Air
Infiltration
Review

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Buildings and the Environment

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This article is based on a keynote presentation made at the Royal Society of Medicine, London, 17th December 1990, on the occasion of the "First Invited Lecture" of Oscar Faber Applied Research, and describes the impact of research in IEA countries on Buildings and the environment.

Research is developing and pushing forward the frontiers of knowledge in how to develop, design, construct and operate buildings of the future; buildings which will be compatible with increasingly severe environmental constraints, and adapted to the needs of comfort and convenience of an increasingly demanding body of users.

"Buildings and the Envronment" is a very general title for a paper, and it is the intention of the author to interpret the word "environment" in a variety of ways. But in an attempt to introduce some order into such a potentially vast field of enquiry, it is suggested that we focus on just a few specific topics, the examination of which may help in presenting an international overview of the way Governments have been thinking, and should be thinking about the building sector in relation to their energy policies.

Firstly, the following points will be considered, which seem to be of particular relevance:

1) The evolution of government policies to save energy in buildings.

2) The forces influencing future policies.

3) The possible implications for the building industry.

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1. The Evolution of Government Energy-Related Policies on Buildings

Few people need reminding that out of the total OECD consumption of energy, nearly one fifth is dissipated in buildings of all varieties, essentially on space conditioning and lighting. In addition, the building industry absorbs the use of substantial energy in the manufacture of materials and products destined for construction. In 1973, 40% of energy consumption in the built environment was satisfied from oil-based products; by 1988 the proportion had shrunk to 25%. This of course, did not happen by accident. Market forces, or in plain language, higher oil prices played their part in inducing consumers to switch to other fuels, and to improve their energy "housekeeping" where this was feasible. But Government policies also played their part in a whole series of measures designed to raise public awareness of the need to save energy, and to provide the incentives and know-how to do so. The ultimate success of this effort can only be judged by the results, but here lies the dilemma; first, because relatively few mechanisms existed for follow up and verification of the *effectiveness* of Government measures at the level of the individual users (i.e. gathering information on how much energy they had actually saved through the tax rebates, grants and loans etc. from which they had benefited); and second, because the contribution of private initiatives for energy saving - partly through better housekeeping, partly through new investment - in the building sector largely remains unidentified. The theme of lack of information will be of further consideration later.

The member countries of the OECD can point with some pride to the substantial reductions they have achieved in reducing oil consumption, and in the amount of energy required to produce a unit of Gross National Product - the so-called "energy intensiveness".(See Figures 1 and 2.)

Given the significance of the residential/commercial energy consuming sector, some proportion of these reductions must be attributed to higher efficiency of buildings and to the effects of State intervention.

As an example of the situation in the UK, many people must be aware of Government energy-related policy developments on buildings over the years, but it might be worthwhile to attempt a short recapitulation. The Home Insulation Scheme to provide grants to owners and tenants for loft insulation and draught-proofing was of course, one of the first Government initiatives, and enjoyed a substantial measure of success while it was in force for all income groups.

We had Insulation Projects by local authorities for lower income groups, but by June 1989, over 600,000 homes had participated in this scheme.

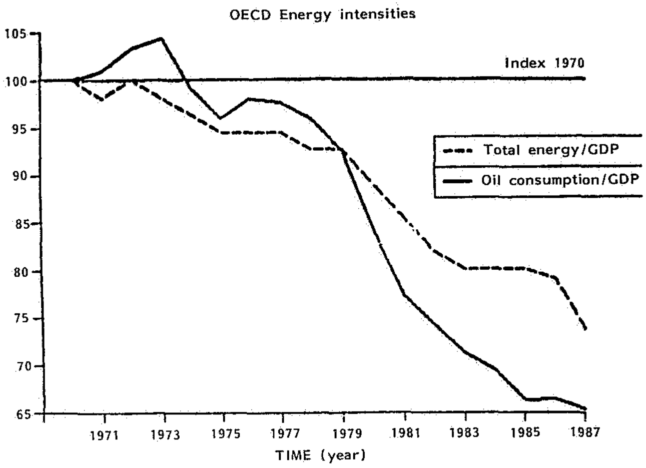

Figure 1:

We have a separate Government Agency and Development Corporation promoting an ambitious scheme for energy saving in housing at Milton Keynes Energy Park, northwest of London, where more than 1000 housing units are planned, fifty of which are already completed with excellent results.

In 1987, the UK government issued guidelines to departments on the use of contract energy management; and a new initiative to promote energy efficiency in the public sector was announced in 1989. With target savings of 15% of current use over the next five years in public buildings, the Government hoped to set the example to the private sector.

But from April 1990, the UK is now subject to new building regulations designed to save about 20% of space heating requirements relative to current levels. As for documentation, a "Code of Practice for Energy Efficiency in Buildings" (BS 8207), and a "Code of Practice for Energy Efficiency in Housing

Air Infiltration Review

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Conclusions and opinions expressed in contributions to Air Infiltration Review represent the author(s)' own views and not necessarily those of the Air Infiltration and Ventilation Centre.

Refurbishment" (BS 8211) - both with an associated Design Guide - were published in 1985 and 1988 respectively. More recently, a series of thirteen booklets has been published, aimed at building occupiers, and includes energy performance yardsticks for all major types of non-domestic buildings.

Looking at the more general picture, we can do no better than to quote from the most recent (1989) review by the International Energy Agency of the Energy Policies and Programmes of its 21 member countries.

Country	Energy Intensity
Canada	0.64
Sweden	0.52
USA	0.44
Germany	0.41
UK	0.41
France	0.35
Italy	0.32
Japan	0.27

Figure 2

In fact, there have been few major changes in Government policies and programmes in the residential/commercial building sector of energy consumption over the recent years. Virtually all IEA Governments have continued some information programmes designed to encourage or assist consumers in saving energy in residences. A number of countries also subsidise or require the provision of energy audits for residences, although some of these audit programmes, such as the Residential Conservation Service in the United States have been recently phased out. Outside the residential sector, there are comparatively few information or technical assistance programmes. With respect to new building, almost all IEA countries continue to maintain efficiency standards in both the residential and commercial sectors, and some countries took steps to update or strengthen the enforcement of these standards during 1988 and 1989.

According to the European Commission, the diversity of building codes in Europe is beginning to narrow, but the Commission is still striving to strengthen building standards with a model reference code, given that 20% of the buildings estimated to be still standing in ten year's time have not yet been built; and that insulation is two to four times less expensive during construction than during retrofit.

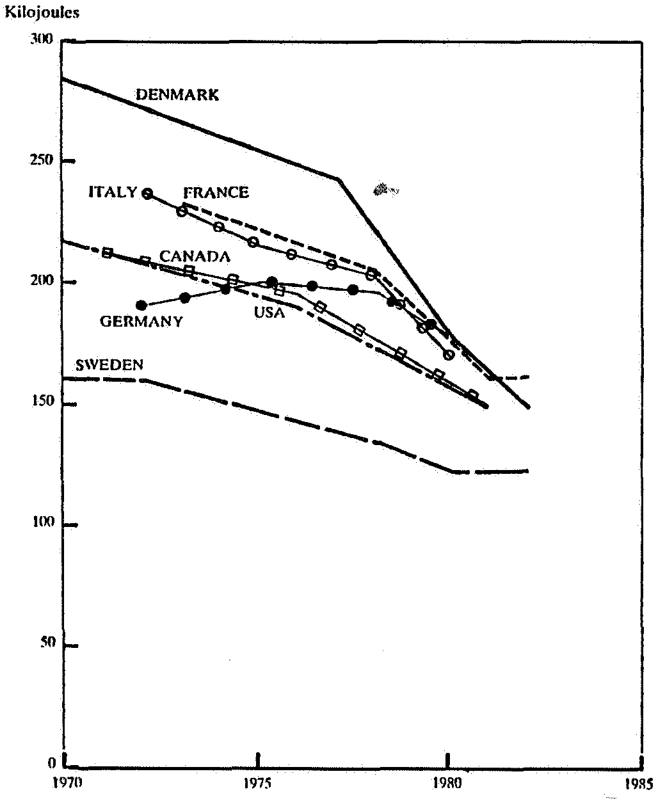
Efficiency standards for new residential equipment and appliances began to be implemented in the United States during the past two years, and the establishment of similar standards was being considered in some other countries, including Australia and members of the European Community. Energy efficiency labels for new appliances have been available in many IEA countries for some years, either under mandatory or voluntary programmes.

While comparatively few countries still have substantial financial incentive programmes for energy conserving investments in building, during 1988 and 1989 action was taken by a few governments or large utilities to initiate or significantly expand such incentives.

Finally, most countries maintained programmes to conserve energy in public, especially government owned buildings.

The limited data available on energy efficiency trends in the residential/commercial buildings energy consuming sector suggests that, as in the transport sector, the rate of efficiency improvement in appliances and whole building is now slowing down.

This is disappointing, considering the important gains in the efficiency of space heating which were achieved in the residential sector in response to the initial oil shocks.(See Figure 3)



Useful energy is energy consumption for space heating multiplied by an average furnace efficiency for oil/gas burners of 66%, for solids of 55%.

Source: Schipper, Ketoff and Kahane, "Explaining Residential Energy Use by International Bottom-Up Comparisons", *Annual Review of Energy* 1985. 10:341-405.

Figure 3: Space heat. Useful energy per degree-day per square metre (1970-1982)

This achievement has to be seen in the context of significant structural change in the residential sub-sector over the period 1972-1982 in the most prosperous OECD countries. Larger living areas were being enjoyed by a smaller number of people per household; people became more addicted to space heating and cooling and additional household appliances; and their energy use per dwelling could have been expected to rise between 10% and 20% had it not been for the higher efficiency of boilers, air conditioners, domestic appliances, insulation etc.

The commercial sub-sector, which also encompasses agriculture and public services, is one which has eluded accurate analysis of energy efficiency trends due to its complexity. However, one study which adopted energy use per employee as an indicator, came up with the following table:

Percentage Change 1970-82	
Denmark (1)	-19
Germany	-12
Norway	-13
Sweden	-15
United Kingdom	-12
United States	-24

(1) For Denmark 1972-82 was used.

It has been concluded that since overall economic activity continued to increase over this period, these gains can only have been achieved through a wide range of energy conservation actions in both new and existing buildings.

Thus has the Residential and Commercial Buildings sector of energy consumption made its contribution to the decline in energy intensiveness to which we referred earlier.

However, it must be borne in mind that energy savings should be compatible with the need to preserve a good indoor environment. Energy reductions of the '70's and '80's took place at a time when many new chemical entities were introduced into building materials, furnishings and furniture. With this became associated the problems of the "sick building syndrome" (which will be discussed in more detail later). Efficient ventilation, for example, is therefore essential if the working environment is to optimise the comfort and health of the building occupants.

No brief review of the topic of Government influence in the sphere of energy and building would be complete without mention of one crucial factor in Government energy policy which attracts less publicity, but which is still vital in maintaining an incentive to economise in the use of energy; that is Government energy pricing policy. The governing principles adopted by OECD Member Governments in the conduct of their economic policies, imply that where a world market exists for a commodity, the price to the consumer should reflect the world market price; and indeed considerable progress has been achieved since 1973 in relating coal and oil consumer prices to the world market. Gas and electricity pricing involve complex issues which will not be discussed now. Sufficient to say in general terms that in some countries there are still fuel subsidies, price controls and other market distortions which tend to result in a lower consumer price than the world price, thus effectively sabotaging the incentive to save energy.

The moment is perhaps now opportune to turn to a review of the major forces which are likely to be influencing the formulation and conduct of national energy policies in the future.

2. The Factors Influencing Future Energy Policies

It is at this point that we may take up the issue of the "Environment", but as was indicated earlier, to explore the implications of that word in the broadest sense, and to avoid limiting discussion to air quality, land and water pollution and possible global climate change. The building industry must also surely be interested in the political, social and economic environment, in which it has to operate; not forgetting the technology environment, for whether we like it or not, many of today's problems, imagined or real, will require solutions which only technology applications can provide.

As far as the political aspects are concerned, one of the main preoccupations will be continuity of energy supply, principally oil, although electricity could also pose some problems. Nevertheless, experience of the last fifteen years has shown that whereas the Residential/Commercial and Industrial energy consuming sectors have the flexibility to switch fuels, the Transport sector remains hostage to oil. This has its implications for the building industry as will be shown later.

Politico-social trends are also emerging which will strongly influence future energy policies for the Residential sector. The decline in population growth in the OECD countries as a group, and the ageing of the population, can be expected to affect residential energy consumption. In order to encourage larger families for the young, more spacious accommodation at affordable prices needs to be available. On the other hand, many older people may resist being moved into special (and more energy efficient) accommodation for the aged, and prefer to remain in their life-long environment, where their energy consumption may be higher than is strictly necessary.

A further potential complicating factor for the housing market could be the urgent need for the renewal of sub-standard housing stock in some ex-Communist countries (100,000 new homes needed immediately in what used to be Eastern Germany); and the possibly massive immigration of people seeking an improved life-style in the West. Such events - largely imponderable - would place an extra burden upon an energy supply system already under constraint from a *further* political issue which also has strong social overtones.

This is the general concern to arrest the progressive degradation of the physical environment, i.e. through acid rain, ozone depletion and to avert a perceived threat of global climate change. Undeniably, this is a strong driving force in the current climate of opinion, and is likely to result in stricter measures for heat and electricity production, and the accelerated development of new materials for building insulation and new working fluids for refrigeration and heat pumps.

All these factors are extremely difficult to quantify in terms of their repercussions on the economic environment. But it seems clear that the result will be higher costs for energy and capital installations, and will give fresh impetus to improved energy efficiency and energy-related technology development.

But like all forces, this impetus requires a means by which its effect can be communicated. This then brings us to the all-important issue of information.

It is almost axiomatic that suppliers of energy-using and energy-saving equipment and energy consumers need to have access to adequate sources of information about what should be done to improve energy efficiency; and above all, how to do it!

At the outbreak of the first oil shock, such organised networks on energy saving information were lacking, but at the same time there was a flood of new conservation products and services, trying to break into a potentially lucrative market. Some of these innovations yielded disappointing results in terms of costs, reliability, and energy savings. For example, the heat pump was regarded as a promising energy-saving device, but did not live up to initial expectations. The use of urea formaldehyde insulation in housing and its subsequent banning in many countries because of health and performance problems is another typical case of the lack of credibility which undermined a number of campaigns to improve building energy efficiency.

The collapse of oil prices in 1986 spelt ruin for a number of energy performance service companies. Potential profits from energy savings in the projects in which they had invested in partnership with industrialists and building owners, disappeared almost overnight.

Whatever public funds were available for energy R&D prior to the first oil shock had been almost entirely devoted to civilian nuclear power applications, but from 1975 onwards we see an increasing Government investment in projects to achieve energy savings in the relatively short-term. (See Figure 4)

The scale of this effort was modest however, never exceeding 7% of the total IEA energy R&D budgets. Even so, much useful work was accomplished in the areas of improved building insulation, heating and ventilating, and in improved techniques for district heating, where oil could be replaced by combustion of waste material and the use of heat pumps.

However, in some countries, this valuable new knowledge and experience was not able to filter through to consumers, due to the lack of an effective national infrastructure for the dissemination of information on energy saving.

But even where information campaigns did work reasonably well, such as in the UK and in Canada, the know-how remained within national frontiers.

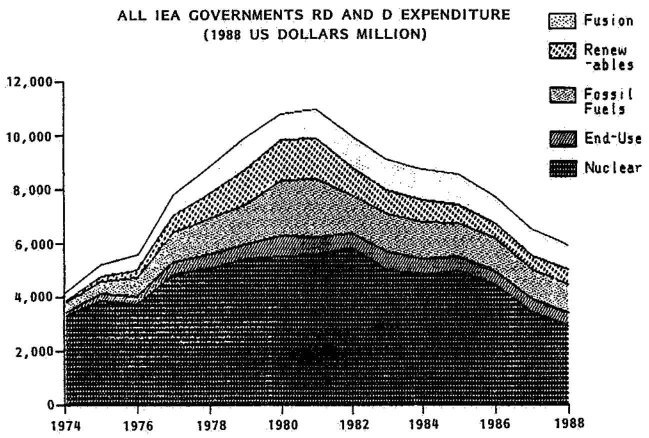


Figure 4

It was with the objective of enlarging the field of awareness of achievements in energy saving and of the economic benefits; and of re-kindling consumer interest in the whole ethic of energy efficiency, that the International Energy Agency pursued a policy of establishing Information Centres, concerned not only with the promotion of energy saving techniques, but also with the dissemination of actual achievements in demonstration of energy saving technology in a wide variety of applications. Some readers will already be familiar with these Centres - the AIVC itself; and two at Sittard, Netherlands, dealing with Heat Pumps and the most recent - CADDET, the Centre for the Analysis and Dissemination of Demonstrated Energy Technologies.

These activities are mentioned as they have a key complementary role to play in shaping the thinking of energy policy planners, architects, engineers, building construction companies and a wide variety of end-users. Reliable information, properly disseminated can thus be regarded as another important force influencing future energy policies.

Energy efficiency regulation as a force has clearly already made its mark upon the building industry. The more energy efficient designs already adopted by the housing construction industry and equipment manufacturers are likely to be retained, regardless of short-term changes in market signals. The procedure for developing and reviewing building codes has been laborious and is likely to continue to be so, given the multitude of special interest groups involved. Moreover, even with the most sophisticated design techniques, energy saving can only be estimated, since consumption depends so much on consumer behaviour, such as opening outside doors and windows and setting thermostats. This is non-technology, an area of research which is still in its infancy.

As far as really large buildings are concerned, relatively few construction companies possess the necessary technical skills and access to finance to embark on the higher investment cost involved in an energy efficient building, which might also render their bid uncompetitive. Moreover, the building owner has less motivation to specify energy saving measures if he does not have to bear building running costs, i.e. where these are incumbent on the tenant.

Finally, when it comes to deciding whether to construct a new building or to retrofit an existing one to comply with new energy efficiency standards, cost will always tend to be the overriding factor in the trade-off (unless energy costs triple or quadruple over the next three or four decades). Only continued regulation can resolve these conflicting interests in determining the building environment of the 21st century.

3. The Possible Implications for the Building Industry

The heavy dependence of transport on oil and oil products was mentioned earlier. In 1973 oil use in the OECD transport sector was 38% of total OECD oil consumption. In spite of two major oil shocks and steep price increases, this proportion is now well over 50% and still rising. In fact, the world's present 500 million road vehicles (which are responsible for 85% of oil consumption in the transportation sector) are expected to triple or even quadruple during the next two or three decades. The implications for acid precipitation and carbon dioxide production are horrific, not to speak of the waste of energy and productive time in traffic congestion.

One possible solution may be a revival of the self-contained community. In bygone days, access to water supplies and the influence of the Church were unifying factors in achieving social agglomerations. The 21st century may see the rational use of energy as the driving force in establishing townships where energy supply and demand are fully integrated into the working and leisure routines of energy self-sufficient communities. These communities would enjoy such amenities as low (or zero) energy housing, electric cars, district heating, and widespread use of energy storage in conjunction with heat pumps; all of which are technology related developments.

If technology and environmental concerns are to mould the future, what must be done in the design, construction, and operation of new buildings to respond?

Environmental factors (in the broadest sense) will be the most difficult to quantify, given the complexity of their interaction and the unpredictability of their scale of influence.

Technology is something we can feel more at home with, since our knowledge and experience is based upon more solid ground for charting a course for the future.

It seems clear that building design may have to change radically if oil and electricity become decreasing options for heating and cooling; and CFC-based foam or advanced plastic (petroleum based) insulation materials are proscribed. Renewable energy can play some part in the range of technology options open to us, but the systems approach in building design together with high quality workmanship, thorough inspection and testing, and skilful operation and maintenance holds substantial potential savings from non-renewable energy sources - in some cases up to 80% of current average consumption.

How well equipped therefore, are the energy technologists to satisfy these needs? It is useful to report here on a list of R&D areas that a group of IEA experts identified as being crucial for energy efficiency buildings of the 21st century:

- more standardisation of design codes/ components/performance specifications;
- system integration;
- cost effective solar energy (photovoltaic and/or thermal panels;
- electrochromic windows and walls;
- transparent/translucent insulation;
- energy storage;
- CFC replacements in insulation and equipment;
- improved distribution and insulation technology for low density DH;
- accurate and fool-proof heat metering for single family homes;
- non-electric heat pumps with environmentally acceptable refrigerants.

As a concept, the heat pump has been around for a long time, as we can see from the following chronological table. (See Figure 5)

But it is only the last fifteen years which have witnessed a growing body of development work and application, all of which has yielded important gains in knowledge.

Coefficients of Performance, i.e. energy out to energy in, have improved significantly; costs have come down, although nowhere near enough; and performance-wise they have had a marked success in the dual operating mode of heating and cooling, particularly in Japan and the Southern United States.

However, with some exceptions, their technical and economic performance in heating applications has only been disappointing. This is particularly unfortunate for most of Europe, which hitherto has had little requirement for cooling applications. One of the biggest problems has been that many of these heat pumps have been oversized for their applications; and in many of the smaller installations, have contained an unnecessary number of system components. These factors have driven up the installation costs, which are already substantially higher than a conventional boiler. Thus the utilisation time has to be maximised, which of course doesn't happen when the heat pump is too big for the job.

HEAT PUMP – a new technology ?

1824	**Carnot**	**Dissertations**
1834	**Peltier**	**Thermoelectric cooling/heating**
1834	**Pelletan**	**Mechanical vapour recompression**
1834	**Perkins**	**Refrigeration – ether compression**
1844	**Gorrie**	**Refrigeration – air compression**
1852	**Kelvin**	**Heat pump – air compression**
1855/57	**Harrison**	**Refrigeration – ether compression**
1855/57	**von Rittinger**	**Mechanical vapour recompression**
1859	**Carré**	**Refrigeration – absorption**

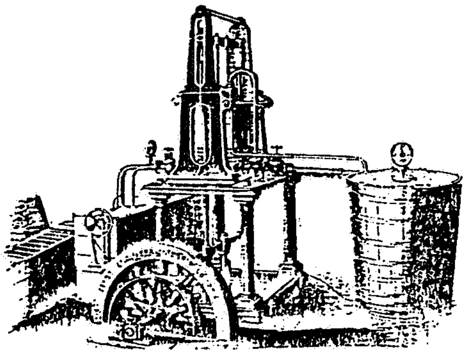


Figure 5

As for the future, the elimination of CFC-based working fluids in compression driven heat pumps no longer seems to be a problem according to an article in the Financial Times of 28th November, 1990.

However, the fact that most compression type units have need for an electric drive could be a further dissuading factor in a more electricity-saving conscious community, but this potential disadvantage could be overcome by substituting with gas engine driven heat pumps, which have already shown much promise in Japan. Nevertheless, the heat pump of the future is most likely to be that which operates on the absorption principle, but here again the working fluid currently involved - ammonia - is again the centre of a polemic, this time for toxicity reasons.

To come back to the listing of research priorities we looked at a few moments ago; of the above aspirations, perhaps the most challenging is that of system integration, which in a way transcends R&D on the efficient performance of specific building materials, components and equipment. The systems integration approach offers further increases in energy efficiency, based upon the premise that a building functions most efficiently when it is designed, constructed, operated and maintained to take maximum advantage of the energy performance *interaction* of its parts. Hence the concept of the "intelligent" building, which reacts not only to its outside environment (temperature, humidity, radiant energy), but also possesses an internal metabolism of its own, much the same as a living organism.

Building research, oriented towards energy saving was something of an orphan until fifteen years ago. Even if the Iranian fiasco of 1951, the 1956 Suez crisis, and the subsequent setting up of OPEC may have created some doubts about the long-term security of oil supplies, expectations from nuclear power in the late 1950's and during the 1960's was so high as to invoke scorn on any attempts to justify the development of energy efficient buildings.

Even when the nuclear dream began to fade, and the "clean use of coal" became the battle cry for electricity generation after the first oil shock, both politicians and the public alike remained convinced until only recently, that there would always be some substitute for oil to generate and to satisfy the burgeoning demand for energy that we witness today.

To quote an example, in Sweden although oil consumption in the built environment has halved since 1974, the use of electrical energy for space heating, operation of building services systems, domestic appliances and office equipment has trebled! This is one of the reasons why the Swedes are having second thoughts about the phasing out of nuclear power.

Now that the spectre of global climate change begins to loom, and Governments are giving sober consideration to penalising emissions of carbon dioxide, there is a growing realisation that electricity does not grow on trees.

This shrinking of the energy supply perspective can only add further force to the argument for higher energy efficiency, in which the building industry can play its part through technology applications. But the history of technology development shows that it can take up to a quarter of a century to span the gap from laboratory to market penetration, so there is no time to be lost in reviving the flagging fortunes of research, development and demonstration programmes to achieve the super energy efficient and environmentally "friendly" buildings of the next generation.

Field Experiments on Airborne Moisture Transport

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Introduction

Within the framework of the Dutch participation in the IEA Annex XIV " Condensation" field experiments have been carried out to study airborne moisture transport in realistic circumstances. The experiments were done in an unoccupied 3-storey dwelling in Leidschendam in the Netherlands. Some of the results will be discussed in this paper.

Airborne Moisture Transport

The aim of field experiments was to study the airborne moisture transport from a local moisture source to other areas in the house. Two distinct phenomena have been considered separately:

- The airborne moisture transport from the zone in which the moisture source is located, to other zones in the same house. This is denoted as the interzonal airborne moisture transport.
- The internal airborne moisture transport inside the single zone in which the moisture source is located. This is denoted as the internal airborne moisture spreading.

Interzonal airborne moisture transport is induced by pressure differences between adjacent zones in the building. These pressure differences are influenced by temperature differences (stack effect), wind pressure and the use of ventilation devices. The basic principles of interzonal air transport are quite well understood, although the complex interaction of the influencing factors may result in unpredictable effects. Internal airborne moisture spreading within a single room is much more difficult to understand. The nature of this type of moisture transport is mainly induced by air movement. Water vapour diffusion does not play an important role in dwellings. Many factors influence the indoor humidity levels caused by an internal moisture source, such as

- the air flow patterns in the room and the associated mixing process; air flow patterns are influenced by factors like type and position of heating systems, shape and geometry of the room, the way in which air is supplied or extracted, etc.
- the removal effectiveness of the extract ventilation (if any)
- the amount of dilution by infiltration
- the absorption/desorption process of water vapour at the room surfaces and furniture.

The variety of possible airflow patterns makes it very difficult to predict quantitatively the airborne moisture movement within a single zone.

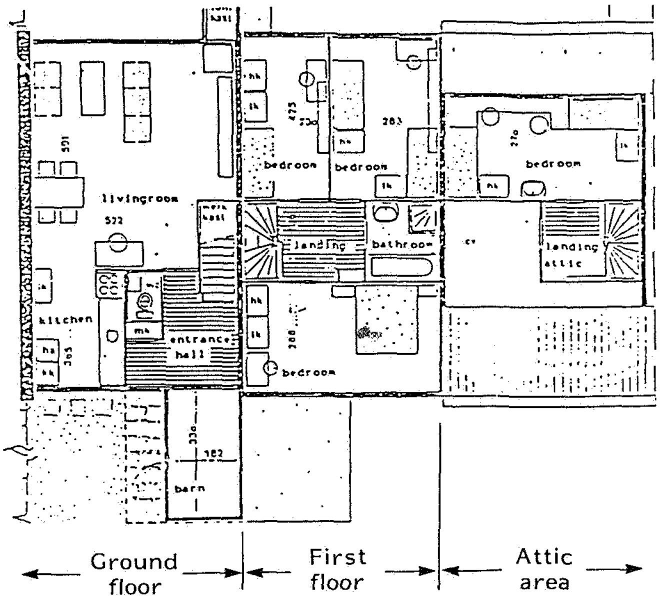


Figure 1 Floor plan of the dwelling used for field experiments

The Experiments

In order to eliminate disturbing influences of occupants the experiments were carried out in an unoccupied house. A floor plan is shown in Figure 1. During these experiments the moisture was generated in a precisely defined and controlled way. Three types of moisture generation experiments have been considered:

a. cooking experiments (800 grams water vapour in 30 minutes);
b. shower experiments in the bathroom;
c. wash drying experiments in the attic;

In this paper only the results of the cooking experiments will be discussed briefly. The full details of all experiments have been reported in a TNO report [1]. The cooking experiments were done for various conditions in order to study the effect of the major influencing factors, like open or closed windows, open or closed interior doors and the use of the ventilation system. A constant evaporation rate was achieved during the chosen moisture generation period of 30 minutes. Only one cooking experiment was done per day to allow the establishment of the moisture equilibrium of the wall surfaces.

Measurement Equipment

Sophisticated equipment was installed to collect the experimental data: a constant concentration gas tracer (N_2O) technique, to monitor air infiltration of all rooms. A constant generation gas tracer (SF_6) technique was applied to monitor the air transport from the moisture source to other ones. Further a 16-channel dew-point sensor system to monitor local water vapour concentrations. Finally, a micro manometer measurement system to monitor air pressure differences.

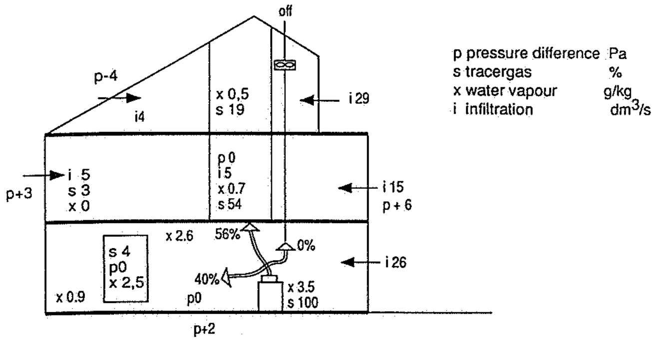
A unique feature of this study was the simultaneous measurement of air transport and airborne moisture transport by using the SF_6 tracer gas and the dew point systems. This feature allowed the study of the moisture storage effects associated with airborne moisture transport. Because SF_6 is an inert non-absorbing gas, the simultaneous measurement of water vapour and SF_6 gas tracer concentration permits to derive quantitative information about the moisture storage effects due to hygroscopic absorption-desorption and condensation-evaporation on wall surfaces.

Results

In Figures 2 and 3 some experimental data are shown for two different cases A and B. Case A can be considered to be the worst case with respect to the moisture load, because the extract ventilation is switched off and the doors and windows are closed. Case B can be considered to be less so as the mechanical ventilation is switched on and the vent lights are open.

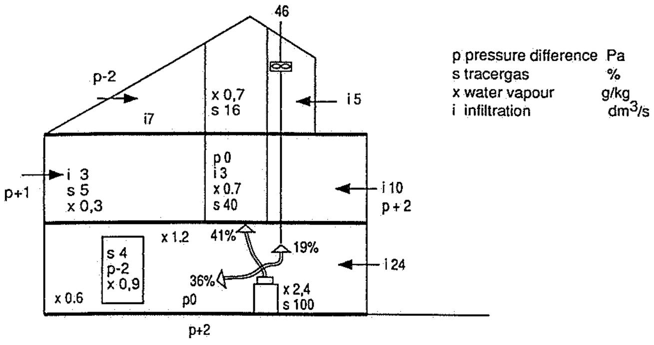
Experimental Decay Curves

In the cooking experiments two kinds of contaminants were released during a period of 30 minutes: water vapour at a constant rate of 27 grams per minute and SF_6 tracer gas at a constant rate of 100 cm^3 per minute. Figure 4 shows the recorded time history of the measured room averaged concentrations for both contaminants for case A. The curves are plotted for an equivalent scale maximum for each of the two contaminants. The scale maximum is computed according to Cmax = M/V, where M is the amount of released contaminant and V is the air volume of the room air.



cooking 30 minutes	yes
door between kitchen/living and hall/staircase	open
vent lights	closed
mechanical extraction ventilation system	off
windspeed	8-10m/s
winddirection	W
outside temperature	11°C

Figure 2 Experimental data from the cooking experiment case A (worst case: fan off, vent lights closed). The data shown refer to: x = water vapour concentration difference (with respect to outdoor air), maximum values are shown as observed after the generated moisture peak at the cooking place.



cooking 30 minutes	yes
door between kitchen/living and hall/staircase	closed
vent lights	open
mechanical extraction ventilation system	on
windspeed	1-3m/s
winddirection	N
outside temperature	10°C

Figure 3 Experimental data from the cooking experiment case B (less worst case: fan on, vent lights open). The data shown refer to: x = water vapour concentration difference (with respect to outdoor air), maximum values are shown as observed after the generated moisture peak at the cooking place.

The example shown in Figure 4 refers to Case A where the air exchange rate is determined by natural ventilation only. The concentrations for both contaminants show a sharp increase during the generation period, as expected. However, there is a significant difference between the maximum concentrations. The SF_6 peak level concentration reached at about 80% of the Cmax=M/V value. This indicates that the other 20% has been removed by ventilation during the generation period. The peak level of the water vapour concentration is much lower: about 40% of Cmax value. Apparently, much more water vapour has been removed with respect to the inert SF_6 gas. This can be explained by the removal of water vapour due to condensation and absorption on wall surfaces. Hence, a comparison of peak values for SF_6 and water vapour concentrations provides information on the moisture storage process that took place during the moisture generation. Figure 4 also gives information on the moisture behaviour by comparing the decay curves. The decay curve of the SF_6 concentration provides reliable information about the real air change rate. This information can be used to predict the decay curve of the water vapour concentration, starting from the time the generation of the contaminants was stopped. The decay curve for water vapour concentration due to ventilation only is indicated by a dotted line. The drawn line represents the observed room averaged water vapour concentration. During the first hours the decay rate of the water vapour concentration is higher compared to the ventilation decay curve. This indicated that additional airborne moisture has been removed by absorption. A few hours later the decay rate becomes lower than the expected ventilation decay rate. This indicates that then moisture is released by desorption. A more detailed analysis showed that absorption and desorption occur simultaneously during the decay time period. During the first few hours absorption is dominating but later desorption becomes dominating.

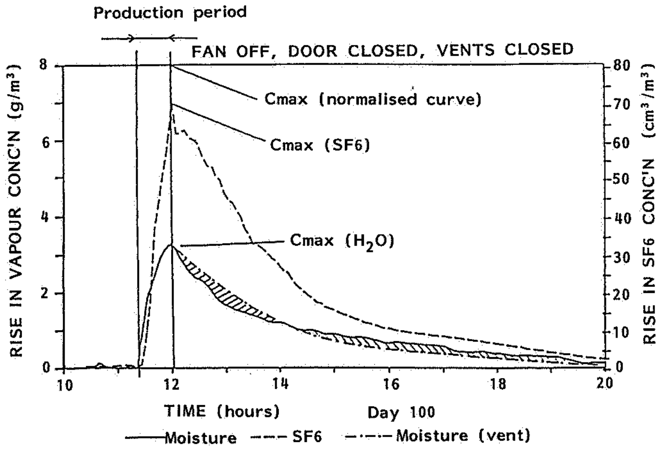


Figure 4 Comparison of water vapour and tracer gas concentration response due to a generation period of 30 minutes.

Moisture Balance And Moisture Removal Effectiveness

The combined gas tracer and water vapour concentration measurements enable us to reconstruct the moisture removal process by deriving the instantaneous moisture balance. The instantaneous moisture balance can be decomposed into the following components:

Mp = amount of moisture released during the generation process
Mv = portion of Mp removed by extract ventilation
Ma = portion of Mp removed by absorption at interior wall surfaces
Me = portion of Mp removed by air transport to other zones
Mi = portion of Mp present in the room air

At any time after the moisture release the following balance is valid:

$$Mv + Ma + Me + Mi = Mp\ [g]$$

or

$$Mv/Mp + Ma/Mp + Me/Mp + Mi/Mp = 1$$

The ratio's Mv/Mp, etc., can be expressed in percentages. The ratio Mv/Mp is of particular interest because it is the figure of merit for the moisture removal effectiveness. Some experimental results for the mass ratios (expressed in percentages) are given in Figures 2 and 3. The percentages shown refer to the instantaneous moisture balance as observed immediately after the moisture generation period. The results have shown that moisture storage certainly is an important factor when considering airborne moisture transport. In case A (Figure 2) 56% of the produced moisture is stored in walls within a very short time during the moisture generation period; 40% is released to the indoor air and 4% is removed by exfiltration. In case B (Figure 3) still 41% is stored in the walls, 36% is then released to the indoor air and 19% is removed by the ventilation system and 4 5 by exfiltration. It was noted that the moisture removal effectiveness Mv/Mp did not exceed 23% in any of the examined cases.

Water Vapour Gradients

The water vapour distribution in the room during and after the cooking experiment was also the subject of study. The moisture distribution was monitored at nine measuring positions located in the kitchen and the living room. During the moisture production large vapour gradients have been observed. Instantaneous differences of up to 5 g/m^3 have been observed between two remote locations in the living room. Data for the observed water vapour concentrations are given in Figures 2 and 3. The water vapour equalization process takes several hours, depending on the ventilation rate. During the equalization period the stored moisture is gradually released again by desorption or evaporation. As noted before moisture storage and moisture release occur simultaneously during the equalization period. This can be explained by the phenomenon that wall areas near to the moisture source have been moistened during the production peak, while wall areas remote from the cooking place are still dry. Apparently, an equalization process of moisture content between wall surfaces occurs: moisture from "wet" areas moves to "dry" areas by airborne transport.

Interzonal Airborne Moisture Transport

In all experiments the effect of interzonal airborne moisture transport was also analyzed. The results showed that interzonal airborne moisture transport appears to be significant only in cases where internal doors between rooms are kept open during or just after moisture production. The interzonal air transport from the kitchen to other zones has been analyzed by comparing the observed peak gas tracer concentrations. It was found that peak ratio varies between 10 to 50% when considering the adjacent hall/staircase. This depends on fan switching and position of the door between living/kitchen and hall/staircase. For the bedrooms this ratio was found to be only a few percent. Comparisons were made to water concentration measurements and it was concluded that a large part of the water vapour is removed by absorption on its way to other zones.

Conclusions

A unique feature in this study was the simultaneous measurement of air transport and airborne moisture transport by using the SF_6 tracer gas measurement technique and a dew point measurement system. This allowed us to study moisture storage effects in association with airborne moisture transport. Interzonal airborne moisture transport was found to be of little importance when considering short term moisture production activities, like cooking. In particular this is true if doors are kept closed in rooms where moisture is produced.

During the cooking experiments large differences between local water vapour concentrations have been observed in the kitchen/living room area. An analysis of the measurement results shows that moisture storage at wall surfaces is a very significant component of the moisture balance. Roughly 40% of the moisture produced is stored at the wall surfaces by absorption and condensation during the 30 minutes period in which the moisture is produced. The stored moisture is gradually released again, but this takes several hours. Moisture storage has an important effect on the ventilation efficiency. Cookerhoods with a proper exhaust capacity and placed on the appropriate distance from the source, will have a positive effect on the internal airborne removal effectiveness. With respect to the internal airborne moisture transport the open kitchen/living room situation is a disadvantage compared to a separated kitchen and living room.

Reference

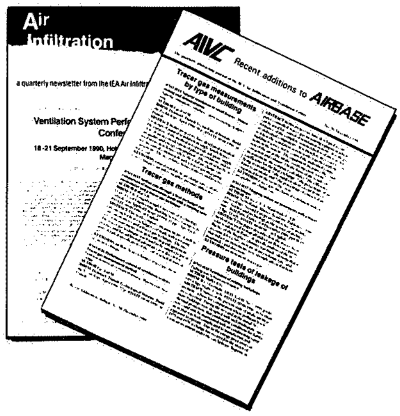
(1) Elkhuizen, P.A., Oldengarm, J., De Gids, W.F., and Van Schijndel L.L.M., TNO-IBBC report B-90-128, Febr.1990

**Willem de Gids is this year's Vice Chairman of the AIVC Steering Group.*

This paper first appeared in the proceedings of the International CIB W67 Symposium on Energy, Moisture and Climate in Buildings, held 3-6 September 1990, at Rotterdam, The Netherlands, and is reprinted with the author's permission.

Important Notice

Enquiries to the AIVC for publications and library items are increasing all the time. We have experienced some delays in receiving requests via the world's postal services. If you wish to ensure a speedy dispatch of documents, please mark enquiries urgent if necessary, and fax them through to us on this number: +44 (0)203 416306.



Two-dimensional Non-Isothermal Supply from Low Velocity Terminals

Mats Sandberg & Magnus Mattsson, National Swedish Institute for Building Research, Gävle, Sweden

Introduction

The distribution of air within a room with traditional mechanical ventilation is based on a principle which entails the supply of air with a high initial velocity, usually several meters per second. These high velocity terminals are used in connection with *mixing ventilation.* Isothermal flow issuing from this type of terminal is governed by the initial momentum flux and is therefore of the jet type.

High velocity air terminals are used for the supply of both isothermal air and non-isothermal air. In the latter case the flow is affected by both momentum (inertia) and buoyancy forces created by the density differences. The ratio between buoyancy and momentum is often expressed by the Archimedes number (see below). When non-isothermal air is supplied with a high velocity air terminal the inlet Archimedes number is very small, typically less than 10^{-2}. This reflects the fact that, due to a high velocity, the momentum is initially stronger than the buoyancy force.

During the last decade air terminals designed for the supply of air with low velocities, typically around 0.2 meters per second, have been introduced. Low velocity air terminals are frequently used as a component in so called *ventilation by displacement.* In this application the terminals are usually located at floor level and air at a lower temperature (negatively buoyant) is supplied and intrudes into the room as a horizontal current, see Fig. 1. Due to the low inlet velocity the buoyancy now becomes relatively more important than with supply by a high velocity air terminal. The nominal Archimedes number based on inlet conditions is large and is often greater than one. Due to the stabilizing effect of the buoyancy, the entrainment of ambient air is hindered. Therefore the kind of flow issuing from this type of terminal is no longer of the jet type. The discharge is more like *gravity currents.*

In the field of ventilation engineering the understanding of jet types of flow is well established. However, the behaviour of buoyant flows with high initial Archimedes numbers has been much less explored. The aim of this short note is to highlight some of the differences between ordinary jet flow and the discharge from low velocity air terminals. Results are presented both from tests carried out in a full scale mock up and from model tests with water as operating fluid. For design purposes, knowledge about the maximum velocity is important in order to avoid complaints about the thermal sensation. Consequently in this note we concentrate on the maximum velocity generated by this type of flow.

Inlet Conditions

We will assume that we have a two-dimensional flow so that the flow fills up the whole width of the room and therefore all quantities are given per unit width. Two-dimensional flow may occur either when the inlet terminal span the whole width of the room or when the radial flow from a narrow terminal reaches the side walls.

At the inlet we have the following variables.

Volumetric flow rate:	q	$[\frac{m^2}{s}]$
Density difference:	$\Delta\rho$	$[\frac{kg}{m^3}]$
Height of the terminal:	H	[m]
Inlet (supply velocity):	U_s	$[\frac{m}{s}]$

It is convenient to express the effect of the density difference as the *reduced gravity:*

$$g' = \frac{\Delta\rho}{\rho_s}g \qquad [\frac{m}{s^2}]$$

From the above variables we derive:

Specific momentum flux: $[\frac{M}{\rho_s}=q.U_s]$ $\qquad [\frac{m^3}{s^2}]$

Specific buoyancy flux: $B = qg'$ $\qquad [\frac{m^3}{s^3}]$

The specific momentum flux and the height give the velocity scale based on momentum

$$\sqrt{(\frac{M}{\rho H})}=U_s \qquad [\frac{m}{s}]$$

From the dimensions of the specific buoyancy we see that a velocity scale based on buoyancy can be derived, which is equal to:

$$B^{1/3} \qquad [\frac{m}{s}]$$

Whether the air will be driven by gravity (buoyancy) or the initial momentum of the discharging air depends on the magnitude of the *initial Archimedes number,* Ar:

$$\mathrm{Ar} = \frac{g'H}{U_s^2} \qquad [1]$$

An isothermal jet (g' = 0) has an Archimedes number equal to 0. The flow is said to be *subcritical* if the Archimedes number is greater than one and *supercritical* if the Archimedes number is less than one. Jump-like transitions may occur if the inlet Archimedes number is less than one.

Measurements

By studying a starting flow situation (the flow is turned on), insight will be gained into the physics involved. Studies of starting flows were carried out in a model with water as operating fluid. Salt was added to the supply water to obtain the desired density difference. Fig. 1 shows a shadowgraph of a starting flow.

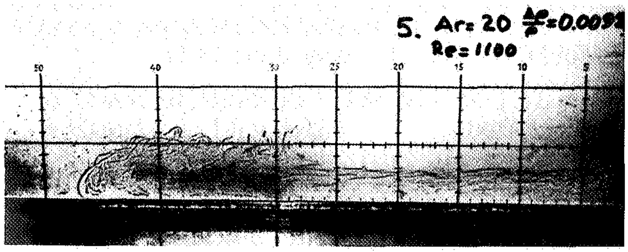


Figure 1 Shadowgraph of the head of the starting flow advancing towards the left

Because we have a two-dimensional flow we should expect the velocity to approach a constant value, after an initial acceleration phase at the inlet . The recorded velocities of the front, U f, are summarized in Fig. 2

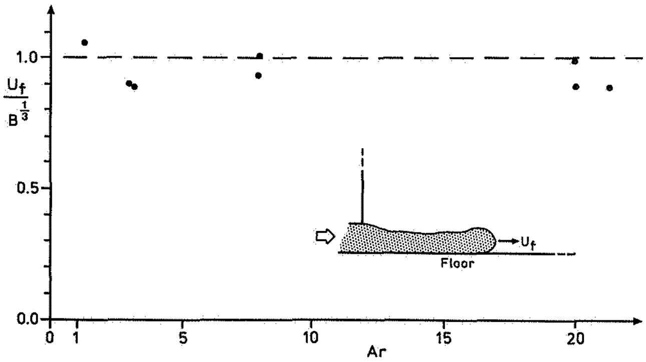


Figure 2 Starting flow. Velocity of the front, U f

We see that the velocity of the front becomes close to the buoyant velocity scale, $B^{1/3}$. This is typical for two-dimensional gravity currents, see e.g. Simpson J E (1987). Simpson's book also gives other relevant references on gravity currents.

The next figure shows the vertical velocity profiles recorded 1.5 m from the supply terminal in a mock up of an office room. The height of the terminal amounted to 0.485 m. Only stationary situations were studied in the mock up.

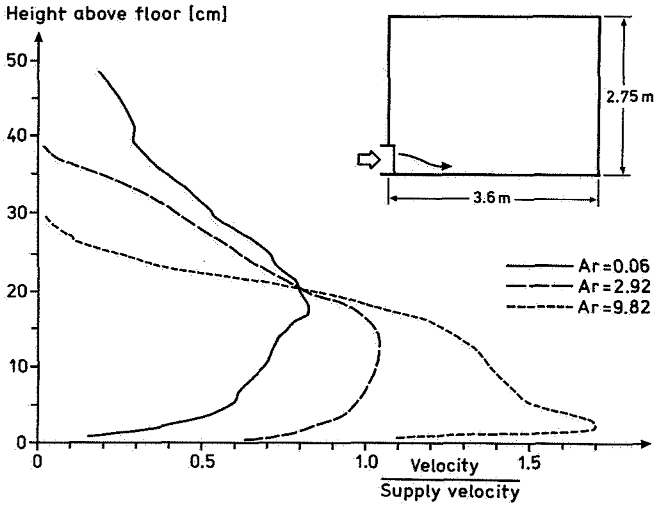


Figure 3 Stationary flow. Velocity profiles recorded 1.5 m from the terminal

We see that the shape of the velocity profile is dependent on the Archimedes number. At the lowest Archimedes numbers the maximum velocity is less than the supply velocity. This is typical for a jet which entrains ambient air so that the velocity is reduced. The buoyancy initially accelerates the flow such that at large Archimedes numbers it becomes greater than the supply velocity. Fig. 4 shows a plot similar to that of Fig. 2 for the recorded maximum velocity. For an inlet Archimedes number equal to or greater than one the maximum velocity has been divided by the velocity scale given by the buoyancy (filled circles), whereas for an Archimedes number less than one it has been divided by the velocity scale introduced by the specific momentum flux (open circles).

We see that for an Archimedes number equal to and greater than one the maximum velocity is given by the buoyant velocity scale. The scatter is now larger than in Fig. 2. This can be attributed to the facts that the experimental difficulties are now greater than in the previous case and that the specific buoyancy flux is no longer conserved. This is due to the circumstance that there is a heat transfer between the floor and the air layer above it that will gradually diminish the initial buoyancy flux. Furthermore in Fig.4 we have assumed that the velocity profile is uniform. However, this far from the case as we see in Fig.2 and therefore an Archimedes number dependent correction factor should have been introduced, which has not been done.

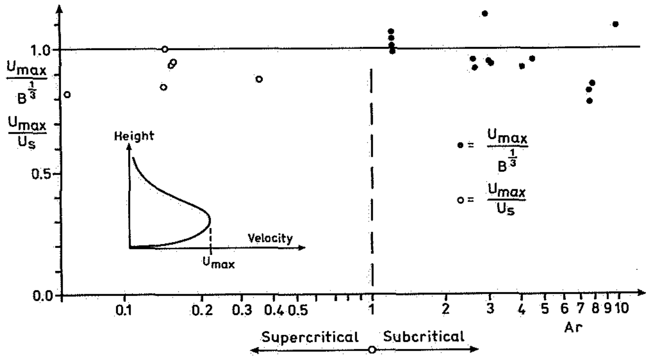


Figure 4 Stationary flow. Maximum velocity

For an Archimedes number less than one the buoyant velocity scale is not the appropriate one. Instead the velocity scale based on the supply velocity, that is to say the momentum induced velocity scale is the correct velocity scale. We see that the maximum velocity is now always less than the inlet velocity. This is because entrainment of ambient air slows down the velocity. Another contrast between the jet type of flow and this type of flow is the influence of the downstream conditions. An ordinary jet supplied at floor level that arrives at a wall is deflected and continues to flow along the wall, whereas a gravity current may be reflected back. Therefore a starting gravity current may in the limit become submerged into its "own" air. However, if the wall is heated then a fraction of the original flow will continue along the wall. There are several other possible types of downstream controls. In the tests reported here the two-dimensional current was allowed to flow out into a wider room far downstream and therefore there was no immediate reentrainment of the supplied air.

Conclusions

For two-dimensional flow it has been shown that when the Archimedes number based on inlet conditions is equal to or greater than one then the flow is no longer of the jet type. The flow is governed by buoyancy and the maximum velocity becomes nearly equal to the specific buoyancy raised to one third, which is the *buoyancy induced velocity scale.* Therefore the buoyancy flux is the decisive factor that governs the velocity when buoyancy is the dominating force. The Archimedes number is a parameter for identifying different flow regimes. An additional contrast between this type of flow and jet type flow is that the downstream conditions may affect the flow.

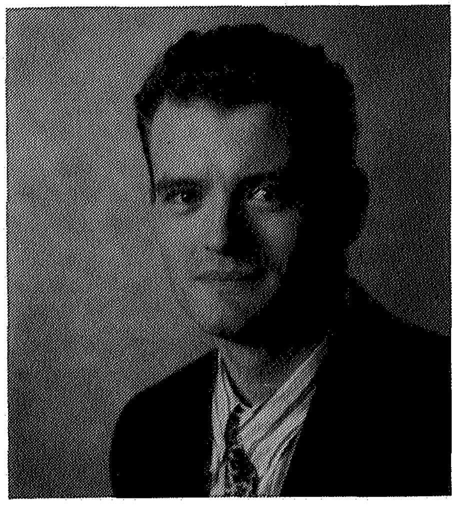
References

Sandberg M & Holmberg S (1990) "Spread of supply air from low velocity air terminals." Proceedings ROOMVENT'90. Oslo, Norway, June 13-15

Simpson J E (1987) GRAVITY CURRENTS. Ellis Horward Limited

Mats Sandberg & Magnus Mattsson, National Swedish Institute for Building Research "Two-dimensional non-isothermal supply from low velocity terminals"

New member of staff at AIVC - John Kendrick



John joined the group in the new year. He has a first degree in Mechanical Engineering from Leicester University and is currently completing his PhD. in aerodynamics, also at Leicester. He has worked on computer and wind tunnel modelling of aircraft drag factors for the development of the British Aerospace A330/A340 Airbus.

He has been involved in extensive wind tunnel testing in Leicester as well as working at British Aerospace in the aerodynamics design office. Experience in flow modelling and an engineering background will be useful for the project he is currently working on at the Air Infiltration and Ventilation Centre.

John is initially involved in the assessment of "state of the art" theoretical models for the combination of fluid flow and heat transfer, with particular attention to model comparison with real life measurement problems and solutions.

AIVC 12th Annual Conference

Air Movement and Ventilation Control within Buildings

Tuesday 24th - Friday 27th September, 1991, Château Laurier, Ottawa, Canada

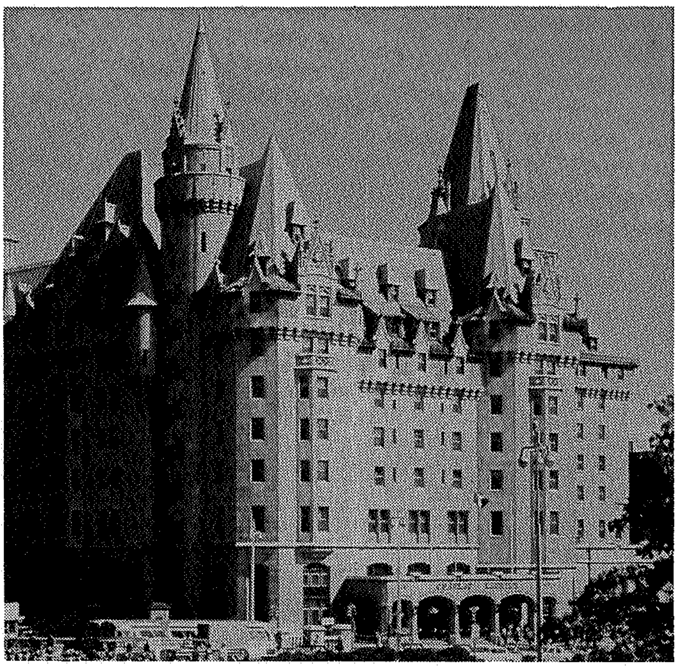
Preliminary Notice

Intensive analysis on the characteristics and control of air flow into and within buildings is currently taking place. The purpose of the 12th AIVC Conference is to review progress in this field with special emphasis on applicability for ventilation design, optimisation and diagnostic analysis. Topics cover:

- Theory of Flow Mechanisms
- Calculation Techniques
- Measurement Methods
- Validation Methods and Data
- Application of Air Flow Simulation in Design
- Demand Controlled Ventilation Systems and Strategies

The conference fee will include full board accommodation on the conference dates.

To give us some idea of the number of likely attendees, please would persons who may be attending return the following form to the AIVC. This application is not binding.



Attention Conference Delegates

I am considering attending the AIVC 12th Conference in Canada, September 1991. Please send me full details when available.

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New Technical Note from the AIVC

Technical Note 32, January 1991

Reporting Guidelines for the Measurement of Airflows and Related Factors in Buildings

David T Harrje, Visiting Specialist, AIVC & James M Piggins, Project Scientist, AIVC

One of the aims of the Air Infiltration and Ventilation Centre is to encourage the collection and dissemination of air infiltration and airflow data as well as energy use data arising from programmes of research and experimental investigation. This task can be made much easier and more effective if the relevant test information and results are presented in a comprehensive and uniform manner.

The Reporting Guidelines have been produced to provide a common reference for research workers, wishing to plan experimental work or catalogue their experimental data, thus making complete information available for entry into a numerical database for subsequent analysis or mathematical model development. The guidelines have been designed to provide the necessary parameters for the calculation of airflow and airflow models, including those that emphasize pollutant factors, and for the validation of thermal models of building energy use. These parameters vary with the application and this has been taken into account. The basic reference for the guidelines is AIVC-TN 6, aided by work in IEA-ECB-Annex XX.

The guidelines structure is purposely rather loose, to cater to the differing interests of the various investigators who will be using it. It has been made as comprehensive as possible but should not be regarded as exclusive. Correspondingly, the user should not feel impelled to fill in all the sections; however, if the results are entered in the order given, it immediately becomes apparent which items of information are present and which absent. Some parameters are more important than others, and this has been highlighted using an Applicability Coding.

The Applicability Code is stated in the parenthesis following each item, as follows:

R = Required, I = Important, U = Useful.

If these codes are listed alone they are assumed to apply to all applications. Individual applications are:

- 1 = Parameters for airflow measurements and models; e.g. model validation, stock characterisation or design studies.

- 2 = Additional parameters for air flow models that include pollutant factors; e.g. indoor air quality work.

- 3 = Additional parameters for thermal measurement and models, e.g. model validation, energy use calculations. If the requirement is for cooling models only it will be noted as -3C;

- 4 = Additional parameters for comfort-related questions that involve: temperature stratification, room airflow, ventilation effectiveness, radiation, etc.

Attention Conference Delegates

AIVC 12th Annual Conference

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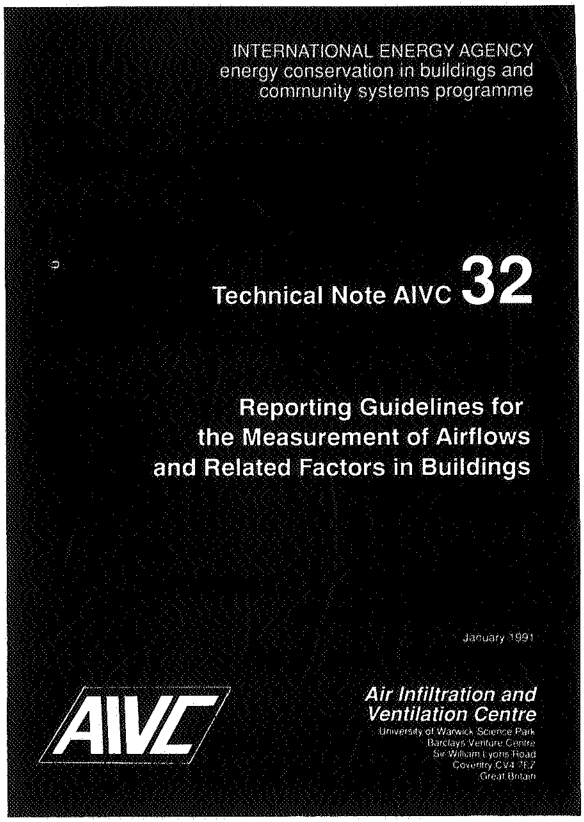
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Technical Note AIVC 32

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January 1991

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Great Britain

Thus an important parameter that would be applied to an airflow model involving pollutants would be listed as (I-2).

The Guidelines may be used directly for entering results and should also serve as a useful checklist to aid those who are initiating projects. Recognising that experimental data today relies heavily upon the computer for both collection and storage, the guidelines have taken this into account. Using a compiled dBase IV application developed by the Centre, text data may be entered in the structure of the guidelines, stored on disk in dBASE IV format and a report produced, an example of such a report is included in the Guidelines. This application will be available from the centre on 3" or 5" disk so that data entry can be further streamlined and made more uniform. Any numerical data supplied to the Centre should be backed up by a report produced according to these guidelines, preferably on disk.

The Reporting Guidelines are split into ten sections:

- General Information, emphasising the purpose and approach used and how to contact the project leaders.
- Test Site Description, including geographic and climatic information.
- Building Description, including leakage paths, heating and ventilation systems, etc.
- Operation/Function of Building, including occupancy and pollutant sources.
- Measurements, procedures, equipment characteristics and accuracy.
- Economic Factors, especially energy savings evaluations.
- Numerical/Computer Models, plus comparison to measurements.
- Disk Data Files, describing data files, formats, and contents.
- General Remarks, and the opportunity to supply conclusions.
- Examples of Reporting Guidelines Application.

The contents of each section are printed on the right-hand pages of the report and are accompanied by explanatory notes on the left-hand pages. Points relevant to the use of various measurement methods are raised in the notes. Also included are details of minimum standards of measurement where these have been indicated by past experience or are predicted to be future requirements.

The AIVC will be pleased to receive copies of the completed Guidelines along with associated numerical data for inclusion in the Centre's numerical database. An up-to-date record of the contents of this database is maintained and copies of the data will be available through the nominated organisations in the participating countries.

Forthcoming Conferences

A New Decade of Progress
The 1991 International Symposium on Radon and Radon Reduction Technology

April 2-5 1991, Philadelphia, Pennsylvania, USA

Further details from:

CRCPD, 205 Capitol Ave, Frankfort, KY 40601, USA,
Fax 502 227 7862

Indoor Environment '91
Chicago, Illinois

April 14-16, 1991, Chicago, Illinois, USA

Further details from:

Ian Chin, Wiss, Janney & Elstner Assoc., 29 Wacker Drive, Suite 555, Chicago, IL 60606, USA, Tel: 312 372 0555

Indoor Air Pollution Symposium

May 2-3 1991,Tulsa, Oklahoma, USA

Further details from:

Centre for Environmental Research & Technology, University of Tulsa, 600 South College Avenue, Tulsa, OK 74104, Tel: 918 749 4358

Measurement of Toxic and Related Air Pollutants

May 7-10 1991,Durham, North Carolina, USA

Further details from:

Jon Fedorka, A & WMA, P O Box 2861, Pittsburgh, PA 15230, USA, Tel: 412 232 3444

IAI Indoor Air International
International Conference: Priorities for Indoor Air Research and Action

May 29-31 1991
Hyatt Continental Hotel, Montreux, Switzerland

Further details from:

Priorities for Indoor Air Research and Action, PO Box 460, Biggleswade, Beds SG18 0AW, England, Tel: +44(0)767 318 474, Fax: +44(0)767 313 929

IBSPA-BS 91
Building Simulation '91
2nd World Congress on Technology improving the Energy Use, Comfort, and Economics of Buildings Worldwide

20-22 August 1991
Nice, Sophia-Antipolis, France

Further details from:

IBSPA-BS '91, Society for Computer Simulation, c/o Philippe Geril, Coupure Links 653, B-9000 Ghent, Belgium, Tel and Fax: 32 91 23 49 41

ISEE 1991
1991 International Symposium on Energy and Environment

25-28 August 1991Espoo, Finland

Further details from:

ISEE International Symposium, Energy and Environment, Helsinki University of Technology, Centre of Energy Technology, Otakaari 4, 02150 Espoo, Finland, Tel: +358 0 451 3580, Fax: +358 0 451 3419, Telex: 125161 htkk sf

Ventilation '91
3rd International Symposium On Ventilation For Contaminant Control

16-20 September 1991Omni Netherland Plaza, Cincinnati, Ohio, USA

Further details from:

Ventilation '91, American Conference of Governmental Industrial Hygienists, 6500 Glenway Avenue, Building D-7, Cincinnati, Ohio 45211-4438, USA

Air Movement and Ventilation Control within Buildings
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24-27 September 1990
Chateau Laurier, Ottawa, Canada

Further details from:

AIVC, Barclays Venture Centre, University of Warwick Science Park, Sir William Lyons Road, Coventry, CV4 7EZ, Great Britain

PLEA 91
The Ninth International PLEA Conference: Architecture and Urban Space

24-27 September 1991Seville, Spain

Further details from:

Adesa, PLEA 91, Apartado 1.183, 41080 Seville, Spain
Tel: (34) (5) 4 23 55 11, Fax: (34) (5) 4 23 62 68

Environmental Quality
ASHRAE Conference

5-8 November 1991Hong Kong Convection and Exhibition Centre, Hong Kong

Further details from:

ASHRAE, Program Coordinator, 1791 Tullie Circle, NE, Atlanta, Georgia 30329, USA

CIB 92
World Building Congress

18-22 May 1992 Montreal, Canada

Themes and Viewpoints: 1. New Materials and Systems, 2. Rehabilitation and Restoration, 3. Environment, 4. Globalization, 5. Computers and Robotics

Further details from:

Congress Secretariat, CIB '92 World Building Congress, National Research Council Canada, Ottawa, Canada K1A 0R6

Roomvent '92

2-4 September 1992
Aalborg, Denmark

Further details from:

Professor Peter V Nielsen, AUC Denmark, Sohnengaardsholmvej 57, DK-9000 Aalborg, Denmark

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Air Infiltration Review. Quarterly newsletter containing topical and informative articles on air infiltration research and application.

Recent Additions to AIRBASE. Quarterly bulletin of abstracts added to AIRBASE, AIVC's bibliographic database.

GUIDES AND HANDBOOKS

Applications Guide 1 (1986) Liddament, M.W. 'Air Infiltration Calculation Techniques - An Applications Guide'

Applications Guide 2 (1988) Charlesworth, P.S. 'Air Exchange Rate and Airtightness Measurement Techniques - An Application Guide'

Handbook (1983) Elmroth, A. Levin, P. 'Air infiltration control in housing. A guide to international practice.'

TECHNICAL NOTES

TN 5 (1981) Allen, C. 'AIRGLOSS; Air Infiltration Glossary (English edition)'
TN 5.1 (1983), 5.2 (1984), 5.3(1985), 5.4(1988) Allen, C. 'AIRGLOSS'; Air Infiltration Glossaries (German, French, Italian and Dutch) Supplements.
TN 10 (1983) Liddament, M,, Thompson, C. 'Techniques and instrumentation for the measurement of air infiltration in buildings - a brief review and annotated bibliography'
TN 11 (1983) Liddament, M., Allen, C. 'The validation and comparison of mathematical models of air infiltration'
TN 13 (1984) Allen,C. 'Wind pressure data requirements for air infiltration calculations'
TN 13.1 (1984) '1984 Wind Pressure Workshop Proceedings'.
TN 16 (1985) Allen,C. 'Leakage Distribution in Buildings'
TN 17 (1985) Parfitt, Y. 'Ventilation Strategy - A Selected Bibliography'
TN 20 (1987) 'Airborne moisture transfer: New Zealand workshop proceedings and bibliographic review'
TN 21 (1987) Liddament, M.W. 'A review and bibliography of ventilation effectiveness - definitions, measurement, design and calculation'
TN 23 (1988) Dubrul,C. 'Inhabitants' behaviour with regard to ventilation.
TN 24 (1988) 'AIVC Measurement Techniques Workshop: Proceedings and Bibliography'
TN 25 (1989) Blacknell,J. 'A subject analysis of the AIVC's bibliographic database - AIRBASE',
TN 26 (1989) Haberda,F and Trepte,L. IEA Annex IX 'Minimum ventilation rates and measures for controlling indoor air quality.
TN 27 (1990) Bassett, M. 'Infiltration and leakage paths in single family houses. A multizone infiltration case study.'
TN 28 (1990) Sutcliffe, H. 'A guide to air change efficiency.'
TN 29 (1990) Feustel, H E, et al 'Fundamentals of the multizone air flow model - COMIS.'
TN30 (1990) Colthorpe, K 'A review of building airtightness and ventilation standards.'
TN31 (1990) Limb, M 'AIVC's fifth worldwide survey of current research into air infiltration, ventilation and indoor air quality.'
DCV (1990) Raatschen, W (ed.) Demand controlled ventilating system: state of the art review.' Annex 18 report.
TN32 (1991) Harrje DT, Piggins JT 'Reporting guidelines for the measurement of airflows and related factors in buildings.'

AIVC CONFERENCE PROCEEDINGS

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