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Drawing Conclusions from Measurement Programs

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1: The 1991 Swedish Energy and Indoor Climate Survey

This paper discusses some inference problems in measurement programs. The 1991 Swedish energy and indoor climate survey is chosen for the purpose of illustration.

The Swedish survey is carried out within the research program "Conservation of Electricity in Existing Buildings" (ELIB). This research program addresses the need to increase the energy efficiency and improve the indoor climate of the Swedish building stock and is currently being be carried out (1990-93). It consists of the following three projects:

Project 1. Technical characteristics of the Swedish housing stock. the objective of this project is to describe the technical characteristics of the existing building stock with regard to energy usage and with special emphasis on use of electricity. This description will also be used in the other two projects of the program.

Project 2. Indoor climate of the Swedish housing stock. The objective of this project is to roughly describe the indoor climate of the housing stock. This description will constitute a support for considerations on how the indoor climate is related to the technical characteristics and usage of the dwellings. The results are also to be used as support in estimating how the indoor climate affects the health and well being of the people.

The descriptive information required about a number of indoor climate variables might look like figure 1. In the Swedish regulations it is prescribed or recommended that a number of particular indoor air quality variables (IAQ-variables) should not exceed, fall below or be kept within certain levels. Some of these levels are presently being discussed, e.g., the prescribed ventilation level of 0.5 air changes per hour. For a number of variables there are no levels prescribed at all. Two reasons for this are insufficient knowledge of occurring levels and dose-response relationships. The harmful health effects are known for just a few chemical substances like radon and

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formaldehyde. The interaction effects are often not known at all.

Additional questions to be answered in descriptions are: "Which types of houses have too high or too low levels of IAQ-variables?", "In which parts of the country are these houses located?", "How is the level related to the ventilation level and to the technical characteristics of the house such as type of ventilation system and foundations?", "How is the indoor climate perceived by the residents?", and "What are their symptoms?"

Thus, one should seek to combine factual information as illustrated by Figure 1 with appurtenant information in the form of indoor climate assessments by the residents and technical characteristics of existing houses. The physical IAQ-measurements should be aggregated and broken down by, inter alia, type of house, age of house and type of region. The physical measurements should also be related to the type and status of the ventilation, heating and control systems and to subjective assessments of the indoor climate by the residents. Indoor variables of prime concern are levels of indoor air temperature, ventilation, air humidity, volatile organic compounds, VOCs, formaldehyde and radon.

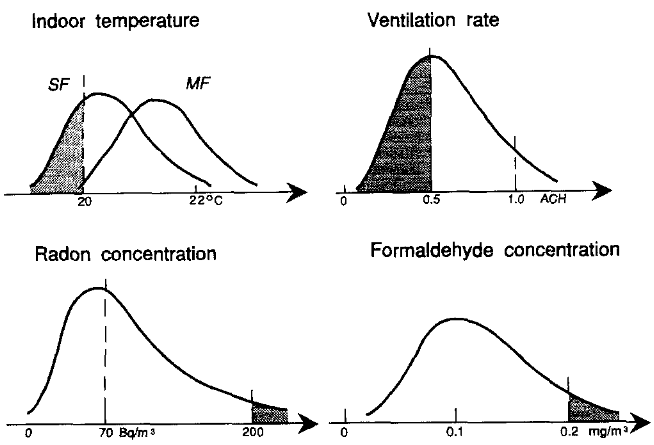

Figure 1 Hypothesized distributions of number of houses by level of indoor air quality variables. Indicated are levels presently prescribed or discussed in Sweden. SF = Single-family houses. MF = Multi-family houses

Project 3. Energy conservation potentials in the Swedish housing stock. The objective of this project is to calculate theoretical potentials for energy conservation and corresponding costs of implementation. Results will be calculated for a number of alternative developments of energy prices. Prognoses on the consumption of energy and environmental impacts will be made under different assumptions on the development of different markets and interventions of authorities.

A computer simulation model using data gathered in the other two projects is being developed for calculation of these potentials and prognoses. Special considerations will be made in the development of this simulation model in order to fulfill the demand of fast and economical ways to carry out the calculations and for analyses of sensitivities of the final results with respect to the assumptions used.

The program is funded by the Swedish Council for Building Research, the Department of Housing and the National Energy Administration.

All projects are based on statistical sample surveys. This paper discusses mainly one of these surveys, i.e., the 1,200-house sample survey. The selection of the 1,200-house sample was carried out in a step wise fashion using multi-stage sampling. Firstly, 60 municipalities were selected by probabilities proportional to their size from the 284 municipalities in Sweden. Then real-estates were selected in the chosen municipalities. Finally, one house was selected on each real-estate.

Data from the selected houses were collected on site, based on a special inspection form. The variables recorded are type and age of the house; the heated floor area and building-volume; areas and U-values of the floor structure, the external walls, the windows and the attic; type and status of the roof, wall and foundation constructions, the heating system and the control system.

Air Infiltration Review

Editor: Janet Blacknell

Air Infiltration Review has a quarterly circulation of 3,500 copies and is currently distributed to organisations in 40 countries. Short articles or correspondence of a general technical nature related to the subject of air infiltration and ventilation are welcome for possible inclusion in AIR. Articles intended for publication must be written in English and should not exceed 1,500 words in length. If you wish to contribute to AIR, please contact the Air Infiltration and Ventilation Centre.

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Consultants with a suitable technical background were engaged to perform the field work. They were given training consisting of how to perform inspections and climate measurements. They also performed a trial inspection and a set of trial measurements.

The technical measurements are all of the passive integrating type giving monthly averages of indoor temperature, ventilation rate, relative humidity, radon concentration, formaldehyde and VOC concentrations. The chosen techniques are relatively inexpensive and were considered to be simple and accurate enough to be used in the present large-scale survey.

All but two of the different types of measurements have been carried out in some 1,600 apartments in the 1,200-house sample. Formaldehyde and VOC concentrations have been measured in a 200-house subsample. In each apartment, the variables were measured in a number of room-units, in the living room, in the largest bedroom and/or in the kitchen, according to detailed instructions given by the survey staff. The tubes containing tracers for the ventilation measurements were installed close to the largest air inlets, also according to instructions.

2: An Overview of Inference Problems

The data collected may be used for production of results of many different types. The results concern descriptions such as the average U-value of the envelopes of the houses. Other results will be given in the form of assessments of "energy and indoor climate impacts" following different courses of action. The results may also be more or less general with respect to time and space. Some results may concern the status of the housing stock at a particular point of time, say the status of the housing stock in the winter 91/92 when the inspections were carried out. Other results may concern the status at some future point of time when a number of measures in the housing stock have been implemented. Still other results may concern houses belonging to a particular subgroup of houses, e.g., only those buildings inspected or all Swedish electrically heated houses. Finally, the results may be more or less accurate.

In producing a particular result we link the data collected with one or more theories of how the data are linked with each other and with the houses investigated. Of course, these links or models may be of different types depending on the type of data used and type of results aimed at:

Measurement error model. Firstly, we need to know the relationships between collected values of the variables and actual properties of the houses investigated. These relationships may be summarized by a measurement error model telling, e.g., the relationship between the energy use, say the average total energy consumption for space and hot water a particular year, and a collected energy figure. These relationships may be illustrated in the following way:

Measured values of the variables

(Measurement error model)

Actual values of of the variables

Sampling model. Secondly, in statistical sample surveys we use the collected data about a sample of houses to draw conclusions about the population of houses from which the sampled houses were selected. These conclusions or inferences are obtained by using a sampling model. This model is constructed using the method for the selection of the houses as the point of departure:

Selected houses

(Sampling model)

Population of houses

We may make the sampling model somewhat more complicated by taking also the non-response into account:

Selected houses for which data are collected

(Non-response model)

Selected houses

(Sampling model)

Population of houses

Population model. Thirdly, we may want to use the data for making inferences about another population of houses than the population from which the sample was drawn. We then use what we call a population model. This model links the properties of the studied population with properties of the other (larger) population:

Studied population

(Population model)

Other population

Prediction model. Fourthly, often the values obtained for a particular period of time are not so interesting as the values for some future period of time or for some particular period of time ("reference period"). A ventilation rate may be measured during a "warm climate" but we are more interested in the ventilation rate during a "normal climate", say during average winter conditions or some other referenced period of time). We call these types of methods for transforming measured values prediction models. Hence:

Studied period of time

Prediction model

Future or reference period of time

Cause-effect model. Fifthly, the collected data may be used as input in calculations of, e.g. the savings obtained by energy conservation measures. These calculations are based on a theory in the form of assumed cause-effect relationships. Inevitably the results are, however, more or less accurate:

Measurements

Cause-effect model

Calculated figures

Summary. Summarizing the discussion so far we obtain the scheme in Figure 2. This figure gives an account of models needed to draw conclusions of different realms in a measurement program carried out within a statistical sample survey.

Spatial dimension of inference	Time dimension of inference: Directly studied properties		Calculated properties	
	Measurement period	Future period of time	Measurement period	Future period of time
The houses investigated	*Measurement error model*	*Measurement error model* *Prediction model*	*Measurement error model* *Cause-effect model*	*Measurement error model* *Prediction model* *Cause-effect model*
The houses in the population	*Measurement error model* *Sampling model*	*Measurement error model* *Sampling model* *Prediction model*	*Measurement error model* *Sampling model* *Cause-effect model*	*Measurement error model* *Sampling model* *Prediction model* *Cause-effect model*
The houses in some other population	*Measurement error model* *Sampling model* *Population model*	*Measurement error model* *Sampling model* *Population model* *Prediction model*	*Measurement error model* *Sampling model* *Population model* *Cause-effect model*	*Measurement error model* *Sampling model* *Population model* *Prediction model* *Cause-effect model*

Figure 2 Scheme of models for making inferences from a statistical sample survey.

3: A Simple Sampling Model: Weighting Collected Data (Hans Högberg, SIB)

Statistical theory gives a basis for constructing a sampling model. The houses are then selected in such a way that conclusions about the population of houses can be drawn from the selected ones. The sampled houses should "mirror" the entire population of houses.

The sampling model includes:

- A scheme for selecting houses from a frame listing all houses in the population, either house by house or in an aggregated way.
- A mathematical formula for construction of weights for each selected house quantifying the "representativeness" of these houses.
- A mathematical formula for quantifying the sampling error in the results obtained.

There may also be other aspects to be taken into account in the sampling model, e.g., nonresponse and noncoverage between the sampling frame and target population. We take these aspects into account by adding a nonresponse model and/or noncoverage model to the sampling model.

Construction of weights. According to our present plans, the parameter estimates will mainly be based on the Horvitz and Thompson (1952) estimator. We may write this estimator of a population total as

$$\hat{Y} = \sum_{i=1}^{D} w_i y_i = \sum_{i=1}^{D} \frac{y_i}{\pi_i} \qquad (1)$$

where π_i is the selection (inclusion) probability, w_i is our weight, y_i is the value of the variable obtained for house number i, and where the sum is extended over all n_D houses selected in domain D.

Hence, the weight w_i is the reciprocal of the inclusion probability for house number i. For a general discussion of how to construct survey weights, see, e.g., Särndal et al (1992).

Consider a selected house in our survey. The inclusion probability may be written as a product of three factors:

$\pi°$ = Prob (Municipality selected)*

Prob (Property selected / Municipality selected)*

Prob (House selected / Property selected) (2)

In the estimation of a parameter describing the population only data from those houses with collected values for all the variables involved in the estimation can be used. Hence, the inclusion probabilities, and accordingly the weights, must be adjusted for nonresponse. Summing up, the inclusion probability may be written as a product π of four factors consisting of the three factors defining π° in (2) times the following factor

$\pi^{\circ\circ}$ = Prob (House investigated / House selected)(3)

if we assume that nonresponse occurs by chance within the particular domain.

Estimation of the sampling error. Drawing conclusions using the estimator (1) requires use of the concept of sampling error. It is necessary to find reasonably accurate and computable techniques to obtain quantitative measures for the size of the sampling errors.

One such quantitative measure is the standard error of the estimate. The standard error is the square-root of the variance of (1). Estimation of this variance in a complex survey design, of perhaps a complex parameter, is complicated. To indicate the complication, we need to compute the inclusion probabilities of both the i:th and the j:th house in the sample for all pair of houses. In terms of π, we need to have π_{ij} for all pair of houses. We will, therefore, consider approximating variances by using the following estimator of variance

$$\hat{V}(\hat{Y}) = \sum_{i=1}^{D} \frac{y_i^2}{\pi_i^2} - \frac{1}{n_D}\hat{Y}^2 \qquad (4)$$

This approximation is obtained if we consider the houses as having been selected independently of each other with replacement by a sequence of n_D independent random drawings. The probability of selecting house number 1 is equal to π_i / n_D in each drawing.

The variance estimator (2) is more or less accurate. There are factors in the sampling design which gives reasons to believe that the variance estimators tend to give underestimates as well as overestimates. The net effect of these factors will be studied.

Construction of a confidence interval. The estimated variance, or rather, its square-root, is used to construct confidence intervals (CI). A confidence interval is a random interval. The probability that an unknown total Y is contained in the interval CI(s) is

$$Prob\ [\ CI(s) \ni Y\ ] = 1 - \alpha \qquad (5)$$

where s denotes the sample and α is the accumulated probability of those samples s for which the interval fails to include Y. The figure 1- α is called the confidence level. Normally the confidence level is chosen to be close to 1.

The confidence interval for the unknown Y may be constructed as follows:

$$\hat{Y} \pm z_{1-\alpha/2}\,[\hat{V}(\hat{Y})]^{1/2} \qquad (6)$$

where $z_{1-\alpha/.2}$ usually is a chosen constant near 2. The interpretation of the confidence interval is that the interval contains the unknown Y with the probability 1 approximately. This means that about 100(1- α) percent of all possible samples s drawn with the given design contain Y.

4: A Complex Sampling Model: Computing Density Distributions (Tommy Waller, SIB)

Figure 1 shows hypothesized distributions for a number of IAQ-variables studied in the survey. The vertical axis for the distribution curves shows number of houses and the horizontal axis contains values for the IAQ-variables.

One objective of our survey is to get good estimates of the actual distributions for the IAQ-variables. This is valuable for several reasons. For example, such distributions will, in a clear and visible way, show the proportions of the houses which are having values within the prescribed or recommended levels for the IAQ-variables. If we let Ap be the area of the distribution that lies within the prescribed levels and A the total area of the distribution, this proportion is equal to the ratio Ap/A.

In statistics it is customary to change the vertical scale of the distribution through multiplication by 1/A. Then the total area will be 1 and the distribution becomes a probability distribution. The function expressed by the distribution curve is a probability density function - and estimation of this function is consequently called density estimation.

One approach to density estimation is to assume that the distribution underlying the data belongs to a parametric family of distributions, for example the normal distribution. The parameters (mean and variance in the case of a normal distribution) are then estimated from the data and substituted in the formula for the density function. In this case it is important to investigate how well the assumed parametric family fits the data, for example through the construction of histograms.

The histogram is the oldest and most widely used density estimator. Because it shows the data (and not any superimposed function) it is an excellent tool for data analysis and presentation. However, histograms have two drawbacks:

Histograms are discontinuous which makes them unsuitable if derivatives (slopes of the curve) are needed in the analysis.

Histograms are sensitive for the choice of midpoints and can have rather different shape for the same data when the midpoints are altered.

There are methods of density estimation which (just like the histogram) allow data to speak for themselves and (contrary to the histogram) produced a smooth curve, see Silverman (1986). These methods have rather recently acquired a broader practical application. The most common of these density estimators is the kernel estimator. If we have a sample of n observations (X1, X2,...,Xn) the kernel estimator is defined by:

$$\hat{f}(x) = \frac{1}{n}\frac{1}{h}\sum_{i=1}^{n} K\left(\frac{x-X_i}{h}\right) \qquad (7)$$

where K is the kernel function which satisfies the condition that its integral is 1, and where h is the bandwidth or smoothing parameter.

According to the above formula a kernel or 'bump' ($K[x-X_i)/h]/nh$) is placed at every observation. Then all 'bumps' are added to get the kernel density estimator. Any continuous function which satisfies the integral = 1 condition can be used as kernel function. One possible kernel is the normal (Gaussian) density function and other examples are the: Rectangular, triangular, biweight and Epanechnikov kernels.

The choice of bandwidth is of crucial importance in density estimation. If the bandwidth is chosen too narrow, spurious noise will appear. If the bandwidth is chosen too wide, all structure and detail will be obscured.

The number of observations required to perform kernel density estimation depends on the shape of the distribution. If the distribution has a symmetric and simple form perhaps 100 observations will be enough but if the distribution is very skew or has detailed structure such as multimodality a lot more (perhaps thousands) observations will be needed to obtain good density estimates.

The sample in our survey is a probability or π - weighted sample where each observation is weighted by the inverse of the probability of selection and response. With these survey weights it is straightforward to compute point estimates of various characteristics of the population - and estimates of the sampling errors in the point estimates.

However, the literature on density estimation does not seem to say so much about survey weights and sampling errors. Therefore, two additional problems in our survey will be:

- The treatment of survey weights in the computations of density estimates.
- The estimation of sampling errors in the density estimates.

5: A Prediction Model: Climate Correction of Ventilation Measurements (Johnny Kronvall, Technergo)

The measurements of building ventilation are related to about one month with the specific outdoor climate prevailing during that particular period of time.

In order to be able to use these measurement data for estimating the ventilation rate of a more extended time base. e.g., the heating season or an "average" heating season, it is necessary to have a procedure for such an extrapolation. In our terminology, we need a prediction model for this purpose.

There are at least two principal approaches possible; the first being essentially a statistical one. We then use our large number of ventilation rate measurements under different climatic conditions for different types of houses with respect to their size, age and type of ventilation. By regression analysis we try to obtain statistical relationships between ventilation rate and factors affecting this rate. These relationships could then be used to estimate - or predict - the ventilation rate for each investigated house for given climatic conditions.

A second approach would be to use a theoretical model for the relationships, where the air tightness performance of the house is taken into account.

We have some doubts concerning the merits of the first approach because only one ventilation measurement is carried out in each selected house. The variation in the measurement results is expected to reflect more the variation between the investigated houses than the variation caused by varying climatic conditions.

The second approach using a theoretically based prediction model will be studied. The following prediction model in the form of a ventilation model is proposed (Kronvall, 1980):

$$n = n_{50} / 50^{\beta}[c_1\ (\theta_{int} - \theta_{ext}) + c_2 u^2]^{\beta} \qquad (8)$$

where

n = Ventilation rate due to infiltration through building envelope and purpose provided openings in the envelope [ach]

n_{50} = Specific air leakage at 50 Pa [ach]

θ_{int} = Internal temperature [K]

θ_{ext} = External temperature [K]

β = Flow exponent from pressurization curve [-]

c_1 = Model coefficient [Pa/K]

c_2 = Model coefficient [Pa/(m/s)^2]

u = Wind speed [m/s]

The model coefficients c_1 and c_2 are planned to be established for a set of "typical buildings" by means of simulations using a simple single zone ventilation and infiltration model, viz. the AIDA model from the AIVC.

The specific air leakage at 50Pa(n_{50}) for the building will be estimated based on empirical knowledge using a particular scheme in which factors such as age of building, construction type etc. are taken into account. Probably there is a strong correlation between n_{50} and the exponent β, cf. Figure 3. This will be analyzed using some hundreds of pressurization test results.

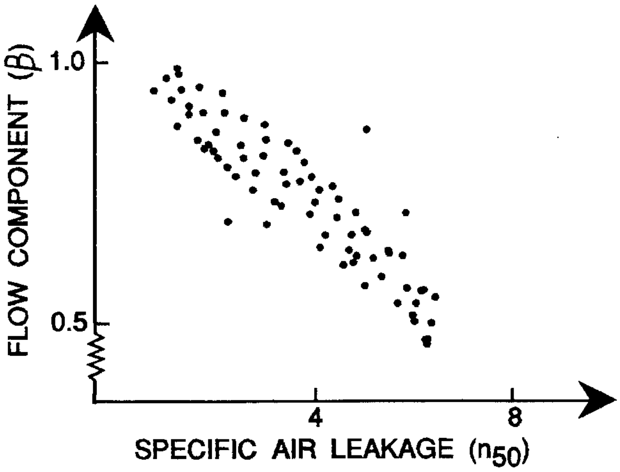

Figure 3 Tentative distribution of the flow exponent β for houses with different air-tightnesses n_{50}.

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Chilled Ceilings and Ventilating Systems Thermal Comfort and Energy Saving

Günther Mertz, Operating Agent of the Fachinstitut Gebäude-Klima e.V., Germany.

The technology of chilled ceilings is currently a favourite issue among HVAC technicians. In this article, Gunther Mertz describes the advantages of this system.

There are different ways to remove the indoor cooling load: by supplying cool air or through heat exchangers or by cooling the building components. Another method is to lower the surface temperature of the ceiling either partly or entirely to a level below room temperature. This system is called "chilled ceiling cooling".

The influence of chilled ceilings on the thermal comfort is clearly positive as the air flow rate can be reduced so that the air velocity in the occupied zone decreases as well.

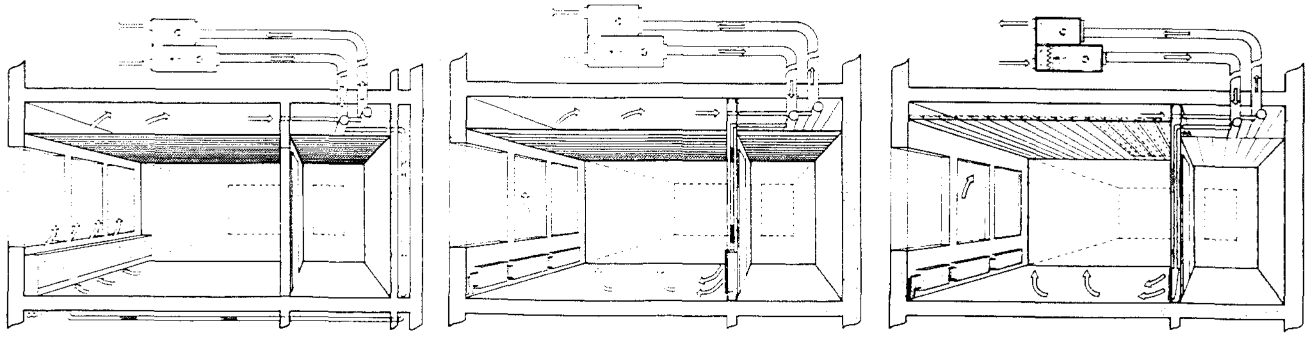
The structure of a chilled ceiling system in offices is relatively simple: the spare heat is cooled by cold water flowing through the ceiling. At the same time, ventilation is effected by low-velocity outlets near the floor (see fig.1) while the heating devices are located conventionally underneath the windows.

Up to now, this system has been installed in many offices, shopping malls etc., and it proved to be worthwhile. In Germany this technique gains more and more importance, especially as the investment costs are proportionately favourable compared to the actual cooling load in offices. Since chilling with water does not produce any noise, as opposed to air cooling, the experts also speak of "silent cooling".

Nevertheless, chilled ceilings always ought to be combined with a ventilating system. Firstly because chilled ceilings only lower the room temperature but do not supply fresh air. Secondly because they extract sensible heat but not latent heat - apart from special versions. Latent heat is produced by moisture emission from occupants, plants etc., and increases the indoor moisture load.

Improving Indoor Climate

To improve the air quality and to diminish draughts, HVAC-technicians more and more focus on displacement flows. The cooling performance of this system was often limited, however, for it produced



VAS Induction - twin pipe system.

Constant Volume flow system with conventional radiators and displacement flow.

Chilled ceiling with central primary air supply, radiators and displacement flow.

Figure 1

temperature stratification at ground level in rooms with low temperatures. According to many experts, this is why the introduction of the system on a broad base has not taken place yet. In combination with chilled ceilings, this typical disadvantage of displacement flow can now be avoided as the ventilation system only has to replace the air - the cooling is done by the ceiling. Since the human body is capable of balancing radiation, the slightly lower ceiling temperature makes the occupant perceive the room temperature to be 2°C lower than it actually is - even at higher room air temperatures (i.e. 26-28°C or 79-82°F). This effect increases comfort, saves energy and allows the reduction of the system's size.

Air quality is determined by the percentage of volatile organic compounds and odours in the air. Mainly in Scandinavia, new benchmarks were again developed concerning this subject and the application of displacement flow systems represents the logical consequence of the research results. With this kind of air flow, up to four times lower contaminant concentrations were measured in conference rooms at inhalation level, compared to the results obtained with conventional mixing ventilating systems.

Moreover, the air quantity is determined in accordance with the required degree of air renewal and remains stable during operation. Since no recirculated air is added, no contaminants are distributed into other rooms through the ventilating system either.

Chilled Ceiling and Ventilating Systems

Chilled ceilings do not contribute to the renewal of the indoor air. Therefore, they should run only as a support system in combination with a ventilating system or an air-conditioning system which ensures appropriate dehumidifying. With a sensible combination the chilled area relieves the strain on the ventilating system, i.e. the air flow is disconnected from the energy load. As a consequence, there are smaller supply air flows which ideally correspond with the external air flow required.

In principle, chilled ceilings can be combined with all kinds of ventilation systems. The latter are grouped into:

1. Ventilating systems to produce turbulent convection.
2. Ventilating systems to produce stratified flows
3. Combination of 1 and 2.

Chilled surfaces do not only contribute to radiation, but also to the energy exchange with the room through convection so that they interact with the prevailing air duct circuit. The latter can produce different room air flows, mainly mixed and stratified flows. The turbulent convection arises from air inlets creating highly inductive air radiation with a strong momentum flux.

As a result of the strong mixing of indoor and supply air an equal distribution of the thermal load and the contaminants is achieved. To this group belong ceiling and wall grilles with high momentum fluxes (e.g. ceiling swirl grilles, slotted outlets and vortex outlets. When cold supply air is blasted in at floor level, a stratified flow might be produced.

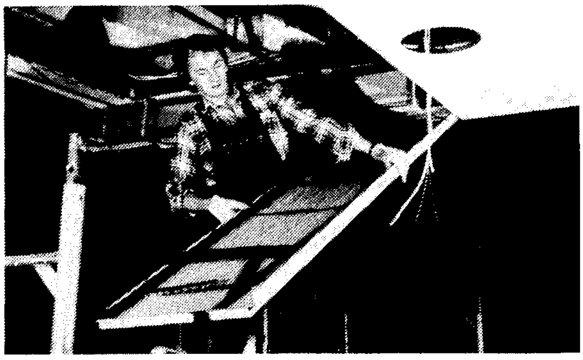
Due to thermal effects, warm air rises and is extracted at ceiling level. In this way, more or less distinct layers of different thermal features and compounds are created.

Underneath the ceiling, the temperature and the contaminant concentration are higher than at working level. The distinction of these layers depends on several factors such as the momentum flux of the supply air, the height of the room, the distribution of the thermal load and the frequency in which the occupants move around.

The windows may well be opened provided that there are sufficient control measures to prevent the temperature from falling below the dew point. Before opening the windows, however, the chilling system ought to be switched off for energetic reasons.

Chilled Ceiling and Ceiling Constructions

Another important feature is the small space this system requires thanks to the low ceiling construction. This results in lower costs of the building shells. Compared to air, the heat capacity of



The installation of the system's cooling panels is relatively simple.

water is four times higher and its density is 800 times higher, respectively.

Cooling systems made of steel, copper, aluminium or synthetic material are commercially available for all kinds of ceiling construction. The cooling system can be integrated directly into the ceiling plaster or into a lowered plaster ceiling, a lowered metal panel ceiling, or a lowered open grid ceiling.

Not only plastered ceiling surfaces can be designed but all kinds of geometrical shapes with processed metal ceilings as well. Illumination devices, air outlets, sprinklers etc. can be easily integrated.

In Combination with Heating

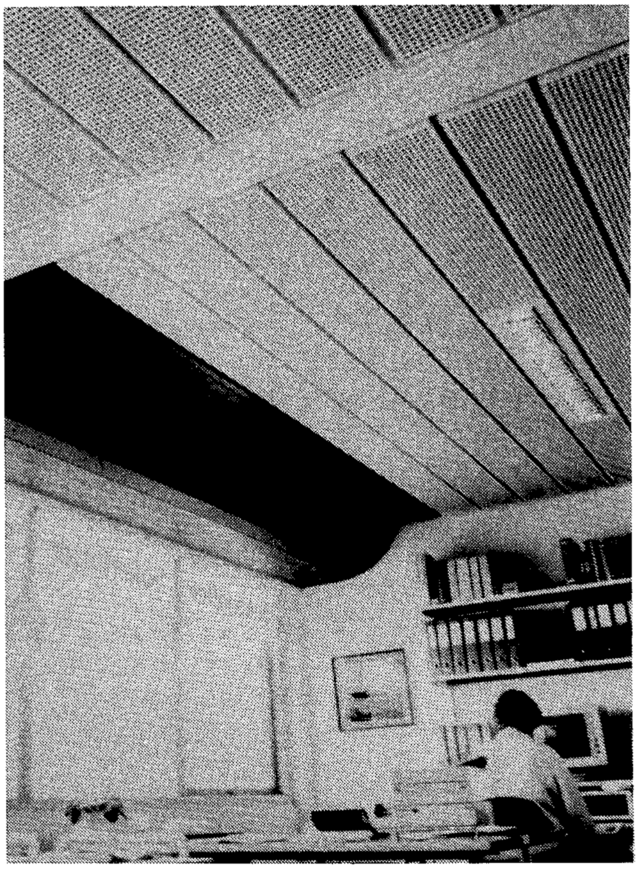
From the construction point of view, cooling systems working on the radiation principle can equally be used for heating purposes. There are radiation heating systems for ceilings built in mainly industrial plants. In all other domains, chilled ceilings cannot replace other heating systems for comfort and energetic reasons. As for the latter, it is important to know that - in case the chilled ceiling does provide the heating, too - a layer of warm air is built up right underneath the ceiling and is usually immediately extracted by outlets situated at this level, leading in this way to a higher energy consumption.

Controlling

As for the controlling of chilled ceilings, there are two requirements: firstly, the control of the system's performance, secondly, the safeguarding against sweating. Both, the control of the water quantity and of the forerun temperature have proved to be appropriate measures regarding the performance control. Sweating above the chilled ceiling occurs much less often than is generally assumed.

The safeguarding against sweating is done by a sensor in the water forerun or by a surface temperature sensing device which is connected to the motor valve.

If the temperature comes too close to the dew point, either the water current is stopped or the forerun temperature of the controlled area is increased. Moreover, it can be taken for granted that the heat carrying medium inside the chilled ceiling - whether water or air - does not produce any noise. Chilled ceilings do work extremely silently.



Chilled ceiling systems can be integrated without difficulties into the architecture of office buildings.

Performance Limits

Depending on how the chilled ceiling is constructed, the share of radiation/convection may differ. With a closed ceiling, radiation reaches its highest share with at least 55 per cent. Convection on the other hand increases when the air is led alongside the cooled surfaces. The performance of a chilled ceiling at a given room temperature is mainly limited by the lowest forerun temperature permissible which follows from the prevailing dew point temperature of the indoor air. Normal cooling loads hardly ever require forerun temperatures below 16°C (61°F). At this dew point temperature occupants start perceiving indoor climate to be muggy. To prevent the temperature from decreasing below the ceiling dew point and to maintain comfortable moisture degrees, it is advisable to combine ventilating and dehumidifying.

The performance is furthermore determined by the difference between forerun temperature and the average surface temperature of the chilled ceiling on which depends the degree of cooling. Here, low values between 1 and 1.5K can be realised and allow the prolonged energetically favourable use of "free cooling" by a water cooling tower.

The share of radiation and convection in the total heat absorption of the chilled ceiling depends on the ceiling's surface structure. The biggest share of radiation is achieved with smooth closed surfaces. Then, no air movement is required to extract most of the cooling load. If there are directly irradiating heat sources in the room (e.g. indirect illumination turned to the ceiling), the ceiling's share in radiation is even higher.

A heat transfer rise can be achieved through ribbed surfaces or by leading the air alongside the chilled surface. The limits of the cooling performance are between 90 and 130 Watt/m² active surface (at a perceived room temperature of 26°C (79°F) - depending on the construction of the ceiling and other conditions in the room.

Order of the Federal Republic of Germany presented to Professor Dr-Ing Fritz Steimle

Professor Steimle is the AIVC's Steering Group Representative for Germany.

On March 26th, 1992, the North Rhine-Westphalen Minister of Science and Research, Mrs Anke Brunn, presented Germany's highest decoration to Professor Dr-Ing Fritz Steimle.

Prof Steimle was awarded this in appreciation of his multiple national and international activities in the fields of air conditioning techniques and energy conservation. According to the Minister, an important justification was the fact that for more than fifteen years Prof Steimle has been chairman of the Fachinstitut Gebäude-Klima e.V. (which is the German representation of the AIVC). Besides, he has been the executive president of the International Institute for Refrigeration (IRR) for many years. Moreover, he has constantly committed himself to standardization as well as to the translation of scientific results into practice.

Professor Dr - Ing Fritz Steimle, AIVC Steering Group Member for Germany.

Contacting the Air Infiltration and Ventilation Centre

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AIVC 13th Annual Conference

Ventilation for Energy Efficiency and Optimum Indoor Air Quality

Tuesday 14th to Friday 18th September 1992, Hotal Plaza Concorde, Nice, France

The purpose of this conference is to identify the energy impact of ventilation and to assess the practical limit of ventilation as an air quality control mechanism. It is also intended that the conference should look to future research needs. The following programme lists the various topics to be considered.

Programme

Tuesday, 15th September

Afternoon

Registration

SESSION 1

Opening and Keynote Presentation

Optimisation of the Thermal and Ventilation Performance of Naturally Ventilated Building Facades. *M.J.Holmes & F. Cousins (UK)*

Healthy Building: An Energy Efficient Air Conditioned Office with Good Indoor Air Quality. *D J Dickson & P M Collins (UK)*

Controlled Background Ventilation for Large Commercial Buildings. *M D A E S Perera (UK)*

Ventilation and Building Characterization for Indoor Air Quality Investigations. *A.K. Persily (USA)*

A New Method for Linking Results from Detailed Air Flow Pattern Calculation with Multi-Zone Models. *A.Schalin, V.Dorer, J.van der Maas, A.Moser (Switzerland)*

Modelling Fluctuating Airflow Through Large Openings. *F.Haghighat(Canada) & J.Riberon (France)*

Evening

Reception

Wednesday, 16th September

SESSION 2
Ventilation Energy and Heat Recovery

Morning

Heat Recovery in Ventilation Systems. *F.Steimle & S. Schaedlich (Germany)*

The Energy Benefits of Sunspaces in Houses with Ventilation Heat Recovery. *R. Wiltshire & J. Littler (UK)*

METOP - Energy Efficient Office Building. *J. Laine & M. Saari (Finland)*

Economic & Energy Use Impact of Exhaust-only & Heat Recovery Ventilation. *M.A. Jackson (USA)*

Energy Savings by Balanced Ventilation with Heat Recovery & Ground Heat Exchanger. *H.Truemper, K-J.Albers & K.Hain (Germany)*

An Efficient Enthalpy Exchanger for Economical Ventilation. *W.B.Rose (USA)*

Free Afternoon

SESSION 3
Display Presentations

Evening

Introduction of Displays

Improved Indoor Environment & Ventilation in Schools - A Case Study in Vaxjo, Sweden. *R.Larsson & S.Olsson (Sweden)*

Air Movements & Air Change Rates Within Nucleus Hospitals. *R.E.Edwards & C.Irwin (UK)*

Factory Buildings: Estimating Ventilation Performance from Leakage Measurements. *R.R.Walker (UK)*

Evaluation of Indoor Climate & Indoor Air Quality in Offices. *D.J.Croome, G.Gan & H.B.Awbi (UK)*

Demand Controlled Ventilation- A Case Study. *B.Fleury (France)*

Efficiency Measurement of Kitchen Hoods. *P.Wouters (Belgium)*

EBES - Energy Efficient Residential Buildings. *J.Laine & M.Saari (Finland)*

Comparison of Four Different Air Conditioning Systems. *B.Barath (Germany)*

Energy Recovery in Ventilation Systems. *F.Dehli (Germany)*

Draughts Due to Air Inlets: An Experimental Approach. *J.Riberon & J.R.Millet (France)*

Practical Guidelines for Using Tracer Gases for the Evaluation of Ventilation Systems. *R.A.Grot (USA)*

A New Ventilation Strategy for Humidity Control in Dwellings. *J.B.Nielsen (Denmark)*

Operation of Passive Stack Systems in Summer. *A.Cripps (UK), J.R.Millet, J.G.Villenave, D.Bienfait, (France)*

Interaction of Heat Load and Air Supply in CAV Systems. *J.L.M.Hensen (Netherlands)*

Ventilation Requirements in Modern Buildings. *F.Steimle & J.Roeben (Germany)*

Comparison of Several Ventilation Systems for an Industrial Water Treatment Hall. *D.Blay & C.Niculae (France)*

Innovative Cooling Strategies. *S.J.Irving (UK)*

Thursday, 17th September

SESSION 4
Energy Use & Indoor Air Quality

Morning

Improved Ventilation Combined with Energy Efficiency in Naturally Ventilated Houses. *A.Blomsterberg (Sweden)*

Correlation Between CO2 Concentration & Condensation in Homes. *M.Creuzevault, M.Cohas, M.Grelat, Mrs Lemaire & M.Fauconnier (France)*

Airborne Moisture Movement in Occupied Dwellings: A Case Study Approach. *M.Kolokotroni, N.Saiz & J.Littler (UK)*

Occupants Behaviour with Respect to Window Opening: A Technical & Sociologic Study. *B.Fleury & C.Nicolas (France)*

CMHC Residential Indoor Air Quality Parametric Study. *T.Hamlin & K.Cooper (Canada)*

Indoor Ozone Concentrations: Ventilation Rate Impacts & Mechanisms of Outdoor Concentration Attenuation. *M.Modera, A.Cano-Ruiz & W.Nazaroff (USA)*

SESSION 5
Presentation of Displays

Afternoon

Introduction of Displays.

Ventilation, Heat and Moisture conditions in Attic Spaces. *J.Kronvall (Sweden)*

Impact of Subslab Ventilation Technique on Residential Ventilation Rate and Energy Costs. *Y.C.Bonnefous (France), A.J.Gadgil & W.J.Fisk (USA)*

Humidity Controlled Exhaust Fan in a Natural Ventilated Single Family House. *L-G Mansson, C-A Boman & B-M Johnsson (Sweden)*

Odour Threshold of Kitchen Exhuast Air During Typical Cooking Situations in a Dwelling. *M.Luoma & K.Kovanen (Finland)*

The Composition & Location of Dust Settled in Supply Air Ducts. *P.Pasanen, A.Nevalainen, J.Ruuskanen & P. Kalliokoski (Finland)*

The Penetration of Gaseous Pollutants into Buildings in the Case of a Sudden Contamination of the Outdoor Air. *K.E.Siren (Finland)*

Control of House Dust Mites by Ventilation - A Pilot Study. *D.A.McIntyre (UK)*

Energy Saving & CO2 Reduction. *G.Mertz & J.Roeben (Germany)*

OPTIBAT: A Real Scale Cell in Simulated Climatic Environment for Multizone Air Flow Pattern in Building. *F.Amara, P.Depecker & F.Allard (France)*

A Combined Pressurisation & Tracer Gas Technique for Air Flow Measurements. *L.Shao, H-G Kula, S.Sharples & I.C.Ward (UK)*

An Analytical Study of Branched Connections: Its Implications to Multizone Air Flow Measurements. *L.Shao, S.Sharples, I.C.Ward & H-G Kula (UK)*

A New Method for Determination of Velocity Pressure Loss - Factors for HVAC System Components. *K.W.Cheong, S.B. Riffat, Q.Zhang & M.Holmes (UK)*

The Air Flow Pattern ATLAS - A Reference Book of Computed Flow Fields. *A.Moser, Q.Chen, A.Schalin & X.Yuan (Switzerland)*

Experimental & Numerical Investigations within a Post-Annex-20-Model. *B.Hanel, E.Richter & P.Vogel (Germany)*

Modelling & Prediction of Pollutant Transfer in Multizone Buildings Coupled with Ventilation Networks. *A.C.Megri, F.Allard & G.Krauss (France)*

Air Flow in a Ventilated Cavity. *H-G Kula & I.C.Ward (UK)*

An Investigation of the Potential Use of Thermography for Building Air Leakage Measurements. *J.W.Roberts, S.Sharples & I.C.Ward (UK).*

Measured Air Flows Across the Ceiling in Typical Residential Attic Assemblies. *W.B.Rose (USA)*

Evening

Conference Banquet

Friday, 18th September

SESSION 6

Measurement Studies

Morning

Measurement of Actual Performances of Ventilation Systems in Buildings. *J.Riberon, J.G.Villenave, R.Simeron & D.Bienfait (France)*

Correction of Tracer Gas Measurement Results for Climatic Factors. *J.Kronvall (Sweden)*

Contaminant Dispersal Measurement Using Laser Light Sheet Illumination & Digital Image Processing Techniques. *J.W.Axley & L.Norford (USA)*

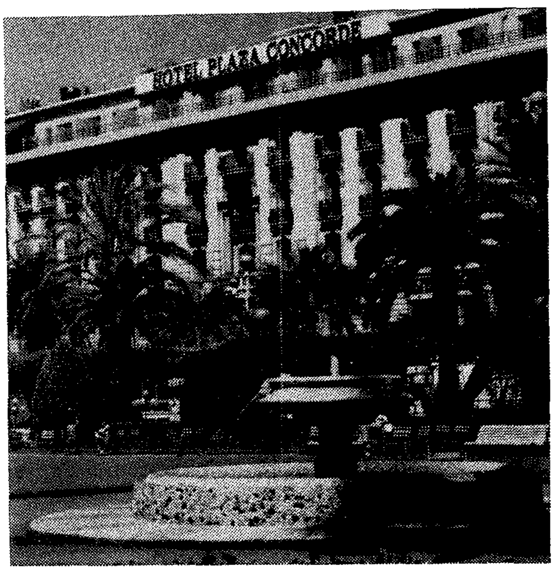
The Measurement of Ventilation Effectiveness Parameters in an Electronics Factory. *J.R.Waters (UK)*

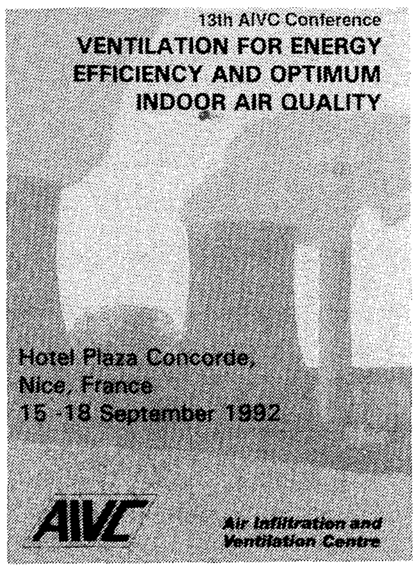
Field Measurements of the Air Change Efficiency by Using the Tracer Gas Technique. *B.W.Olesen (USA)*

Ventilation for Energy Efficiency & Optimum IAQ. *E.Cafaro, N.Cardinale, G.V.Fracastoro, E.Nino & G.Pacifico (Italy)*

Final Summing Up - Peter Jackman (UK)

End of Conference ☐





Attention Conference Delegates

I am considering attending the AIVC 13th Conference in France, September 1992. Please send me full details when available.

Name..

Address...

....

Heat Recovery In Ventilation Systems

Sven A. Svennberg
Professor, Department of Building Services Engineering Royal Institute of Technology, Stockholm

1.0 Background

1.1 Energy Situation : Energy supply is a global question, as the population rises and the industrialization goes on. Even if it is stated that a fully industrialized community can reduce its energy turnover and protect the environment, those communities on their way to that "final stage" cannot. They temporarily need more efforts in the form of energy and other means that often can be referred back to energy turnover.

1.2 Environmental protection : There is a connection between energy turnover and environmental influence. Energy output in Swedish cities has an influence on outdoor air quality, as regards the concentrations of sulphur dioxide. Another example is the carbon dioxide concentration of the atmosphere globally, measured at Mauna Loa observatory, Figure 1.

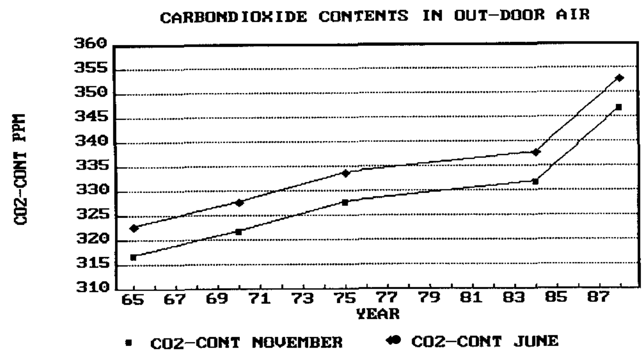


Figure 1. Carbon dioxide concentration of the atmosphere globally
After the last ice age the CO_2 concentration in the atmosphere has been constantly increasing. The pace has accelerated from the beginning of the 19th century due to inductrialization. 20,000 years BC the CO_2 concentration was about 180 ppm; in1800 it was about 280 ppm. The pace of increase has varied from about 50 to 200 pphm in recent decades.
Source: Keeling et al, Mauna Loa Observatory.

Those areas using local energy sources such as coal and pit (as in Eastern Europe) are causing large environmental problems. This calls for measures to be taken not only in developing countries but also in neighbouring countries belonging to our own type of community. As a matter of fact, what we can contribute to those countries to improve their environmental situation also represents the best investment we could find to further improvement of our own!

The use of electricity produced in hydro power or nuclear power stations to diminish the use of local energy sources is a "powerful" means for reducing the disturbance of the environment.

1.3 National and private economy: The use of oil as an energy source has become most important for the industrialized areas. Most of these areas have no oil wells of their own and thus have to import oil, which causes a heavy load on their economy. Part of the solution to improve the economy and energy balance is energy conservation by reducing energy demand for heating and ventilating buildings.

2.0 General Purpose Of Heat Recovery

The general purpose of heat recovery can be said to be threefold:

a) to reduce energy use

b) to reduce peak power need

c) to increase the time constant of the building for heating and ventilation as well as domestic hot water production.

In this document the interest is concentrated on heat recovery in ventilation systems and their influence on power and energy balance for buildings.

3.0 Recovery Methods

3.1 General: Recovery of heat from exhaust air normally is a question of heat balance for a building. Thus the calculated performance of a heat exchanger apparatus is not the same as the heat recovery performance of the system in a building.

In most cases, because of moisture in the exhaust air, the performance by temperature is higher than that of enthalpy, see Figure 2.

3.2 Static exchangers: In a static heat exchanger the warmer fluid is isolated from the colder fluid by a wall or an intermediate transfer system. A static heat exchanger normally has one of the following designs:

a) Sheet metal (paper, plastic) (see Figure 3)

b) Tube (see Figure 4)

c) Heat pipe (see Figure 5)

d) Liquid fluid circulation (see Figure 6)

e) Heat pump

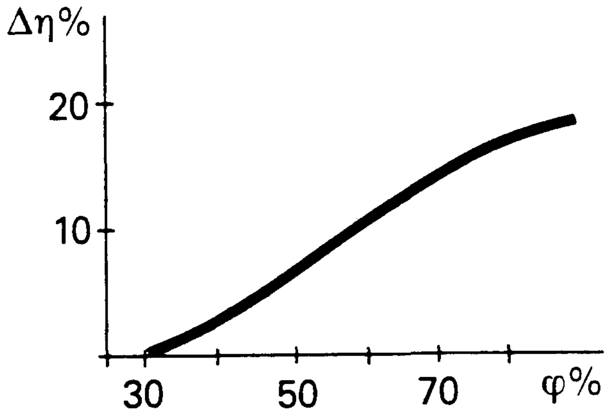


Figure 2. Difference between enthalpy efficiency and temperature efficiency related to relative humidity of the exhaust air.

The relationship, given as the efficiency on the supply air side, can be illustrated by the following example where the heat capacity flow rates are equal for supply and exhaust air:

Exhaust air data:

t_{el} = 22 Deg. C
fi_1 = 60%
h_e = 47 kJ/kg
t_{e0} = 2 Deg. C
fi_0 = 100%
h_{e0} = 14 kJ/kg

Supply air data:

t_{s0} = - 20 Deg. C
h_{s0} = - 19 kJ/kg
dh = 33 kJ/kg
h_{s1} = 14 kJ/kg
t_{s1} = 12 Deg. C

$$eta_t = \frac{ts1 - ts0}{te1 - te0} = \frac{12+20}{22+20} = 0.76$$

Index 1 for warm side

Index 0 for cold side

$$eta_h = \frac{hs1 - hs0}{he1 - he0} = \frac{14+19}{47+19} = 0.50$$

Note: A condition for the calculus is that a complete mixing takes place, which cannot often be reached in practice. In reality the difference in efficiency therefore is reduced.

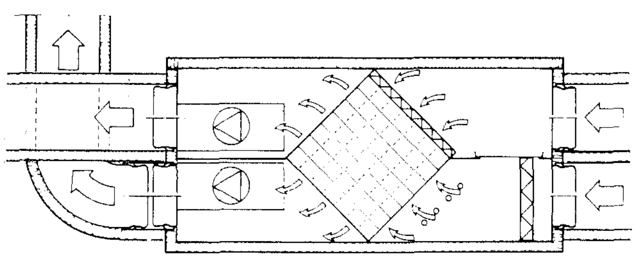


Figure 3. Sheet metal exchanger, cross flow arrangement.

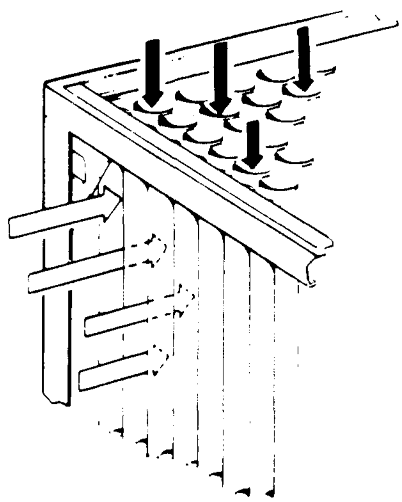


Figure 4.Tube exchanger, cross flow arrangement.

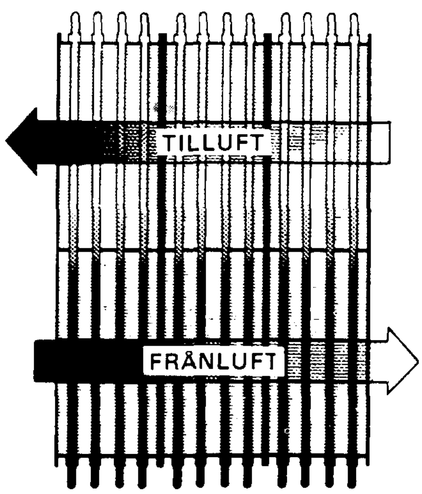


Figure 5.Heat pipe exchanger, cross flow arrangement.

Heat from exhaust air ("FRANLUFT") evaporates the liquid. The steam rises to the upper part of the exchanger, where cold supply air ("TILLUFT") is heated by condensing fluid. Fluid is returned by gravity to the lower part again.
Fluid transportation in horizontal heat pipes can also be made with hygroscopic material (wicks).

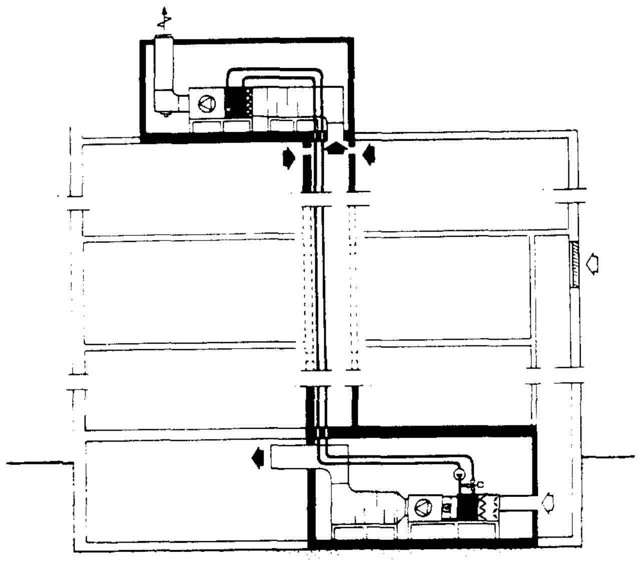


Figure 6.Liquid fluid circulation exchanger.
This type is often used in the reconditioning of old ventilation systems, where space for connecting supply and exhaust sides is not available or fire safety restrictions call for separate systems.

3.3 Cyclic exchangers: In a cyclic heat exchanger the warmer fluid delivers heat to heat accumulating areas which afterwards come in contact with the colder fluid where heat is transferred to that medium. A cyclic heat exchanger can have two principal designs:
a) Rotary heat exchanger where the accumulating area is rotating, see Figure 7.
b) Fixed accumulating bodies with valves to regularly change flow direction and fluid through exchanger bodies, see Figure 8.

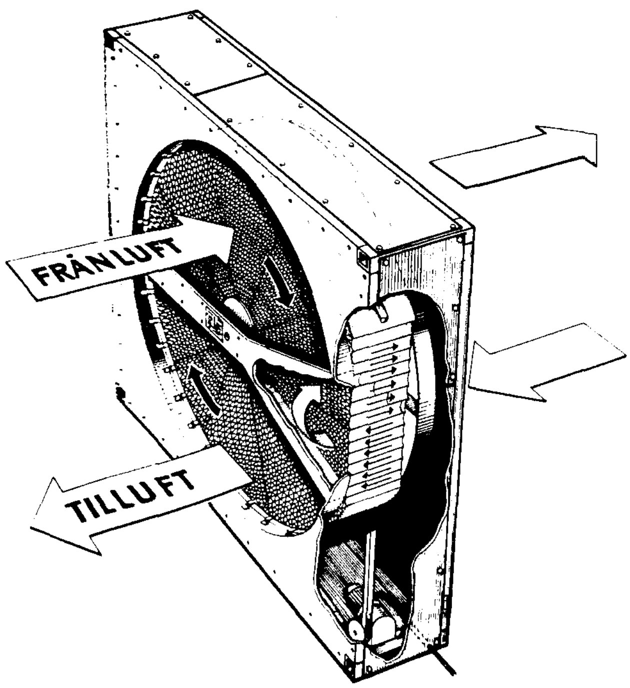
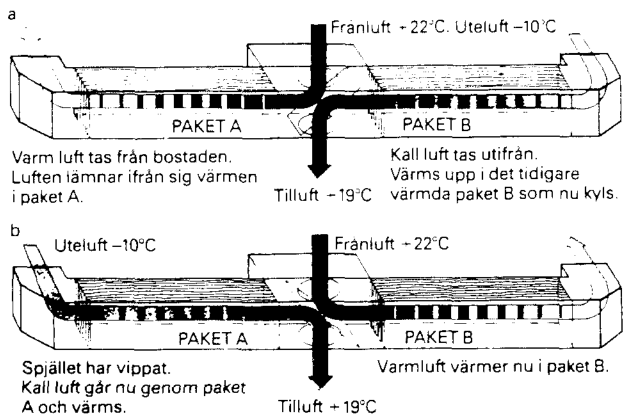


Figure 7 .Rotary heat exchanger. A small sector of the rotor is used for cleaning the exchanger channels from exhaust air pollutants by using outdoor air. ("FRANLUFT" = exhaust air, "TILLUFT" = supply air).



a) Package A receives heat from exhaust air, while Package B heats supply air.
b) About one minute later, the valves have been put in a position to change flow direction, so that Package B receives heat from exhaust air, while package A heats supply air.
The efficiency is influenced by the length of the cycling period.

Figure 8.Heat exchanger with fixed accumulating chambers and valves to regularly change flow direction through exchanger.

4.0 Restrictions

The necessity of having simultaneously available both a source and a receiver in energy conservation is normally well fulfilled in recovering heat from exhaust air. Heat can be directly transferred from exhaust to supply air. It can also be transferred, via a heat pump system, to a system for heating domestic hot water or a system for water heating of the building. In the latter case an accumulating system in the form of a water tank will be necessary.

The calculated performance of a heat exchanger system is very much dependent on the performance of the building. It is therefore necessary for the profitability of an installation, especially for ventilation systems with supply and exhaust by mechanical ventilation, to keep the building as airtight as possible. This, of course, is not actual for a system with only mechanical exhaust.

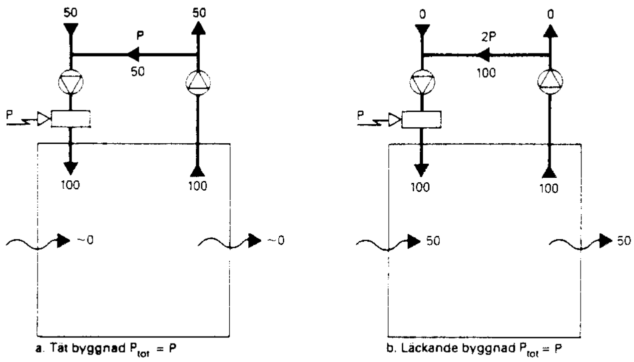
5.0 Return Air

Return air systems have been very much criticized because of "alleged guilt" of causing bad room air quality. The fact is, however, that a leaking building envelope can be used as a diffuse supply air terminal device, while a return air system can be used to equalise differences in air supply and temperature and also to recover heat from the exhaust air system, see Figure 9. The question of influence on room air quality on return air has been dealt with in (2). It can be shown that a minimum on the curve of air quality as a function of the rate of return air exists, see Figure 10.

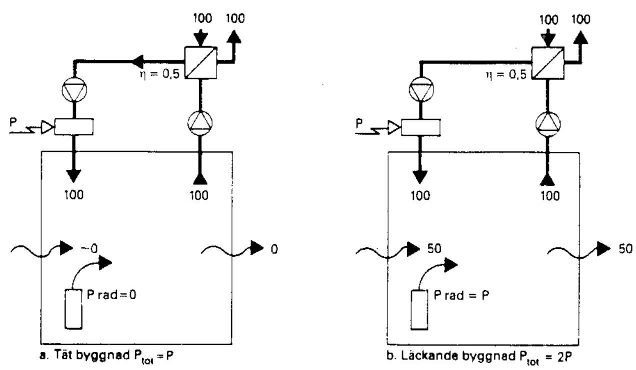
6.0 Economy

The profitability of a heat recovery system is very much dependent on performance, investment level, maintenance cost, and interest rate. A simple model for calculating profitability by using the present value method is presented in Figure 11.

The life time expectancy for different parts of heating and ventilation systems as well as the expected relative maintenance costs have been presented in a CEN/TC89 document (3), see Figure 12.

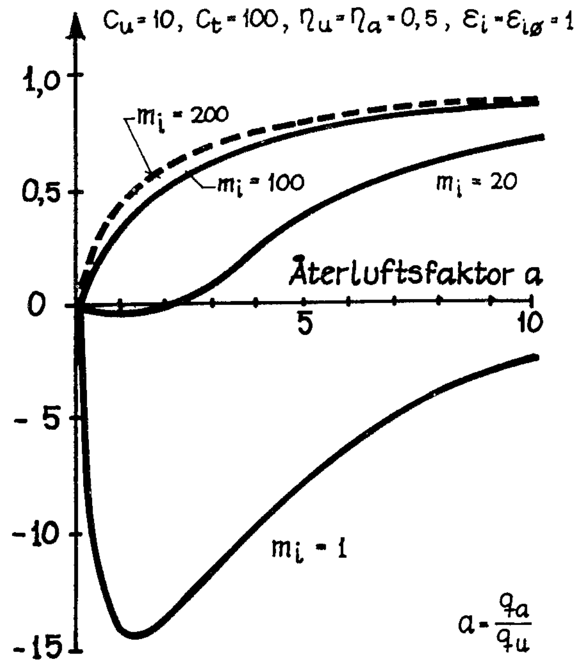


Air tight building. Ptot = P / Leaky building. Ptot = P
Figure 9a Building with return air system



Air tight building. Ptot = P / Leaky building. Ptot = 2P
Figure 9b Building with heat exchanger, eta = 50%

Figure 9 Influence of a leaky building envelope



Assumptions:
Filter efficiency 50%;
Relative particle concentrations
in outdoor air 10, in indoor air 100;
Air exchange efficiency in all rooms 100%;
Production of particulate pollutant m_i = 1, 100, 200

Figure 10 System dust separation efficiency as a function of the portion of return air for a system with filtered supply air and filtered return air.

Air flow rate	q	m³/s
Exhaust air temperature	t_e	Deg. C
Outdoor air temperature	t_o	Deg. C
Operational time	T	days/year
Market interest rate	r	%
Inflation rate	i	%/year
Energy price	p	£/kWh
Exchanger efficiency	eta	%
Investment (building cost incl.)	I	£
Life time expectancy	n	years
Increase of operational energy	d_e	kWh/year
Increase of maintenance cost	d_m	£/year
Present value factor	v	-

Economy sensitivity to be calculated for:
* Different energy price
* Different operational time
* Different market interest and inflation rates

Figure 11 Checklist for the calculation of heat exchanger profitability

Component	Life Span Years	Maintenance Cost % of Investment
Ductwork	30	2-6
Sound Attenuators	30	1
Air Terminal Devices	30	4
Air Heaters, Water, Steam	20	2
Fans, Constant Speed	20	4
Air Conditioning Units	15	4
Air Heaters, El	15	2
Control Equipment	15	4
Control Valves	15	6
Dampers	15	4
Dual Duct Boxes	15	4
Fans With Variable Flow	15	6
Heat Exchangers, Static	15	4
Heat Exchangers, Cyclic	10	4
Heat Pumps	15	4
Filters, Rinsible	10	10
Humidifiers, Water	10	6
Humidifiers, Steam	10	4
V-belt Drives	10	6

Figure 12: Examples on expected life spans and maintenance costs for components in ventilation systems
From: Work document, CEN/TC156/WG7 and TC89/WG4

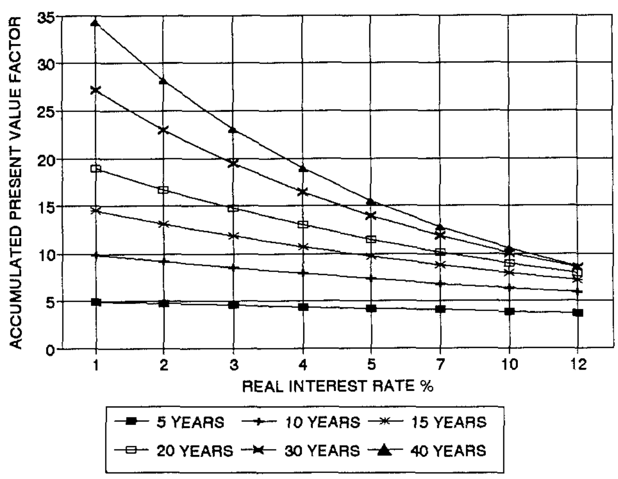


Figure 13 Accumulated present value for yearly cost or income from investments with expected life spans from 5 to 40 years as a function of real interest rate (approx = market interest rate minus inflation).

7.0 Recommendations

7.1 Checklist for decision : The following check list may be of use when considering a heat recovery system:

a) System type (S/E, E, Industrial)
b) Air flow rates, Supply and Exhaust
c) Decentralized/Centralized system
d) Fire and smoke protection
e) Humidity level of exhaust air
f) Minimum level of exhaust air
g) Corrosive atmosphere?
h) Dust polluted atmosphere?
i) High temperature?
j) Required return on investment?
k) Market interest rate
l) Yearly inflation rate

1) In most cases where the flow rate exceeds 1 m^3/s a rotary heat exchanger is recommendable.

2) For lower flow rates a sheet metal exchanger is the best buy, if the exhaust air is relatively clean.

3) In one-family houses a cyclic heat exchanger with exchanger chambers is often a profitable solution.

7.2 Specification of data for a heat recovery system A specification should be set up for the actual situation: Design, Installation, Operation, Maintenance. The following short list could serve as a guideline:

a) Performance data
Process description, controllability
Data for primary and secondary fluids
Pressure drop
Filtration of air

b) Construction
Mechanical stability, air tightness
Coordination with the building and with other installation

c) Availability
Corrosion resistance,
Demand for maintenance
Spare parts service

d) Economy
Investment level,
Life time expectancy
Operational and maintenance costs
Economic dimensioning

7.3 Checklist for operations and maintenance: According to (4), (5), and (6) the following points should be considered:

a) General orientation on systems, responsibility levels, safety precautions, measures in case of fire. Heat recovery system connections to the ventilation installation.

b) Orientation on function and labelling of installations Principal schemes and description of control system.

c) Time schedules for operation.

d) Maintenance instructions for systems and products for planned maintenance and necessary service.

e) Measures to be taken at alarm: error identification, check of alarm system

f) Instructions for the users: Building, Installations

g) Manufacturers' instructions for products

h) Principles for testing and rating of the heat exchanger in situ.

Literature

1. Svennberg S.A: Heat Recovery from Ventilation Air Handbook H2, the Swedish Association of HVRA Engineers, Stockholm 1989, ISBN 91-971262-0-9.

2. Svennberg S.A, Malmstrom T G: Return air, good or bad? On System dust retention efficiency (In Swedish). Paper and reprint, VVS & Energi no 10, 1987.

3. "Economical Aspects". Work document on estimated life times and relative maintenance costs for systems and products in HVAC systems. CEN/TC89/WG4 and CEN/TC156/WG7. Stockholm 1992.

4. "Instructions for operation and maintenance of installations" (In Swedish). Rep R30:1970, Sw.Council for Building Research, Stockholm 1970.

5. CEN standards for heat exchangers: CEN/TC 110. Secr. SMS Sweden, Chairman: S A Svennberg

6. "Requirements on instructions for operation and maintenance of installations". CEN/TC 228 Work Documents Feb 1992. Secretariat: Denmark, Chairman: Kaj Ovesen. □

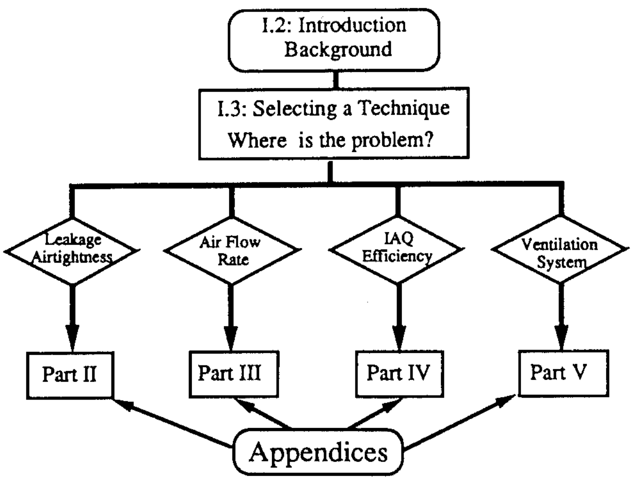
New Technical Notes from the AIVC

AIVC Technical Note 34

Air Flow Patterns within Buildings: Measurement Techniques

December 1991
IEA Energy Conservation in Buildings, Annex 20 Final Report
By C-A Roulet and L Vandaele

This handbook is concerned with the measurement of those parameters which are important in gaining an understanding of air infiltration and ventilation. The handbook has been designed so that the material suited to one's particular level of interest or current expertise, is readily accessible. The flow chart below illustrates the structure.



The introduction provides a general overview of infiltration and ventilation in buildings. Ventilation studies are discussed and the aims of the handbook outlined.

Part I defines the parameters which are important, presents the reasons why they should be measured and gives a guide to the selection of techniques for particular applications. Summaries of the main techniques available are presented, which are cross referenced with the main body of the handbook.

Part II presents the theory and practice of measuring the airtightness of the building envelope and its components. Leakage location and leakage path distribution within the building are also examined.

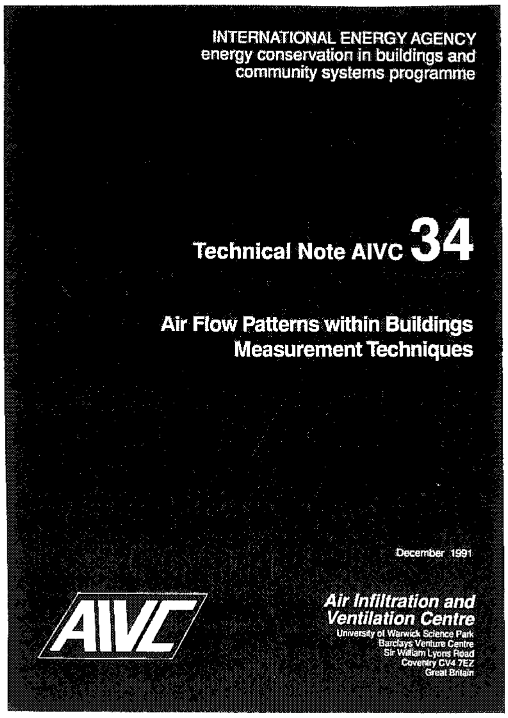
Part III presents the theory and practice of measuring air exchange rates and the related contaminant flow rates. Air exchange between a building and the external environment is examined, as is the air exchange between the various internal spaces of a building.

Part IV presents some measurement methods which may be useful to qualify the indoor air and the efficiency of the ventilation system. Measurement of contaminant concentrations are however not described, since another book will be necessary to describe all the possible methods to analyse the thousands of possible contaminants.

Part V describes measurement methods which are able to qualify a system, namely to measure the flow rates in the ventilation network and the control its tightness.

Appendices are provided either to give information on general tools as units transformations, error analysis, identification methods or to lighten the main text of information which may be useful only to specialists.

A glossary and an index are also provided to facilitate the use of this handbook.



IEA Energy Conservation in Buildings and Community Systems Programme
Annex 20: Air Flow Patterns within Buildings: Subtask 2 Technical Report

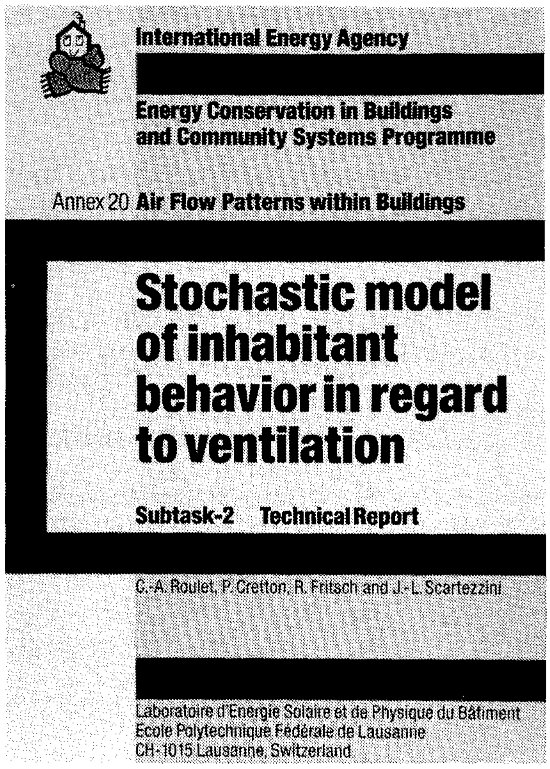
Stochastic Model of Inhabitant Behaviour in Regard to Ventilation

By C-A Roulet, P Cretton, R Fritsch and J-L Scartezzini

Laboratoire d'Energie Solaire et de Physique du Batiment, Ecole Polytechnique Federale de Lausanne, Switzerland, November 1991, Price £8.00

The objectives of the Annex were to evaluate the performance of single- and multi-zone air and contaminant flow simulation techniques and to establish their viability as design tools.

The specific objectives of Subtask 2 were to develop new algorithms for specific problems, such as flow through large openings, inhabitant behaviour, air flow driven contaminants, or multi-room ventilation efficiency; to develop new, or improve existing measurement techniques; to collect and test input data sets of experimental data (reference cases for code validation). The above publication is the final report for this subtask.



New AIVC Publications - AIVC Technical Note 35

Advanced Ventilation Systems - State of the Art and Trends

By Bas Knoll, visiting specialist from TNO in the Netherlands

March 1992

Increased health standards and the need to save energy in colder climates caused residential buildings to advance to the modern airtight and well-insulated dwellings we have today. In these dwellings ventilation has become a dominant factor, both from an indoor air quality and an energy conservation point of view.

This situation asks for consciousness on the part of applied ventilation systems. The report presents a review of present and advanced systems for basic ventilation and notes possible trends.

It focuses on residential ventilation systems for basic needs, regarding ventilation as a means of removing human generated pollutants to achieve acceptable indoor air quality.

After a resume of the demands for basic ventilation, a review is given of the major design consideration for residential ventilation systems in each country, considering ventilation standards, ventilation system requirements, commonly applied ventilation systems, weathertype, building traditions, and specific ventilation problems.

To get an extended view of possible future developments, advanced ventilation system approaches are reviewed. The advanced systems are put into four categories: air movement control systems, flow quantity control systems, ventilation heat recovery systems, and alternative ventilation energy gain systems.

New AIVC Publications

AIVC Technical Note 36

Air Infiltration and Ventilation Glossary

By Mark Limb

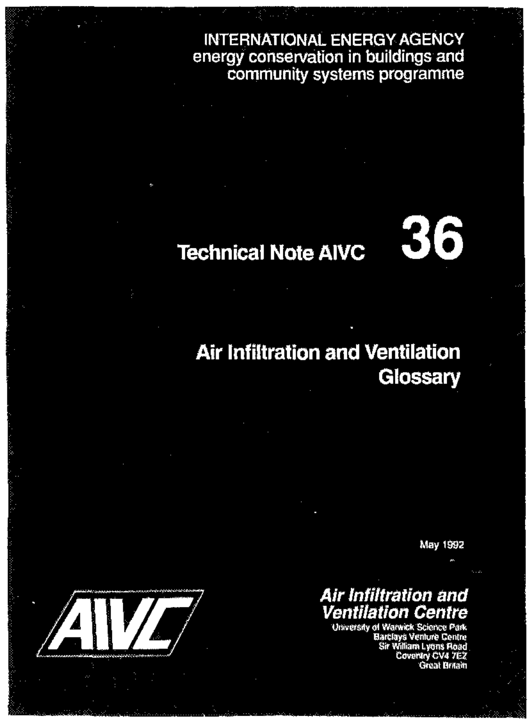
May 1992

The AIVC's first glossary of ventilation terms was published in 1981 as AIVC Technical Note 5 and contained definitions of words relating to air infiltration and ventilation. Since then, many definitions have been updated and new terms have been added.

This technical note incorporates the changes that have been made since the first edition was published. It also includes the principle terms associated with ventilation technology.

The revised terms have been compiled from a variety of sources including those listed in the bibliography.

The intention of the document is to promote a more uniform use of terms in the area of ventilation.



Forthcoming Conferences

ESM 92
European Simulation Multiconference
DATE: June 13, 1992
VENUE: York, UK
CONTACT: The Society for Computer Simulation International, European Simulation Office, c/o Philippe Géril, University of Ghent, Coupure Links 653, B9000 Ghent, Belgium
Tel/Fax: 0032 91 234 941
THEMES: Simulation methodology and practice; simulation in aerospace; simulation in society; simulation of electronic circuits and systems; industrial simulation and simulators; simulation in energy systems.

ISRACVE International Symposium on Room Air Convection and Ventilation Effectiveness
DATE: July 22-24, 1992
VENUE: University of Tokyo, Japan
CONTACT: Professor S Murakami, Chairman of ISRACVE, Institute of Industrial Science, University of Tokyo, 7221, Roppongi, Minatoku, Tokyo, 106 Japan
Tel: +81 3 3402 6231 ext 2575
Fax: +81 3 3746 1449
THEMES: Indoor airflow and pollutant diffusion analysis; definition and measurement of whole building and/or room ventilation effectiveness; specialized ventilation; conventional ventilation.

CWE '92 First International Symposium on Computational Wind Engineering
DATE: August 21-23, 1992
VENUE: University of Tokyo, Japan
CONTACT: Professor S Murakami, Chairman of CWE '92, Institute of Industrial Science, University of Tokyo, 7221, Roppongi, Minatoku, Tokyo, 106 Japan.
Tel: +81 3 3401 7439
Fax: +81 3 3746 1449
THEMES: Basic theories, turbulence models etc.; methodology of numerical simulation; flow and pressure fields around structures; wind loading on and wind induced vibration of structures; wind environment; dispersion of pollutants; modelling of natural wind; computer graphics for flow visualization; computer aided experiments.

CIB W67 Workshop Energy Efficiency and Ventilation
DATE: September 1992
VENUE: UMIST, Manchester, Great Britain
CONTACT: Prof. K M Letherman, Department of Building Engineering, UMIST, Manchester M60 1QD, Great Britain
Tel: +44 61 200 4242
Fax: +44 61 200 4252

Roomvent '92 Air Distribution in Rooms Third International Conference
DATE: September 24, 1992
VENUE: Aalborg, Denmark
CONTACT: Roomvent '92, Danish Association of HVAC Engineers, Orholmvej 40B, DK2800 Lyngby, Denmark
Tel: +45 42 87 76 11
Fax: +45 42 87 76 77

AIVC 13th Conference Ventilation for Energy Efficiency and Optimum Indoor Air Quality
DATE: September 14-18, 1992
VENUE: France
CONTACT: AIVC, University of Warwick Science Park, Barclays Venture Centre, Sir William Lyons Road, Coventry CV4 7EZ, Great Britain
Tel: +44 (0) 203 692050
Fax: +44 (0) 203 416306

Energy Economy 1992 European exhibition and conference on energy efficiency and environment
DATE: September 15-17, 1992
VENUE: Maastricht, Netherlands
CONTACT: RAI Gebouw bv, Europaplein, NL1078, GZ Amsterdam, Netherlands
Tel: +31 (0) 20 5491212
Fax: +31 (0) 20 6464469

Building Pathology 92
DATE: 23-25 September 1992
VENUE: Magdalene College, Cambridge, UK
CONTACT: Dr Jagjit Singh, Hutton and Roston Environmental Investigations Ltd, Netley House, Gomshall, Surrey, UK, GU5 9QA
Tel: 048641 3221
Fax: 048641 2911
THEMES: User information, proactive and remedial maintenance, conservation and use of historic buildings, indoor air quality and health, facilities management, management of museums, community housing and community health, post occupancy assessment, building failures, damp and decay, environmental assessment.

International Conference: Indoor Climate of Buildings: Indoor Air Quality in Central and Eastern Europe
DATE: 30 September - 2 October 1992
VENUE: High Tatra, Czechoslovakia
CONTACT: Conference Secretariat, IAQ in Central and Eastern Europe, SSTP, Kocelova 15, 815 94 Bratislava, Czechoslovakia
Tel: 42 7 627 24 (651 17, 681 36)
Fax: 42 7 685 74
THEMES: General IAQ framework (policy, legislation, standards), physical agents (heat, lighting, aerosol, electric and magnetic fields), chemical pollutants (radon, formaldehyde, biological contaminants, asbestos, tobacco smoke, odour, toxic substances), building constructions and materials, environmental technology (heating, ventilation and air conditioning, refrigerating)

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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 5.1 (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 28.2 (1991) Brouns C, Waters JR, 'A guide to contaminant removal effectiveness'.

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.'

TN32 (1991) Harrje DT, Piggins JT 'Reporting guidelines for the measurement of airflows and related factors in buildings.'

TN33 (1991) Liddament M W 'A review of building air flow simulation.'

TN34 (1991) Roulet C-A, Vandaele L 'Air flow patterns within buildings: measurement techniques.'

TN35 (1992) Knoll B 'Advanced ventilation systems - state of the art and trends.'

TN36 (1992) Limb M J 'Airgloss Air Infiltration Glossary.'

IEA ANNEX REPORTS

DCV (1990) Raatschen, W (ed.) Demand controlled ventilating system: state of the art review.' Annex 18 report.

DCV2 (1992) Raatschen W (ed.) "Demand Controlled Ventilating Systems - Sensor Market Survey" Annex 18 report

C&E (1991) Annex XIV Report "Condensation and Energy", in four volumes; 1. Sourcebook, 2. Guidelines and Practice, 3. Catalogue of Material Properties, 4. Case Studies,

Annex 20:2 (1992) Roulet, C-A, Cretton, P., Fritsch R, Scartezzini J-L "Stochastic model of inhabitant behaviour in regard to ventilation". Subtask 2 Technical Report.

AIVC CONFERENCE PROCEEDINGS

- 1st 'Instrumentation and measuring techniques',Windsor, UK,1980.
- 2nd 'Building design for minimum air infiltration', Stockholm, Sweden, 1981.
- 3rd 'Energy efficient domestic ventilation systems for achieving acceptable indoor air quality', London, UK, 1982.
- 4th 'Air infiltration reduction in existing buildings', Elm, Switzerland, 1982.
- 5th 'The implementation and effectiveness of air infiltration standards in buildings', Reno, USA, 1984.
- 6th 'Ventilation strategies and measurement techniques', Het Meerdal Centre, Netherlands, 1985.
- 7th 'Occupant interaction with ventilation systems' Stratford-upon-Avon, UK, 1986.
- 8th 'Ventilation technology - research and application', Uberlingen, West Germany, 1987.
- 9th 'Effective Ventilation' Ghent, Belgium, 1988
- 10th 'Progress and trends in air infiltration and ventilation research' Espoo, Finland, 1989
- 11th 'Ventilation System Performance' Belgirate, Italy, 1990
- 12th 'Air Movement and Ventilation Control within Buildings', Ottawa, Canada, 1991, 3 volumes.
- mf Proceedings of AIVC conferences numbers 1-10 are also available in microfiche form.

LITERATURE LISTS

1) Pressurisation - infiltration correlation: 1. Models.
2) Pressurisation - infiltration correlation: 2. Measurements.
3) Weatherstripping windows and doors.
4) Caulks and sealants.
5) Domestic air-to-air heat exchangers.
6) Air infiltration in industrial buildings.
7) Air flow through building entrances.
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9) Air infiltration in public buildings.
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11) Occupancy effects on air infiltration.
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13) Air infiltration measurement techniques.
14) Roofs and attics.
15) Identification of air leakage paths.
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