yet oppose each other. On the lower leeward and upper windward sides they oppose, on the lower windward and upper leeward they enhance. At the positive extremes of either effect it dominates the ventilation mechanisms. At low wind speeds, ventilation is virtually independent of wind speed. It is difficult to switch off the weather but by building a house in an environmental chamber it was shown that stack effect was, in the absence of wind, proportional to temperature differential, but that at zero differential the ventilation was small but non-zero ([5]).

There is an other ill-investigated and unquantified mechanisms of ventilation. This is due to the turbulent nature of air flow near building openings, which causes instantaneous pressure differences arising from the varying nature of the wind. This may be illustrated by the example of a terrace of houses with the wind along the terrace. The pressure coefficients on the two faces are identical but instantaneous fluctuations in pressure cause flow into and out of the houses.

PATHWAYS OF VENTILATION

In this section we look at the nature of the openings through which flow may occur into or out of the house.

The types of openings fall into the following categories:-

Flues	- brick chimneys, flues for gas appliances, water heaters, boilers etc.
Purpose Provided Ventilators	- such as those installed to meet Building or Gas Safety Regulations
Gaps Around Room Openings	- doors, windows etc.
Background Areas	- cracks in the building fabric gaps around electrical conduits, service pipes, skirting boards, ill-fitting joists, etc.

In this country we are the victims of our own history and traditions, from fires in the middle of the floor through huge open fire places to brick chimneys and coal fires.

The ventilation induced by a heated chimney could be as high as 4 or 5 a.c.h.$^{-1}$, towards achieving this rate ill-fitting doors and windows made a great contribution. Without this large open area to ensure sufficient flow the coal fire could not function properly. In our energy-conscious times ill-fitting doors and windows are our inherited legacy. Our standards for new installations do not offer much hope, in contrast to our European neighbours (5). The Swedes are investigating the extreme of building their houses with an integral impermeable membrane and supplying all air requirements by mechanical means (7). Figure 2 compares the leakiness in a pressurisation test, of the SEGAS house to that of a Belgian, a Swedish house and the Swedish Standard 1978.

The vagaries of our climate dictate that during the middle months of the year, known euphemistically as summer, it may sometimes be necessary to open a window to increase the ventilation rate and counteract excessive solar heat gains. So we will, for some time at least, have openable windows with their unlegislated gaps, when closed.

Flues and chimneys ventilate by both wind and stack effects. They are normally terminated in regions of negative wind pressure so in general are outlet routes although exceptionally they may admit fresh air.

Purpose provided ventilators are usually sized to give a flow of air sufficient for the safe operation of a gas burning device or to reduce air-borne moisture to a satisfactory level or to control the quality of air within the house by diluting contaminants, body odours, carbon dioxide, cigarette smoke, etc., to acceptable levels.

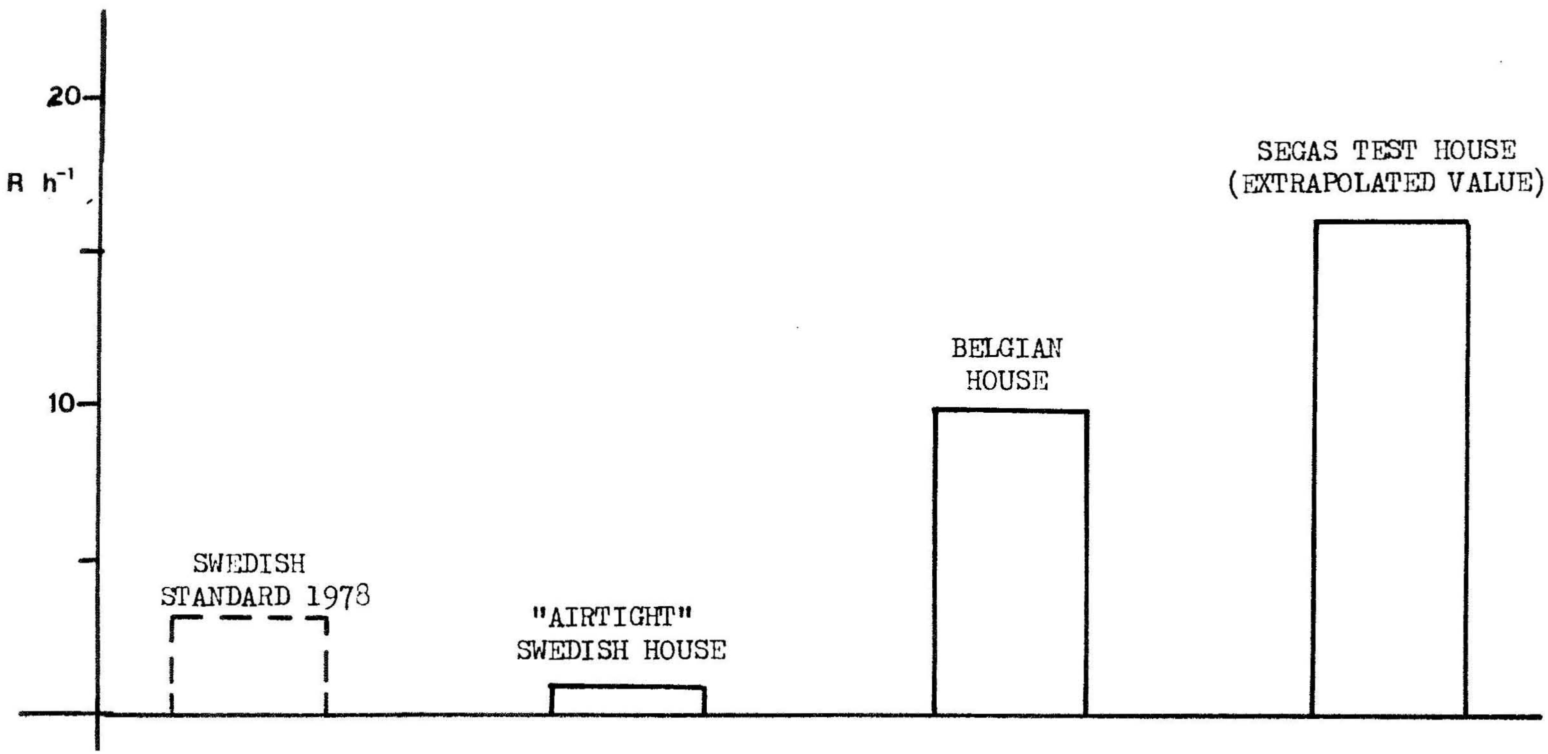
In houses without open flues an important contributor to the open area is the cracks around external openings. By external we mean those which communicate with the outside of the building or with freely ventilated spaces, such as the roof void.

By no means an insignificant contributor and sometimes a dominant one is the so-called background area. This is made up of hairline cracks in the structure which themselves may change with time, gaps around service pipes and electrical fittings. Other major background areas are associated with pathways from the sub-floor space or the wall cavity to the house. These include gaps between floor boards and around skirting boards and cracks or gaps around the ends of floor or ceiling joists. Some houses have solid walls and floors. In these cases the number if not the importance of background

FIGURE 2

THE LEAKINESS OF HOUSES DETERMINED BY PRESSURISATION AT 50 Pa

COMPARISON OF SEGAS TEST HOUSE, A BELGIAN HOUSE, A SWEDISH HOUSE AND THE SWEDISH REGULATIONS 1978



areas may be diminished.

It is customary to collect open areas together and to express them as an effective open area. This depends somewhat on the physical dimensions of the opening. The flow through openings depends on the nature of the openings. It is assumed for most purposes to be proportional to the square root of the applied pressure. This approximation improves with the size of the opening. Work at Watson House has led to the qualification of crack types and their quantification into crack flow equations.

CONTROLLING VENTILATION

Accepting that control of the weather is not yet possible the control of ventilation falls into two categories, the use of mechanical ventilation systems and the regulation of open areas.

Ventilators installed to comply with Safety Regulations must not be interfered with but the gaps around room openings may be. The BRE asserts that ventilation may be reduced by up to $\frac{1}{2}$ a.c.h^{-1} by sealing the principal external doors with proprietary foam strips. We ourselves have some quantitative information regarding the effect of sealing external doors and windows to which we will return later.

An alternative control philosophy is to use a mechanical system to supply air to and/or remove air from the house at the desired rate. Much of the recent work in the SEGAS Test House has been geared towards the evaluation of mechanical systems and their impact on the ventilation rate. We shall review this after a short digression to discuss methods of measuring ventilation rate.

VENTILATION RATE MEASUREMENT

As stated earlier, the assessment of ventilation heat loss must be founded upon a secure knowledge of ventilation rates. This section discusses briefly what we term manual methods of ventilation rate measurement,the final section will deal with the current trend towards automating these methods.

There are two basic methods of measuring air infiltration rates, air movement methods ([8]) and tracer gas techniques. The former, involve the measurement of the instantaneous air velocity at several points around the dwelling from which the pattern of air movement is determined and the ventilation rate inferred. The variations in methodology reflect the instruments used to measure air velocity.

The latter, tracer gas techniques can be divided into 3 types, rate of decay, equilibrium concentration and transfer index methods.

The transfer index method (9) determines the time integral of tracer concentration at a site distant from the release point of a known volume of contaminant. The reciprocal of the transfer index is the effective ventilation. The advantage of this method is that no assumption about mixing of tracer and room air is inherent. Indeed recirculation is specifically accounted. The disadvantages are many measurement points are needed to complete the picture and the tests are either of long duration or need continuous measurement of concentration at several points.

The equilibrium concentration method (10) involves the release of tracer gas at a fixed rate until equilibrium is reached. At this point the ventilation rate may be calculated from the release rate and the equilibrium concentration. If the mixing between the tracer and the room air is perfect then the equilibrium concentration will be equal at all points.

The advantage of this method is that a single measurement suffices if the mixing is perfect. The disadvantages are that a long time is essential to the attainment of equilibrium so that problems may arise regarding the control of the tracer flow rate. It is difficult to guarantee steady weather conditions throughout the test duration.

The rate of decay technique has been widely used. The reason for this being the quite detailed information which may be extracted from a tractable technique. The test space, anything from a room to a whole house, is first filled with a uniform concentration of tracer. The change of tracer concentration with time is determined by discreet or continuous sampling techniques.

In a test space, where, all the air change is due to the infiltration of fresh air, the tracer used is not abundant in the atmosphere, the mixing is perfect and the weather conditions are stable, the ventilation rate can be obtained from the relationship

$$C(t) = C_0 e^{-Rt}$$

$C(t)$ is the concentration of tracer at time t

C_0 the initial concentration

R the air change rate

R is best extracted from a semi-logarithmic plot of concentration, relative, $C(t)/C_0$, or absolute, $C(t)$, in arbitrary units, against time. The negative of the slope is the air change rate

WHAT'S IN A TRACER?

The qualities needed for the ideal tracer gas are that it should be:-

- Easily detectable
- Not harmful in the concentrations used
- Similar in density and physical properties to air
- Inert
- Not present in the atmosphere
- Not adsorbed by the fabric of the test space
- Cheap and easily obtainable

No gas fulfills all these requirements but some are a good approximation and have found wide usage as tracer gases. The following table lists some of the commonly used gases, their methods of detection and references to further reading.

TRACER GASES

Tracer Gas	Detector	Reference
Hydrogen/Helium	Katharometer	11, 12
Carbon Dioxide/ Nitrous Oxide	Infra-red	13, 14
Sulphur Hexafluoride	Electron captive	15
^{85} Krypton, ^{41} Argon	Geiger tube	16
Methane/Ethane	Flame ionization/infra-red	17

TO MIX OR NOT TO MIX?

There are probably as many opinions about the benefits of mechanically mixing tracer gas and room air as there are people who make measurements. Most methods of analysis are simplified by uniformity of tracer concentration or rely on it.

In still air the mixing mechanism is diffusion which can be very slow and varies from gas to gas. In a ventilated room air currents will assist the mixing, in an heated and ventilated room thermal currents will add their contribution.

Without mixing it is possible for the tracer to become trapped at a particular level in the room air. If there is a temperature and thus a density gradient or if the tracer is unduly more or less dense than air the tracer gas may become stratified. If this occurred the measurement of tracer concentration would be a sensitive function of the location and type of sampling apparatus.

Some advocate the use of mixing fans to stir the house contents at the stage where the gas is first injected [18], others prefer to mix the air continually [19] and still others prefer the do nothing option [20]. This latter approach disrupts the natural pathways and interactions as little as possible. It is the most satisfying but least practicable approach. It resembles the old paradox, that you cannot know the taste of a pear without changing it by eating it. To measure the subtle movements of air into and out of a house one needs must affect them in order to know them with confidence. J.B. Dick [21], the pioneer of post-war ventilation research, was of the opinion that mixing fans were unnecessary. Our experience, to be related in the next section has tended towards the partial use of mixing fans.

Some advantages and disadvantages of mixing fans are summarized below:-

Advantages	Disadvantages
The tracer gas concentration is uniform and thus may be sampled at one point	The air flow paths are destroyed
Stratification is avoided	Streams of air may impinge upon room openings

Without the use of mixing fans it is necessary to sample the air in a room or house at many points to arrive at a mean concentration of tracer. Different parts of a room may be subject to different ventilation mechanisms and thus different rates. The use of a mixing fan gives a better average result but affects the ventilation rate in an unknown and unknowable way.

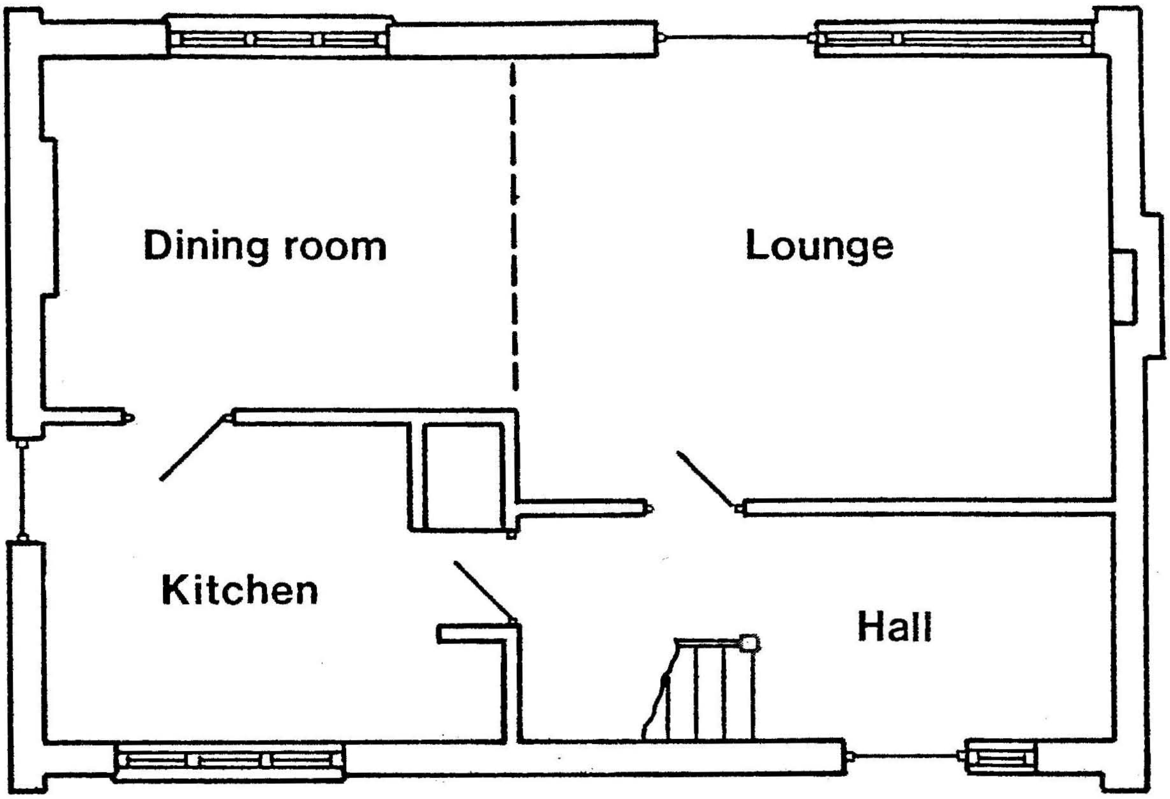
WHOLE HOUSE VENTILATION RATE MEASUREMENT

In this section we will review some of the experimental results obtained from the Segas Test House. We will re-cover much of the ground trodden so far putting examples to the generalities. We will discuss our methods of estimation of whole house ventilation rates and look at the effects of mechanical systems on that rate. We discuss, also, the necessity for sealing of room openings when mechanical systems are used and the effect of this sealing on air infiltration rates. The aim of the work was to measure the extent to which the mechanical ventilation systems modified the ventilation rate of the house.

THE SEGAS TEST HOUSE

This is a four-bedroomed town house of conventional construction about 10 years old. The ground floor is suspended above a cellar space but the boards, gaps around services and skirting boards have been sealed. The doors

GROUND FLOOR



FIRST FLOOR

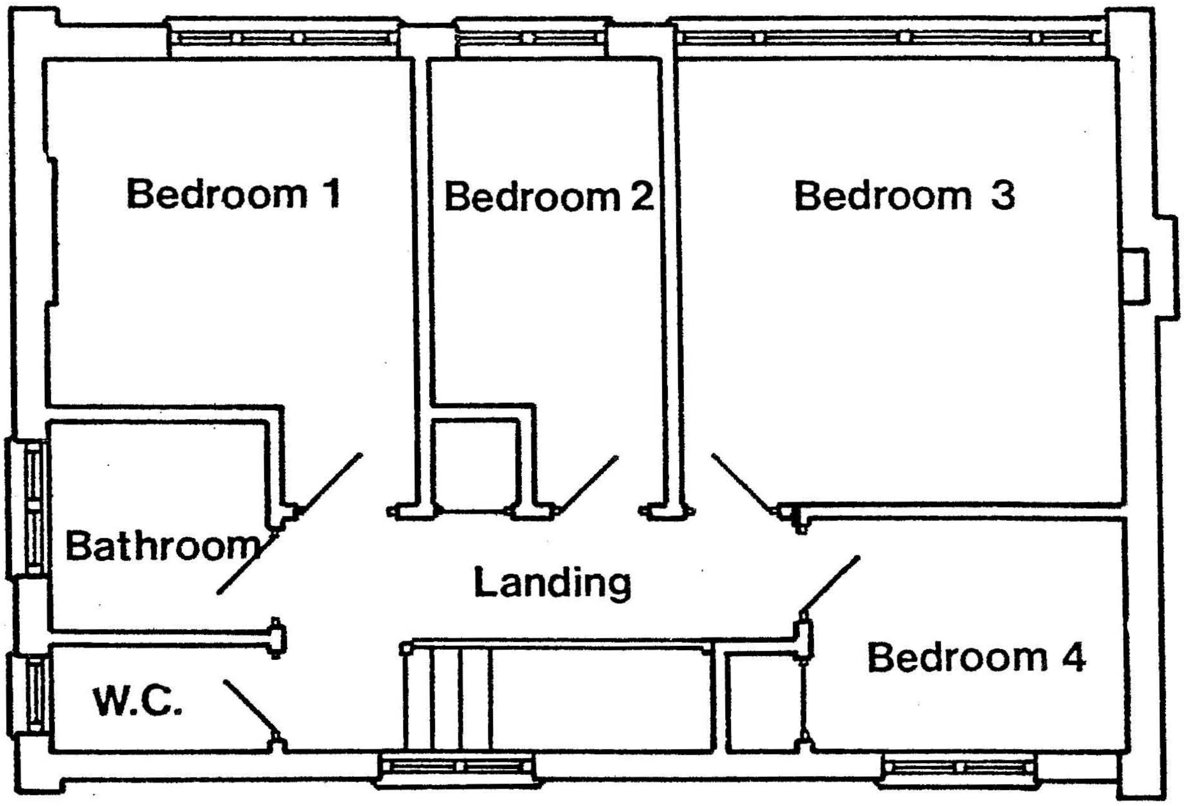


FIGURE 3 SEGAS TEST HOUSE PLAN

and windows are of a conventional type. The walls are 11" cavity construction. The basic heating unit of the house is a gas-fired boiler, the emitters are steel panel radiators. Figure 3 shows the plan of the house. The ground floor has entrance hall, kitchen and a lounge/dining room which may be partitioned. The upper floor contains the toilet, bathroom and 4 bedrooms.

The house is equipped with several ventilation systems:-

Extract System - drawing air from the bathroom, toilet and kitchen through adjustable registers. The fan is in the attic,

Supply System - supplies fresh air via an air handling unit in the basement through rectangular nozzles and out behind the radiators in all rooms, except the hall and those with extract registers,

Warm Air System - low pressure warm air semi-stub duct with outlets in all rooms. The air is heated via an heat exchanger in the basement.

MEASUREMENT METHODS

The technique employed was a tracer gas decay method using Helium tracer detected with a Katharometer (Cambridge Instruments).

To compute the whole house ventilation rate we needed to measure the individual room ventilation rates. We had 6 Katharometers and these were assigned to the most important rooms. In the remaining rooms samples of air were taken at discrete time intervals for later analysis. Sampling lines were located at the geometric centre of each room.

It was inevitable that a certain subjectivity should enter the choice of rooms in which continuous records of tracer gas concentration would be made. Our policy was to use Katharometers in the downstairs rooms and in the upstairs rooms on the windward side of the house. These being the rooms most likely to admit fresh air.

Helium was injected into all rooms to achieve a uniform concentration of about 0.5% throughout the house. Tests were continued for about 1 hour, 5 minutes of which was taken up by the mixing time and sampling time of the detectors. Mixing fans were used in the downstairs rooms.

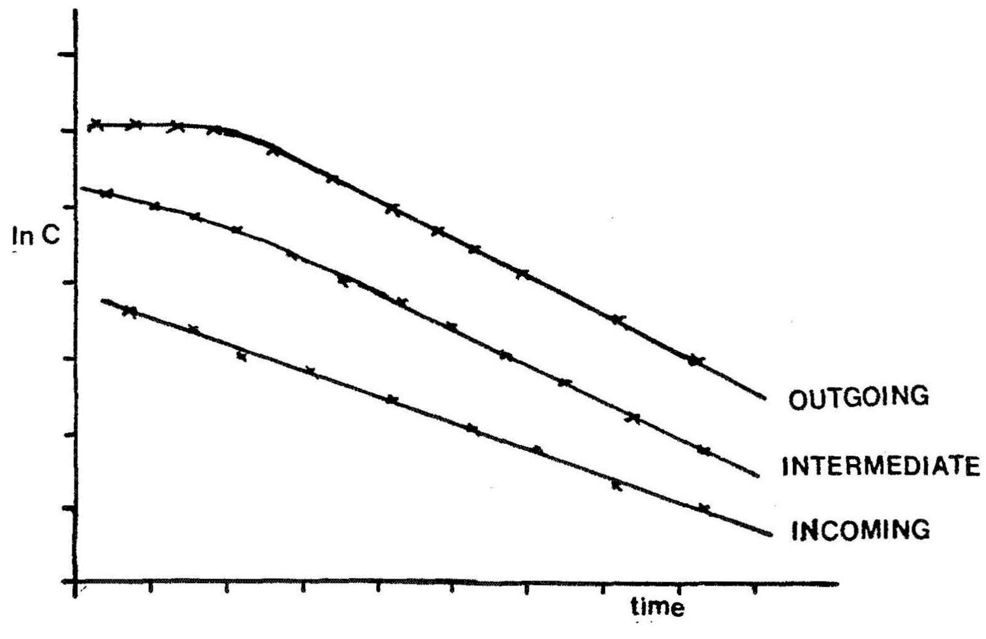
For each room a semi-logarithmic plot of concentration against time was produced. Two methods were then used to extract from these plots a figure to which could be ascribed the label, whole house ventilation rate.

Difficulty of analysis arose not with those rooms whose sole supply of air is from outside since the plot was linear with a slope the negative of the air infiltration rate, but with those rooms that were subject to varying ventilation conditions, sometimes admitting fresh air and sometimes constituting a pathway for outgoing house air. Those rooms that acted solely as outgoing routes were of no concern in calculating the ventilation rate since the fresh air is accounted for as it enters the house.

The two methods we used were: Firstly, to look at the wind direction, shape of the decay curve and smoke visualization tests to determine those rooms into which fresh air entered. If any doubt existed or if the room was of intermediate type, sometimes admitting fresh air, sometimes an outflow path, then it was included in the summation. This gave an upper bound. The second method was based on that of Dick ([21]). This method necessitates close attention to the first portion of the decay curve during which time the concentration of the tracer gas has not changed greatly from its initial value. For rooms with fresh air intake the semi-logarithmic plot is linear with a negative slope. For rooms that are outgoing the initial slope is zero since air coming from other parts of the house has the same concentration of tracer gas. As time passes the slope will reflect the average ventilation rate of those rooms that connect with it. Figure 4 shows some typical decay plots.

FIGURE 4

TYPICAL HELIUM DECAY PLOTS



By a series of tests such as these we measured the natural ventilation rate of the house in a variety of weather conditions. Some of the tests were done with the house in its natural state, some after the house had been draught-proofed by sealing the windows with tape and the front and back doors with proprietary foam strips.

THE EFFECT OF SEALING

The natural ventilation rates measured in the house after the application of the sealing measures when compared with the results for the unsealed house gave a direct measure of the effectiveness of the sealing measures. The range of values thus calculated showed that sealing the doors and windows reduced the ventilation rate by between 30 and 45%, the average reduction being 34%. This example illustrates the important contribution made by the background areas to the total open area of this particular house. It illustrates too, the dangers of 'calculating' ventilation rates for houses from a knowledge of the open area of doors and windows alone (1). The other important consequence of these findings is that the maximum reduction in ventilation rate that weatherstripping this particular house could produce was only 34%. To reduce it further it would be necessary and difficult to seek out hairline cracks and small gaps all over the house. In this house such additional measures are unlikely to be cost effective.

MECHANICAL SYSTEMS

Tests were done on three mechanical systems. These were, the supply system, balanced to give an house air change rate of about one per hour, the extract system, removing about 1 house volume per hour mostly from the kitchen and the combined supply and extract systems both operating at a rate of 1 h^{-1}. All 3 systems were tested on the house in its sealed and unsealed states providing further evidence on the efficacy of sealing and highlighting the need for stringent sealing to accompany the installation of a mechanical system.

Some very interesting results emerged from these experiments. A fuller analysis is to be given elsewhere [22] here the major conclusions are presented.

In general the measured ventilation rates for the mechanical systems were higher than the corresponding natural ventilation result under comparable weather conditions. The ventilation rates for all three mechanical systems were higher than the design rate. Of the 3 systems, the extract seemed to be the least unattractive. An ideal mechanical system would provide the design air change rate regardless of the weather condition. The extract system exceeded the design rate by the least, the combined supply and extract system exceeded the design rate by the greatest amount, sometimes by as much as 1.5 a.c.h.$^{-1}$. The combined system did not affect the pressure within the house and so its effect added on to the natural ventilation. The extract system tended to depressurize parts of the house and it remains surprising that it should be the best of the systems that were tested.

The results mentioned are preliminary and represent a minimal data base, but the overall trends remain valid. The results indicate that the problem of the interaction of a mechanical system with the natural ventilation is a complex process.

The earlier discussion showed some of the limitations of the tracer gas decay technique and some of its difficulties. To overcome some of these problems we devised an automated ventilation measureing apparatus which will be described at the end of the next and final section after a review of concurrent developments towards automating air infiltration measurements.

AUTOMATED METHODS

In this section we will discuss 3 automated methods of air infiltration measurement. The main impetus for automating ventilation measurement is the long time scale necessary fully to understand the effects of weather parameters and the labour intensive nature of the analysis of these results of tracer decay tests. Automated methods can reveal additional information and this is discussed below.

HONMA'S METHOD

Honma's Method (24) used CO_2 as the tracer gas and used it in the form of a solid. The dry-ice was heated by an electric hotplate so that the heat input and thus the gas release could be determined with some precision. The method was applicable to multi-cell dwellings. Equipment to produce and mix the CO_2 was installed in each room. Honma's experiments used a mixing fan at the outlet of the polystyrene box containing the solid CO_2 to ensure thorough mixing of the tracer gas with the room air. He also found it preferable to heat the CO_2 gas to a point at which its density was comparable to that of air to overcome a tendency to stratification. The concentration of CO_2 in each room was measured every 10 minutes. Honma's test space consisted of 3 rooms in a line, room 2 was the middle one.

Assuming a knowledge of the concentration at time t_1 and t_2 and the rate of gas production in room 2 in the time interval then the gas concentration in room 2 can be calculated as:

$$C_{22}.V_2 = C_{12}.V_2 + W_2.\Delta t + (C_{11}.\nu_{21} + C_0.\nu_{20} + C_{13}\,\nu_{23} - C_{12}.\nu_{02})\,\Delta t$$

where

C_{ti} is the concentration in room i at time t

V_2 is the room volume

W_2 is the gas production rate

ν_{ij} are the various flow rates into and out of the room.

Equations such as that above may be set up each time the concentration is measured. Together with continuity equations they may be treated as a linear system if the concentration measurements are made at short intervals and if the changes in concentration may be taken as linear.

In practice the equations must be reduced to a system of linear differential equations and solved by a computer program. The resultant of all this effort is the complete solution of the flow equations. From this we obtain not only the ventilation rate but also some idea of the cross-ventilation flows.

HARRJE, HUNT, TREADO, MALIK

Harrje et al [25] use SF_6 as a tracer gas and have automated the tracer gas decay technique. SF_6 is injected in controlled volumes at discreet time intervals and the rate of change of tracer gas with time is found by automatic sampling and measurement using a gas chromatograph and an electron capture detector. The timing sequence is provided by electronic cam timers.

CONDON, GRIMSRUD, SHERMAN, KAMMERUD

P.E. Condon and co-workers [26] have developed an automated controlled-flow air infiltration measurement system with the possibility of use to study, concentration decay, continuous flow in a single chamber and in a multi-cell dwelling. Their system is built around a microprocessor controller and uses Nitrous Oxide tracer gas and a Miran analyser.
The control strategy that is adopted is to adjust the gas flow rate to cause the concentration to move towards a range of target concentrations. The update interval from the microprocessor must exceed the mixing time of the test space to prevent resonance and other instabilities. They do not use mixing fans. The gas is injected in known quantities by releasing a calibrated dump volume of gas into the test space.

Assuming perfect mixing, the volume of the test space, V, times the change in concentration is the difference between the amount of tracer gas injected into the space, F, and the amount lost by exfiltration, VAC

$$V \frac{dC}{dt} = F - VAC$$

re-arranging this gives:

$$R = AV = \frac{F}{C} - \frac{V}{C}\frac{dC}{dt}$$

If the flow rate can be controlled to keep C constant, $\frac{dC}{dt}$ vanishes and the exfiltration rate is simply the flow rate over the concentration.

Having measured the exfiltration Rate, R, the effective volume of the space may be determined. In the absence of a measurement this is taken as the total volume less that of any cupboards, furniture, fittings,etc.

Re-arranging the previous equation we get:

$$V = \frac{F - CR}{dC/dt}$$

by adjusting F to cause a rapid change in C, then, dC/dt can have a significant value and V can be determined. This apparatus can thus be used to produce the mean ventilation rate and the effective volume of the test space. To date the system has been tested on a single-celled test space.

The automatic ventilation measurement apparatus that we are developing at SEGAS, as part of a project sponsored by WATSON HOUSE, is based on a similar principle to the system just described. We elected to use Nitrous Oxide as the tracer gas and to use Infra-red detection. In our case a Leybold Herraeus detector is used. The differences between our system and that previously described lie in; the scope of the system, the facility to perform multiple gas experiments and the computer control.

PRINCIPLE AND SCOPE OF THE SEGAS SYSTEM

The basic principle behind the method is to have a direct measure of ventilation rate rather than a subjective inferential one. To do this we maintain the level of Nitrous Oxide tracer gas constant throughout the test house. By this strategy the effect of air movement from cell to cell within the house is eliminated since all air in the house has an identical concentration of tracer gas. It is this movement of air within the house that renders uncertain the tracer gas decay technique. In the automatic control and measurement system that we are developing only the incoming fresh air is measured and indeed the air is measured only in the room whereinto it enters.

The volume of air entering each cell or room of the house is directly proportional to the volume of tracer gas that is injected to maintain the target concentration.

Our system can control tracer gas concentration and thus measure fresh air infiltration in up to 12 interconnecting rooms simultaneously. Gas is injected by way of a pressure equalizing manifold and through lines of equal length (and resistance) into each room. The control of gas concentration is effected by varying the duration of the injection period. This can be any whole number of seconds from 0 to 63. The room air is sampled through continuously purged lines on a 6 second cycle. Solenoid valves control the sampling and injection processes. The air supply lines are connected to the analyser through a 12-legged spider!

COMPUTER CONTROL

Our apparatus is controlled by a Mycalex Data Logger/Nova minicomputer system. The individual solenoid valves are activated by a command from the computer which operates an isolating relay to which the valve is connected. The sampling valves are opened, in sequence, for 6 seconds. The injection valve opening times are computed, using incorporated algorithms, from a knowledge of the present value of tracer concentration and the previous one.

Preliminary experiments with the system have shown that basic control strategy is sound at the time of writing we had just begun to record information on the effect of weather parameters on natural ventilation rates.

MULTIPLE GAS EXPERIMENTS

Single gas experiments based on controlling concentration can yield room ventilation rates or, by summation, whole house ventilation rates. The importance of cross flows can be ascertained from controlled injection experiments, like those of Honma, or from multiple gas techniques where more than one gas is injected into certain rooms. The primary tracer is used to determine the room ventilation rate and the secondary tracer to investigate the destination of air leaving the room. This type of experiment is to be used to determine the role of the loft space in house ventilation and could be used to ascertain flows from the ground floor to the first floor, or from one room to any other in the house.

THE FUTURE

This type of automated system has, we believe, a great future due principally to the ease with which one can produce a value for ventilation rate of any simple or complex space running from one room up to 12 inter-connecting rooms. There is no reason to stop at 12, although our experience would suggest that 12 is a reasonable upper limit. The ventilation rate obtained from using the system is available after 1 hour and a further result is available in every succeeding hour. The value of air infiltration is, based on a direct measurement, free of subjective assessment and bereft of unnecessary human labour.

IN CONCLUSION

We have shown the present and future significance of ventilation heat loss, discussed causes of ventilation and ways of controlling it.

Experiments performed in the SEGAS Test House have been reviewed. These have shown how mechanical ventilation systems affect the natural processes. In the last section we indicated the current trend towards automation and glimpsed some of the future benefits of using such automated systems in terms of the ease and accuracy of measurement.

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