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UK VERSUS EUROPEAN HOUSING VENTILATION (HEAT RECOVERY)

by

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Abstract

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In order to understand why Mechanical Ventilation with Heat Recovery is common in some countries of Europe yet installed in a small minority of domestic dwellings in the UK, surveys of Regional Electricity Companies and distributors have been carried out to identify whether there are grants available to promote the system in the UK and what influences sales of the system across Europe. A review of other heat recovery systems is provided to assess whether they are competitiors. As a major application of Mechanical Ventilation with Heat Recovery is for condensation problems, a review is also provided of the mathematical theory of ventilation of enclosures particularly orientating it to understanding the application of Mechanical Ventilation with Heat Recovery. Notes on the application of the system have been identified.

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GLOSSARY

ach. Number of air changes per hour.

ach at 50 Pa. Number of air changes per hour when the dwelling is pressurised to 50 Pa (see Chapter 4, Page 13).

COP. Co-efficient of performance. As refrigeration cycles give out more energy than they take in, it is not appropriate to talk about their efficiency. COP is used as a measure of effectiveness. It is the heat output divided by the energy input.

Hygroscopicity. The process whereby vapour diffuses into or out of the pores of materials.

MHVR. Mechanical Ventilation with Heat Recovery.

SYMBOLS

G_p	vapour production kg/h
n	air change rate of the enclosure (per hour)
p_e	vapour pressure of the outside air (Pa)
p_i	vapour pressure of the outside air (Pa)
R	water vapour Gas Constant (462 J/kg.K)
T_i	temperature of the air in the enclosure (K)
V	volume of the enclosure (m^3)
m_v	vapour mass transfer (kg/m^2 s)
Δp_v	difference in vapour pressure (Pa)
G	vapour resistance (N s/kg)

Chapter 1

INTRODUCTION

Mechanical Ventilation with Heat Recovery (MHVR) has been applied in domestic dwellings on the continent for over 20 years. As extract air must be removed from where there may be unpleasant odour or humidity, such as the kitchen and bathroom, the opportunity is taken to retain the heat in that air by ducting it onto an air-to-air heat exchanger complete with small supply and extract fans. Filtered fresh air passes over the other side of the heat exchanger collecting 65 - 85% of the heat from the extract air. The warm fresh air is then ducted to the most commonly occupied rooms of the house, such as the Lounge and Bedrooms.

There are other configurations of this concept and comparable options. These have been described and reviewed.

The system has proved highly effective in applications in solving condensation problems, especially where a low income family lives in a house or flat only just large enough for them, or where a lightweight dwelling has been retrofitted with heat saving measures such as thicker loft insulation or double glazing. Other building owners have installed the system to provide a cleaner atmosphere for asthma or hayfever sufferers, or to minimise the pollution entering their home in areas where there are high levels of traffic. The system

is able to do this because it filters pollen and particulate pollutants out of the intake air. Some asthma sufferers are allergic to the household dust mite, and the drying out effect of the system controls the numbers of these mites.

Mechanical Ventilation with Heat Recovery is also a method of introducing fresh air to a tightly sealed small building in an energy efficient manner. Yet its uptake in the UK lags behind other European countries by up to 20 years.

Several reasons are cited for its slow take up in this country. Houses in Britain are supposedly less airtight than in Europe. Air leakage prevents perfectly balanced supply and extract, and under some conditions of wind direction and speed, there will be leakage of warm air. As this air does not pass over the heat exchanger, the leakage detracts from the effectiveness of the system.

It is also claimed that the British are much more conservative in their attitude to new ideas than their European counterparts, and that the Government does not do enough to promote the system.

It is important to look closely at the differing standards of airtightness in construction of dwellings across Europe and to identify whether there are any regulations that govern this quality of build. However subjects such as national outlook and Government policy must be beyond the scope of an Engineering research paper. The incentives offered by Government or other bodies to potential purchasers of ventilation systems are relevant to this research and have been reviewed from the point of view of a Design Engineer identifying

the most appropriate ventilation system for a single family or single person dwelling and a survey of Regional Electricity Boards has been carried out as they are the most convenient outlets of Government incentives or subsidies.

No study of why Mechanical Ventilation with Heat Recovery is less popular in the UK has been carried out and, in the end, the people with the greatest experience are the manufacturers and distributors of this system. To identify their undocumented findings, a survey of their sales offices has been carried out. Also a review of research of similar types of competing systems has been provided.

As condensation problems are a major application of the system it is useful to have an insight into the theory of the conditions promoting condensation and whether Mechanical Ventilation with Heat Recovery may be successfully applied to solving them.

Attitudes to Mechanical Ventilation with Heat Recovery, the extents of research both geographically and going back in time, and information about the take up and use of domestic heat recovery, all form the background to the subject and help describe the situation in the other countries of Europe.

Chapter 2

THE EUROPEAN SITUATION

Finland[1]

There was rapid development of warm air heating systems has from 1976 at least until 1983. Prior to 1976 there were small numbers of mechanical extract systems, and a few balanced ventilation systems with heat recovery were installed every year. Then a system combining warm air heating systems with mechanical supply and extract ventilation plus heat recovery became popular with thousands of small house builders choosing it every year.

Hungary[2]

Balanced ventilation was studied as early as 1980 analysing problems caused by the decreased ventilation due to official measures to install airtight windows in multi-storey tower blocks. The results of this study gave rise to the comment that a "remarkable amount of heat energy could be saved."

Norway[3]

Norway has good supplies of energy. The price of electricity from hydropower compares with the price of energy from fossil fuels. Direct electric resistance heating is common and inexpensive.

Netherlands[4]

The number of dwellings in the Netherlands with advanced ventilation systems was about 2% in 1995. This despite many demonstration programmes and much technical research since the early 1980's.

The selection of the type of ventilation system is determined by the principal, a consultant would only be involved if there was a particular problem. Contractors do not select the ventilation but they do select an installer based on lowest price, with the usual effect on quality of components. In the social housing sector there are limited budgets for new buildings, but there is more money available for retrofitting. The decision makers in this case are more aware of the problems caused by a poorly functioning ventilation system. The result is that for newly built houses the ventilation system is no more than sufficient to meet the requirements of the building code, but in retrofits there is more interest in the quality of the system. Discussion sessions were held across the Netherlands in 1995 involving building contractors and installers, architects and principals (especially housing corporations). Among all participants the most important criteria were thermal comfort, noise and indoor air quality. For the housing corporations acceptance by the occupants, maintenance and user friendliness are important. The architects wanted to see the practicality of fitting the system into their design. They like "natural ventilation" meaning openable windows rather than carefully designed vents. Most of the participants had heard of balanced ventilation with heat recovery, but had a limited knowledge of it.

Sweden

There is a widespread view that mechanical ventilation with heat recovery is not appropriate for the UK because it is only suitable for airtight houses, otherwise there will be leakage of warm air. It is interesting to note the inverse attitude in Sweden[23]: "Airtight houses are also necessary if heat recovery from the ventilation system is to function well and profitably."

By 1980[5] there were approximately 20,000 mechanical supply and extract systems with heat recovery (known as an FTX system) were installed outstripping mechanical extract (F system) at 19,000 systems. Nearly all the new houses built that year had a ventilation system. Half the systems were balanced supply and extract with a heat exchanger, the other half were extract only including those with a heat pump.

There is a common perception that because F ventilation produces a low pressure in the house that makes the airtightness of the house less dependent on the weather than the FTX system. F systems include ventilators in window frames. These should normally be open. Measurements were taken across the ventilators when open and closed. The pressure differential across them was 2 Pa when open and 6 Pa when closed, which would scarcely counterbalance the effects of a windy day. Houses with these systems are more draughty, and the occupants cope with it by closing the vents leaving the extract to produce a stabilising low pressure. Houses with FTX systems are seldom draughty and on these rare occasions the problem is to be cured by turning up the thermostat on the supply air ducts.

When the energy savings of an FTX system are converted to money savings and the higher price of the system is included the cost saving corresponds to an annual interest of only 5% to 7%, though if the airtightness is good there could be a profit.

UK

In 1997 Vent-Axia Ltd. brought out a unitary heat recovery unit. There is nothing new in these units which include fan, filter and heat exchanger. They have been around for some time with the option to wall mount or, for a single room such as a bathroom, to mount in a window. Vent-Axia are using what they claim is "a new generation of electronically-controlled dc stepped motor-driven fans which consume just 2.3W compared to 15 to 20W for conventional designs." The product is targeted at "smaller commercial ventilation systems" such as pubs and clubs.

For a research project in Milton Keynes a standard Mechanical Ventilation with Heat Recovery system was installed in a demonstration house. It was found that: "When assessing the system for superinsulated houses the capital cost was discounted by the reduced specification heating system and the savings on other ventilation devices that would have been required. The auxiliary energy saved by the heat exchanger should more than offset the running costs of the system, and possibly even the maintenance costs." The saving in the demonstration house was £9.40 over 100 days in 1987. [6]

Chapter 3

EXPERIENCES OF DIFFERENT TYPES OF SYSTEM

Mechanical Ventilation with Heat Recovery Linked to Gas Central Heating (Germany)[7]

Because the supply and extract air of a mechanical ventilation system do not mix in or leak across the heat exchanger, it is safe to duct the flue gases from a gas fired boiler to the return air side of the heat exchanger. Then heat may be extracted both from the return air and the boiler exhaust and then transferred to the supply air. That way more heat is retained within the house.

Mechanical Extract with Heat Pump

These units are based on the familiar refrigeration cycle. The refrigerants piped through the warm extract air where it takes in heat and evaporates. The warm vapour is transported through the hot water or central heating system where it gives up its heat and condenses. No supply air system is required saving space and the disruption of retrofitting ceiling voids. The heat pump has the additional advantage of being able to reclaim latent heat from the extract air.

Sweden[8]

Existing brick ducts in the chimney stack have an exhaust air unit with extract fan fitted to the their outlet. The unit also contains a filter and cooling coil. The cooling coil extracts heat to the domestic hot water by using a heat pump.

In a study 60 houses were fitted with the system. The results allowed the following estimates to be made:-

Increase ach 0.25 to 0.5	+42 MWh/year
Electrical energy absorbed by heat pump	+52 MWh/year
Total heat gained by domestic hot water	-130 MWh/year
Net heat recovered (=52 - 130 MWh/year)	-78 MWh/year
Saving despite improved ventilation (78 - 42 MWh/year)	-36 MWh/year

Notes: "+" denotes that money is being spent and "-" denotes that effectively money is coming in. The bottom row in the table emphasises that even though there is a higher flow rate of fresh (initially cold) air into the property, an energy saving has been achieved.

UK

A Danish heat recovery unit based on a heat exchanger augmented by a heat pump was installed in an Electricity Council Research Centre at Capenhurst.[9] To allow the heat exchanger to operate at highest effectiveness, the evaporator of the heat pump was placed downstream of the heat exchanger where it would reclaim any residual sensible heat and the latent heat not collected by the heat exchanger. The condenser and compressor of the heat pump were placed in the supply air stream, again downstream of the heat exchanger. Trials were made 1986/87.

Because latent heat is taken in, condensation was expected to be formed by the heat pump. In fact the heat exchanger also formed condensation in cold weather.

It was found that the supply air temperature never fell below 20°C even though the trials were carried out through Winter. The air exhausted to atmosphere was always below the intake temperature form outdoors. It was found that the temperature rise through the unit had a linear relationship to intake temperature (°C) and the temperature (°C) of the air extracted from the space. It was higher with a low intake temperature and a high extract temperature. The overall co-efficient of performance (COP) of the system had the form

$$COP = A + B \times \text{Outside temperature } (^\circ C)$$

where A and B are constants. In this case, A was 2.99.

A Genvex heat pump ventilation unit (HPVU) has been tested in another UK house[10]. Genvex are also a company based in Denmark.

The house was semi-detached with three bedrooms built in 1969. The airtightness was improved to 0.25 ach. The HPVU provided a further 0.5 ach distributed to the bedrooms and living rooms in approximate proportion to their volume at about 0.75 ach. The extract rate was 0.5 ach for the whole house, of which 60% was from the kitchen, and 40% from the bathroom.

In practice the COP was about 3.0 and the unit generated about 1kW of heat. The predicted energy consumption of the house had been 325 to 375 kW.

Two methods of supplementary heating were studied. It was found that room panel heaters gave more flexible control of timing and temperature than heaters in the central ductwork. As supply air was balanced for ventilation, bedrooms tended to receive more warm air than was required for heating, and became too hot. It was not always possible to ensure that the HPVU had priority in providing heating over the supplementary heating.

Sunspace

There is potential for warm air from a sunspace, such as a conservatory, to be used as part of the heating of the whole house. With air inlet vents fresh air is pre-heated before entering the main part of the dwelling.

The single-glazed sunspaces attached to a group of experimental houses in Peterborough[11] reduced the energy consumption by some 15%. However when the sunspace temperature was high, air was drawn from the living area to the sunspace. To correct this a separate fan would be necessary. Consideration could be given to heat recovery. On sunny days one side of the heat exchanger would flow warm air from the sunspace and on the other side warm air from the living spaces. With this configuration the gains would be small or negative. At other times the heat recovery system would act as usual. The benefits from the two systems are not additive: air warmed by the sunspace is less able to collect heat from the extract air.

Chapter 4

AIRTIGHTNESS OF EUROPEAN DWELLINGS

Regulations

Access to international standards and regulations is not readily available to the average designer in the UK. The national Standards Library is not able to provide information by subject.

In 1983 the Swedish Council for Building Research undertook a study for the International Energy Agency (IEA).[12] The participating countries were Canada, Netherlands, Sweden, Switzerland, UK and USA. At that time of these countries and Norway only Sweden and Norway had Regulations relating to airtightness. The Norwegian regulation was Byggeforskrifter av 1969 (BF). (Kommunal og Arbeidsdepartementet.), the chapter on thermal insulation and airtightness was revised in 1980. It allows a maximum air leakage of 4 air changes per hour (ach) at 50 Pa (this term will be explained in the next section). Further regulations were enforced in 1994 and 1995. The Swedish regulation was Svensk Byggnorm (SBN) 1980. It allows a maximum air leakage of 3 ach at 50 Pa. The introduction of airtightness standards occurred in 1975, prior to this the airtightness was commonly 5.5 ach.[13]

In the UK The Chartered Institution of Building Services Engineers (CIBSE) recommends a standard of $5m^3/h/m^2$. This method of expressing infiltration is under review after a joint workshop with the Building Research

Establishment (BRE) where the delegates including those from the retail industry agreed that a more meaningful unit of measurement should be used and that research should be carried out with a view to providing the British Government with specifications to incorporate into the Building Regulations Part L.[14]

Field Data

The Air Infiltration and Ventilation Centre has developed a numerical database relating to the air infiltration and ventilation of buildings.[15] They used it in 1994 to produce a study including the whole building leakage of dwellings in various countries, presenting the data as histograms whose interval is 1 ach. For some countries, they were able to break the data down for year of construction. The graphs for the European countries are summarised in Table 4.1, and are referred to in the section below entitled The Airtightness of Buildings in the UK Compared with Other European Countries.

Country	Sample Size	Range (ach at 50 Pa)
Belgium	57	1 - 35
France	66	0 - 11
Netherlands	303	0 - 38
Norway	40	1 - 8
Sweden	144	0 - 23
Switzerland	37	1 - 9
UK	385	3 - 30

Table 4.1 Comparison of Air Change Rates in European Dwellings

It is possible to measure air change rates directly. The usefulness of doing so is explained by an example. In the UK a four storey office building with

not English. The suppliers contacted and their responses are listed below. The responses are not necessarily verbatim, but the researchers notes reconstituted.

ABB [Sweden] Tel. 0046 171 22000

1. It's the law. New building has been banned. There are to be no more flats, though villas are permitted.

2. Swedish houses are very airtight, often wooden construction which would rot without a ventilation system. People want better air quality, they spend 90% of their life indoors, and half of that at home. 20g[/hr?] moisture from food and 40g[/hr?] from breathing is diffused into the indoor air. The company likes to argue that as it is important to you to have good quality food, you should also have good quality air to breathe.

ABB [UK] Tel. 01203 368500

1. All types from flats to commercial [buildings] depending on the MVHR model.

2. It's energy saving potential. They have information sheets available on annual costs per year and heating period.

ADM INDUX [UK] Tel. 01274 690260

1. Popularity varies...self build people. They do the design.

2. Last year there was a lot of talk about the benefits for asthmatics, leading to more enquiries. Also councils.

APV VENT-AXIA [UK] Tel. 01293 526062

1. Social housing, 3 bedroom houses.

2. Condensation problems in local authority owned accommodation.

BENZIG VENTILATOREN [Germany] Tel. 0049 7720 62041

They are a sister company to Vent-Axia.

1. They have two sizes of units: AHRV for pubs and bathrooms, and AHRV4 for kitchens. No applications are particularly popular.

2. An increase in sales is expected as new regulations come into force demanding the installation of heat recovery units instead of fans.

GENVEX KLIMATEKNIK A/S [Denmark] Tel. 0045 43 62 26 00

1. Single family houses - space is too restricted in flats.

2. Houses in Denmark are too air tight, giving increasing humidity problems. Houses are also better insulated than in the UK, 300-500mm wall cavity insulation being the norm.

NILAN A/S [Denmark] Tel. 0045 75 89 22 22

1. They have three models:-

    1. Air-to-air heat recovery in ventilation systems.
    2. Air-to-water heat recovery.
    3. Combination of the two.

Any of these systems is suitable for houses up to 200m² or larger if required.

2. [A Danish company contacted previously saw this question as commercially sensitive, so this time it was rephrased as "What makes people buy these?"] To save energy by recycling it and the quality of the supply air. It is clean and very healthy for people and houses - 0.5 ach is provided.

Chapter 7

CONDENSATION

It is generally accepted that MVHR is successful at solving condensation problems. For example among the superinsulated houses of Milton Keynes with mechanical ventilation with heat recovery it was noticeable that misting of mirrors after bathing or showering quickly disappeared, and tumble dryers could be vented directly into the house to take advantage of the heat generated with no sign of condensation.[6]

However experience of these systems has shown that "Even a small amount of internal positive pressure can cause moist air to leak through pervious structures." [23] Such positive pressure can be caused by the imbalance of a supply and extract system and it is important to ensure that it is avoided during the design and commissioning stages.

Mathematical Analysis

The mathematical analyses carried out by H. Hens (1991)[24] gives an interesting understanding of when increasing the ventilation rate will affect the amount of water vapour diffusing through exterior walls, the types of accommodation most prone to condensation problems. Here we will consider only the simplest where there is no condensation and no hygroscopicity (due to vapour diffusing into or out of the pores of the materials forming the structure of the

openable vertical sash windows and secondary glazing was studied[16] over seven days. The building air change rates were assessed by measuring the decay of a tracer gas, or the decay of CO_2 after occupants had left the building. The air change rates varied between 0.9 and 2.24 diurnal average ach. Wind speeds were recorded at the nearby Meteorological site as ranging from 5 m/s to 10 m/s with gusts of about three times the mean speed. Here the results were inconsistent with the highest result being nearly 250% of the lowest, because the value does literally change with the weather.

Expressing air leakage data ach at 50 Pa has evolved as a standard way to compare the air-tightness of buildings. By pressurising a building to a pressure well above atmospheric, any variation due to wind pressure becomes negligible, and repeatable results may be obtained. There has been a suggestion that dividing the number of air changes at 50 Pa by a factor between 10 and 30 may give a useful indicator of actual air change rate.[17] A separate experiment produced data that indicates this rule may be useful. Measurements were taken in a UK house:[18] A single fan test indicated 8ach at 50 Pa, and actual measurements over 8 months averaged 0.4 Pa ($8 \div 0.4 = 20$).

Belgium

Data from Belgium Building Research Institute (BBRI), Rue de la Violette 21-23, 1000 Brussels, Belgium.

The majority of the buildings are under 10 ach at 50 Pa, mode 2 - 3 ach at 50 Pa (the other results are scattered).

A paper dated 1984[19] speaks of a fall in mean ventilation rate from 0.7 ach to 0.2 ach (note that this an actual rate and not at 50 Pa).

Air flow rate is specified by Belgian standard NBN D50-001[20], and has been tabulated in Table 4.2 for a particular dwelling[21]:-

ROOM	AIR FLOW RATE (m^3/h)	REMARKS
Bedrooms (3.6 $m^3/h.m^2$)	34	Outside air
Bedroom 2		
Bedroom 2	33	Outside air
Bedroom 3	33	Outside air
Bedroom 4	33	Outside air
Office	22	Outside air
Living Room	134	Recirculated Air
Kitchen	50	Air Extraction
Bathrooms (2 No.)	50	Air Extraction
Toilet (2 No.)	50	Air Extraction

Table 4.2 Nominal Air Flow Rates in the PLEIADE Dwelling as Given in Belgian Standard NBN D50-001

Finland[1]

Pressure tests have been carried out in hundreds of small houses in 1980-81. The results are summarised in Table 4.3.

	Range (ach at 50 Pa)	Average (ach at 50 Pa)
Older wooden houses with sawdust insulation	6.0 - 10.4	7.3
New wooden houses built on site with mineral wool insulation	2.9 - 17.8	6.5

Prefabricated wood element houses with mineral wool insulation	2.2 - 12.0	6.0
Concrete element houses with mineral wool insulation	2.3 - 5.3	3.5
Lightweight concrete houses	1.8 - 4.5	3.0

Table 4.3 Infiltration Rates in Houses in Finland

France

Data from Moye C.. *La permeabilite a l'air des batiments d'habitation,* Cahiers du Centre Scientifique et Technique du Batiment, livr 262, cahier; 2019, Septembre 1985 (AIVC No. 1898)

The graph is similar to normal distribution with a mode of 3 - 4 ach, the mean is 3.59 ach at 50 Pa.

Netherlands

Data from TNO Building and Construction Research, PO Box 29, 2600 AA Delft, The Netherlands.

The majority were below 22 ach at 50 Pa, with the mode at 9 - 10 ach, even neglecting the fourteen leakiest dwellings (these look like scatter on the graph) the mean is about 9 ach at 50 Pa, 10.14 ach at 50 Pa overall.

In the sample were 45 dwellings built between 1980 and 1989. They had 3 to 2 ach at 50 Pa. The data indicate a tighter standard coming into effect in 1980. Houses built in 1975 - 1979 had about 11 ach.

Norway

Data from Norges byggforskningsinstitutt, Postboks 123, Blindern, N-0314 Oslo, Norway.

There is a fairly consistent frequency between 2 - 8 ach at 50 Pa, possibly a mode at 3 - 4 ach.

Sweden

Data from Swedish Institute for Building Research, PO Box 785, S-80129 GAVLE, Sweden.

There is a distinct mode at 3 - 4 ach at 50 Pa, the mean is 5.10 ach at 50 Pa. Disregarding the four highest results as scatter, the mean becomes 18 ach at 50 Pa.

Since before 1940 up to 1988 the has been a decrease in the leakiness of buildings. In the period 1976 - 1988 the mean was 2.2 ach at 50 Pa. for 15 single family dwellings, and 5 multi-family dwellings had a mean of nearly 1 ach at 50 Pa.

There was found to be a difference in air tightness between 1-storey and 2-storey houses of 3.2 ach versus 1 ach at 50 Pa. There was also a slight difference in that houses with balanced supply and extract were a little more airtight than those with extract only.[5]

Switzerland

Data from NEFF 226; Zumoberhaus M, Preisig H R, Harmann P, *Luftdurchlasssigkeit der Geboudehulle im Holzbau* [Air leakage in Swiss wooden housing], Schweizer Ingenieur und Architekt, No 10, 8th March 1990, pp246 - 250 (AIVC No.3894); and EMPA, Uberlandstrasse 129, CH-8600 Dubendorf, Switzerland.

There is a distinct mode at 3 - 4 ach at 50 Pa, otherwise there is a fairly consistent frequency between 1 and 6 ach at 50 Pa.

<u>UK</u>

Data from the Building Research Establishment Air Leakage Database.

There is fairly consistent frequency between 4 and 24 ach at 50 Pa, with four distinct spikes in the curve. The mean is 13.62 ach at 50 Pa.

Dwellings constructed between 1935 and 1989 showed differing air change rates. The tallest histogram is for the period 1945 - 1949 where two dwellings averaged 22 ach at 50 Pa. The interval with the lowest average of nearly 10 ach at 50 Pa is for the 64 dwellings constructed between 1985 - 1989. There is insufficient information to argue that more modern buildings are more airtight.

An Electricity Council Research Centre test house in 1989[9] achieved 10 ach at 50 Pa after "all accessible and obvious leaks had been sealed with tape." This was believed to be above average, but poor for a modern house constructed with airtightness in mind.

BSRIA have found that maximum air leakage (normal) for dwellings is 7 $m^3/h/m^2$ at 50Pa and suggest that best practice is 3 $m^3/h/m^2$ at 50Pa.[14]

Chapter 5

SURVEY OF REGIONAL ELECTRICITY COMPANIES

A survey of all electricity companies in the UK was carried out for this research project in July 1997 to ask whether they subsidised or promoted Mechanical Ventilation with Heat Recovery . The responses are given below. Their telephone numbers were obtained from the Yellow Pages. Where a choice of phone numbers was given the title or a description of the number chosen is also given.

<u>Eastern Electricity plc, Ipswich Tel. 0345 626513</u>
No

<u>East Midlands Electricity plc, Nottingham Tel. 0500 201000</u>
No

<u>London Electricity plc, High Holborn Tel. 0181 535 000</u>
No

<u>Manweb plc, Chester, Tel. 0345 112211</u>
Redirected to 01978 832008

MVHR is not promoted.

<u>Midlands Electricity plc, Halesowen Tel. 0800 02 22 20</u>
Redirected to their "Technical People" and then to the Electricity Association.

MVHR is not promoted.

Northern Electricity plc, Newcastle Tel. 0800 440800

They retail two mechanical ventilation with heat recovery systems: whole house, upper floor only, and a supply only system with a filter.

Northern Ireland Electricity plc, Belfast, 01232 661100

No

Norweb plc, Manchester, Tel. 0161 224 9696, General Enquiries 0800 834550

A specifiers guide was provided in hardcopy and on CD-ROM that included descriptions of mechanical ventilation with heat recovery and heat pumps among others.

Scottish Power plc, Glasgow, Tel. 0141 248 8200

Redirected to 0141 568 3000. They promised to direct their sales rep. to respond, but it didn't happen.

Seeboard plc, Crawley, Tel. 0800 581255

No, though their technical department had a good understanding of the system.

Southern Electricity plc, Maidenhead

Sales line 0345 240415
Energy line, advice and information on using electricity wisely, 0345 776633

MVHR is not promoted. Builders have made similar enquiries. They were aware that the Energy Efficiency Office, Tel. 01923 664258, was carrying out tests on the system. The phone number of the Environmentally Friendly Building, Tel. 01559 370908 was also provided.

Swalec plc, Cardiff, Tel. 01222 36505

No

South Western Electricity plc, Almondsbury, Avon, Tel. 0345 650650

No

Yorkshire Electricity Group plc, Leeds Tel. 0113 241 5000

No

Chapter 6

SURVEY OF SUPPLIERS

The promotion of ventilation systems with heat recovery is likely to be of most interest to suppliers. A simple survey was carried out in July 1997 to find out who is buying these systems, and if there are any particular reasons.

The suppliers chosen for the survey were all the ones listed in the *European Directory of Energy Efficient Building 1994.*[22] It was readily available in the library of one large consultancy and therefore may well be in others; and has been taken as being accessible to a typical designer. Other reference books in the library did not pinpoint this type of system with sufficient accuracy.

The introduction to the survey was "I am interested in heat recovery systems for domestic applications." This also served as the request for the person to whom the call had been directed by their switchboard to take part. The questions asked were:-

1. For what kind of buildings are they most popular?
2. What influences sales?

When question no. 2 was not clearly understood the Government and the weather were given as examples. Question no.1 was never queried. More flexibility was introduced when speaking to people whose first language was

enclosure or even of furniture within the enclosure). Hens also assumes constant internal temperature, this applies to well controlled central heating.

Analysing the amount of moisture in the internal air gives an illustration of the types of enclosure most prone to condensation without using surface film analysis or hygroscopicity theory to predict whether condensation will actually occur.

The mass balance of water, also known as the hygric balance, for an enclosure such as a room, given the assumptions above, is:-

incoming vapour	+	vapour produced in the zone	=	outgoing vapour	+	vapour stored in the air in the enclosure

Incoming Vapour

The Gas Laws (Gay-Lussac's law pV = mRT, to be precise) and the concept of partial pressures mean that the product of the partial pressure of water in the air and the volume the air occupies equal the product of the mass of the water, the Gas Constant of water vapour, and the temperature in Kelvin. Substituting that the volume flow rate of air into the enclosure is the air change rate times the volume of the enclosure and re-arranging this gives the mass flow rate of water into the enclosure:-

$$= \frac{\mathbf{n\,V\,p_e}}{\mathbf{RT_i}} \qquad (7\text{-}1)$$

where

n air change rate of the enclosure (per hour)

V volume of the enclosure (m^3)

p_e vapour pressure of the outside air (Pa)

R water vapour Gas Constant (462 J/kg.K)

T_i temperature of the air in the enclosure (K)

Is Hens right to use the inside temperature? Consider the air outside. The mass of water it holds depends in the temperature outside. As the air passes through the structure into the enclosure where it is warmer, either the mass remains constant, or water mass is gathered from the structure as the temperature increases until it reaches T_i assuming it is warmer inside. A real structure has thickness and is unlikely to be perfectly dry, the air could well gather additional mass, though depending on the materials and relative amounts of water, mass could be deposited. If the mass does not change then substituting the inside temperature for the outside temperature would only mean substituting perhaps 293K for 263K (taking a large temperature difference applicable across Europe). The error involved is within the tolerances of building services design calculations and the analysis is conveniently simplified.

Outgoing Vapour

The mass flow rate depends on the vapour pressure and temperature within the enclosure, but the analysis is similar to that of the incoming vapour described above.

Vapour Stored in the Air in the Enclosure

At any instant in time the mass of vapour stored in the enclosure is again given by the Theory of Partial Pressures. Assuming constant temperature mass is proportional to the product of vapour pressure and volume of the enclosure.

The air change rate then is irrelevant and the change of mass stored with time depends on the rate of change of vapour pressure.

The Hygric Balance As a Mathematical Equation

$$\frac{nVp_e}{RT_i} + G_p = \frac{nVp_i}{RT_i} + \frac{V}{RT_i} \cdot \frac{d}{dt}(p_i) \qquad (7\text{-}2)$$

where
G_p vapour production kg/h
p_i vapour pressure of the outside air (Pa)

Re-arranging,

$$\frac{d}{dt}(p_i) + np_i = np_e + \frac{RT_i G_p}{V} \qquad (7\text{-}3)$$

Steady-State Solution

When the internal vapour pressure does not vary with time, the differential term is equal to zero and Equation 7-3 becomes

$$p_i - p_e = \frac{RT_i G_p}{nV} \qquad (7\text{-}4)$$

The first observation is the well known fact that the internal vapour pressure is always greater than the external vapour pressure, because the quantities on the right hand side of the equation are positive scalar quantities.

It is the difference in vapour pressure that drives mass transfer through a solid structure by the process of diffusion. Diffusion was first studied as a phenomenon by the German Physicist Fick as long ago as (1855).[25] He

identified that the diffusion flow per unit cross section of a substance in a mixture is proportional to the negative rate of change of concentration with direction. In a steady state the diffusion flow is equal to a constant for the material multiplied by the difference in concentration per unit thickness. The concentration of water vapour in air is the mass per unit volume and from the Gas Laws, this is proportional to pressure. These two concepts combine to support the basic formula for the calculation method to predict interstitial condensation[26] in which the difference in vapour is directly proportional to vapour mass transfer through a material in a wall:-

$$\mathbf{m_v} = \frac{\mathbf{\Delta p_v}}{\mathbf{G}} \qquad (7\text{-}5)$$

$\mathbf{m_v}$ vapour mass transfer (kg/m^2 s)
$\mathbf{\Delta p_v}$ difference in vapour pressure (Pa)
G vapour resistance (N s/kg)

We can now understand Equation 7-4 as illustrating that in an enclosure with a low air change rate there will be a high vapour mass transfer through the walls, even though there may be only a low rate of vapour production. Figure 7-1 shows that changing a low ventilation rate will have a significant effect on the tendency to condensation, whereas changing a high ventilation rate will not have much effect.

It is also to be noted from Equation 7-4 that the vapour mass transfer out of the enclosure is higher for small rooms.

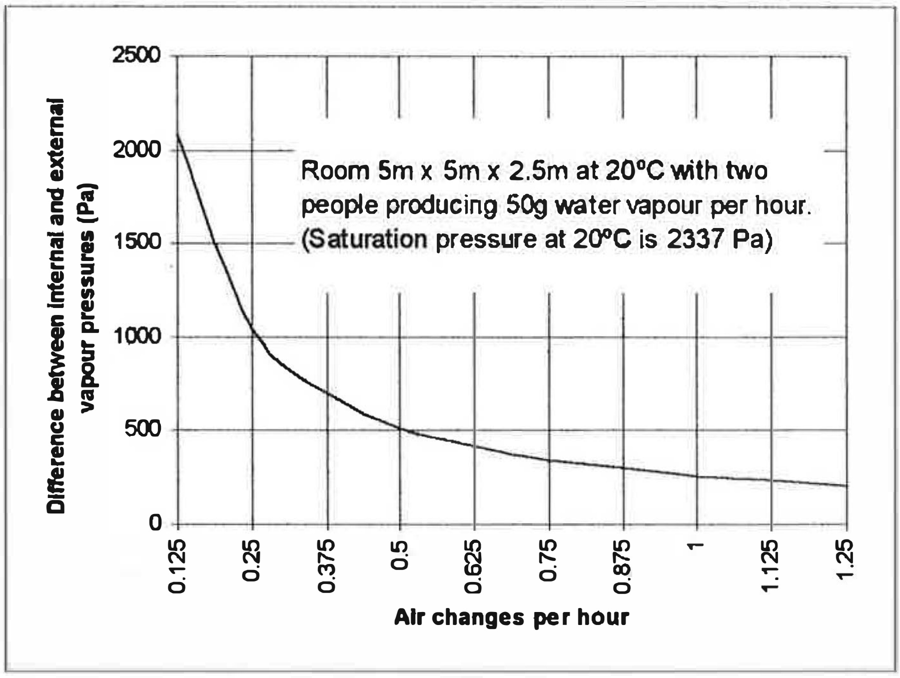

Figure 7-1 The Relationship Between Internal and External Vapour Pressure Differential and Infiltration Rate in a Typical Small Room.

Some Notes On Solutions When The Parameters Vary With Time

With the ventilation rate, inside temperature, outside vapour pressure constant, and the inside vapour production starts or changes; then the more ventilation, the quicker the exponentially rising internal pressure will reach its steady state level, and the lower that level will be.

When all parameters vary analytical solutions are not possible. Hens offers a finite difference approximation to a solution which may be used to produce histograms and gives an example where an extract fan causes underpressure but cannot ventilate.

When the outside vapour pressure oscillate harmonically, the internal vapour pressure also oscillates with an amplitude and a phase shift. The phase shift is the arctan of an inverse function of the air change rate.

Chapter 8

DISCUSSION

Mechanical Ventilation with Heat Recovery has been used in Europe since the late 1970's. Studies in the early '80s in countries from the UK through Scandinavia to Hungary demonstrate that it saves energy.

Although Scandinavian countries do not have natural fuel supplies, but source much of their energy as electricity from hydropower, this is not necessarily an advantage to Mechanical Ventilation with Heat Recovery. For example in Norway the costs of these two types of fuel are comparable, though in contrast to the UK electric resistance heating is considered inexpensive. In countries like Norway there would be an approximately equal pressure to save the running costs of electrical systems and the running costs of fossil fuel systems whereas in the UK there may be slightly more pressure to reduce electricity bills and possibly a householder may be less reluctant to switch on a gas fire than an electric fan system.

Over the year in Sweden only small cost savings are to be expected taking into account the high initial costs of the system. In the UK savings in a superinsulated house in 1987 were £9.40 over 100 days including the initial cost and excluding the savings from the reduced specification of central heating. The cost of the system is also high in the UK compared to the cost of a fan in

each of the kitchen and bathroom. A marginal cost saving per year would not be a sufficient incentive for large capital outlay and inconvenience.

Yet in Sweden Mechanical Ventilation with Heat Recovery is very popular. It is preferred to extract only which causes draughts especially on a windy day. Complaints of draught due to extract systems and local fans are not common in the UK, though while the bathroom is occupied the extract fan is perhaps less likely to be used in Winter than in Summer. The colder climate in Sweden would make infiltration more noticeable. This would be the case for countries with similar climates. In Sweden the make-up air for extract only systems is provided through vents which could be at least partly why there is a broader range of air change rates in Swedish dwellings than in the UK.

A major marketing research project in the Netherlands revealed that contractors involved in building new houses make decisions based on low initial cost, and that despite much research and demonstration projects there was limited knowledge of Mechanical Ventilation with Heat Recovery. This is probably similar to the experience of most consulting engineers in the UK of their home country.

Does Mechanical Ventilation with Heat Recovery Suffer from Competition from Similar Types of System?

A useful variation found in Germany is to mix the extract air and the flue gases from a gas fired central heating boiler before passing them over the heat exchanger. It is not known whether this is more effective than using the flue

gases only. This system is not commonly observed in the UK. It is not a competitor, but would be an advantageous configuration.

The heat pump is a different type of unit being based on a refrigeration cycle. Two separate studies of its application to different houses in the UK have been made. In the house where the unit supplemented a heat exchanger the COP of the system found to be 2.99. In the house where there was no heat exchanger the COP was found to be about 3.0. In both cases the manufacturer of the heat pump was the same but it is not known whether it was the same model, so no conclusion can be drawn as to whether the heat exchanger contributed to energy savings. The heat pump should be more effective than a heat exchanger as it is able to take in latent heat from water vapour diffused into the air forming condensation, as well as the sensible heat that is gathered by a heat exchanger, though on cold days condensation was observed on the heat exchanger. It is disappointing that there was no cost comparison incorporating initial cost and projected fuel savings in either of these studies. Heat pumps are not common in the UK.

Sunspaces such as conservatories are common in the UK, but when combined with a Mechanical Ventilation with Heat Recovery system the energy savings were not additive. However there has been no study as to which system provides higher cost savings. In the experience of the author, sunspaces are not provided as a ventilation system but as an attractive amenity for the home.

It would seem that their amenity is more appreciated than a high quantity of fresh filtered air.

The Airtightness of Buildings in the UK Compared with Other European Countries

The least airtight buildings of the UK are probably no more leaky than Belgium, the Netherlands and possibly Sweden. Higher measurements have been taken in Netherlands where there is a colder climate, and where there are no fossil fuel resources which would normally put pressure on a country to be thrifty with energy. None of the measurements taken in France, Norway and Switzerland are above 11 ach at 50 Pa compared with 30 ach at 50 Pa in the UK.

The mean of the data gathered from the Netherlands is higher than that for the UK, until the highest measurements are taken to be scatter, then the mean comes into line with the rest of Europe other than the UK. The mean for the UK is 13.62 ach at 50 Pa. A general figure for the other countries in Europe where data has been gathered is 4 ach at 50 Pa. Countries where no data has been gathered indicate a lack of interest in the air tightness of buildings, and it could be speculated that the buildings are less air tight than the UK. However it may be taken that dwellings in the UK are less air tight than several countries in Europe.

Air tightness in Norway and Sweden has been regulated to low levels since 1980, this would necessitate methods of controlling condensation and make

mechanical supply of air more popular. In fact the survey of distributors carried out in this project revealed that Mechanical Ventilation with Heat Recovery is a legal requirement in Sweden.

Are There any Monetary Incentives Available from the Regional Electricity Companies?

Of the 14 companies contacted, 7 were able to say immediately that there were no incentives and did not volunteer further assistance, 4 were able to provide technical information, 1 retailed a choice of system, and Southern Electricity had experienced interest from builders in Mechanical Ventilation with Heat Recovery but it is not known whether the lack of financial incentive discouraged the builder's from installing the system. It does however indicate an interest in Mechanical Ventilation with Heat Recovery in the South, a more prosperous region of the UK.

Suppliers Experience of the Market

The names and telephone numbers of only seven European suppliers would be accessible to a typical designer in the UK. Of these seven, four were in countries outside the UK. 2 companies, one from Sweden and one from Germany cited legislation or Government regulations as affecting sales. Most companies were vague as to applications, though each of the following types was named once: social housing, three-bedroom houses, homes that had were self-build projects and single family houses. Council owned homes were mentioned by two UK companies. Energy saving was mentioned as an important feature by one UK company and one Danish company.

Condensation problems were referred to by one company in the UK and two companies from the rest of Europe. One company in the UK profited by some publicity given to the benefits of the system to asthmatics.

The Application of Mechanical Ventilation with Heat Recovery to Condensation

Equation 7-4 for steady state conditions shows that higher levels of water vapour diffusing through walls occur for small rooms with low air change rates, even though there may be low rates of moisture production. Homes with small rooms tend to be occupied by people on low incomes. Here could be the explanation of why Borough Councils are one of the major purchasers of Mechanical Ventilation with Heat Recovery. Those on low enough incomes to be awarded council houses are often concerned about the size of fuel bills and will block up vents to prevent ingress of cold air. Once a council house has condensation problems it is in the council's interest to provide a remedy to ensure it is providing healthy living accommodation and the cost of Mechanical Ventilation with Heat Recovery is less inconvenient than the redress of the tenant after mould has developed.

Where condensation occurs in spaces with a high air change rate increasing the extract rate will not solve the problem.

When there are cyclical variations in outdoor and indoor vapour pressures then the phase shift for the indoor vapour pressure is related to the arctan of an inverse function of the air change rate, thus when there is a low air change rate

there will be a slower response to the variation in outdoor vapour pressure changes.

Chapter 9

CONCLUSIONS

There are a variety of ways of recovering heat in the home from extract air. None are in widespread use in the UK where local extract is commonly used and the amenity of a sunspace is preferred to the amenity of filtered fresh air.

The initial cost of the system is a disincentive, and only small cost savings are achieved. The survey of Regional Electricity Companies revealed that they do not offer any financial incentives to offset the disadvantage of the initial cost. The British Government does not use this route to offer grants, neither does it publicise the existence of grants. However there is no evidence of there being any grants being available elsewhere in Europe. In Sweden where Mechanical Ventilation with Heat Recovery is popular again only small cost savings are to be expected. In spite of this the energy saving aspect of Mechanical Ventilation with Heat Recovery was quoted by several manufacturers as being an important selling point by two out of the seven manufacturers contacted.

The argument that Mechanical Ventilation with Heat Recovery is common in countries where due to the availability of hydroelectric power electicity is cheaper is countered by similarity of price of electricity and gas in Norway.

The Governments in Norway and Sweden regulate the air tightness of buildings. In Sweden the installation of Mechanical Ventilation with Heat

Recovery is covered by law. Law is a factor influencing sales in Sweden and Germany.

In European countries where data is available, the dwellings are generally more airtight than in the UK, though those in the Netherlands are comparable. In countries where there are no data available the dwellings may well be less airtight than the UK. Dwellings in the UK are less suitable for the installation of Mechanical Ventilation with Heat Recovery than in several countries in Europe.

In colder climates than the UK air infiltration is more noticeable. In Sweden extract only ventilation systems are disliked and cause complaints of draughts presumably because the incoming air has not been warmed.

It was found in the survey of manufacturers that Council owned dwellings and dwellings with condensation are important applications.

Mathematical analysis of water vapour pressure in a ventilated enclosure indicates that small enclosures with low air change rates are most prone to condensation problems. This is typical of dwellings for families with low incomes, and typically only Councils would be owners able to afford the capital cost of Mechanical Ventilation with Heat Recovery to solve condensation problems, especially for situations severe enough to warrant a court case. Where there is a low air change rate there will be a slow response of the

enclosure to an improvement in the outdoor vapour pressure or moisture content.

The slow take up of Mechanical Ventilation with Heat Recovery was the subject of a market research paper in the Netherlands. The results of that research were that most new dwellings are built by contractors who design for low initial cost, and there is little knowledge of Mechanical Ventilation with Heat Recovery despite research and demonstration projects. These in the end must be contributing factors to the lack of popularity of the system in the UK.

Chapter 10

APPLICATION NOTES

Where the structure is pervious, consideration should be given to designing for a negative pressure, as internal positve pressures can cause moist air to leak into the structure.[23]

The heat exchanger and heat pump unit installed in the Capenhurst research centre in 1986[9] had condensation occur on the heat exchanger as well as the heat pump. This is not generally a problem and the manufacturers experience, as always, is to be respected when designing the installation. However it is worth knowing that it is not impossible for condensation to form on the heat exchanger in a Mechanical Ventilation with Heat Recovery Unit.

H. Hens (1991)[24] has shown mathemaically the difference in vapour pressure between the inside and outside of an enclosure has a hyperbolic relation to the ventilation rate. There is an asymptotic minimum vapour pressure difference approached by increasing venitlation rate. Practically this means that if there is a condensation problem in spite of a high air change rate (probably because there is a lot of water vapour being produced in a small space), increasing the ventilation rate further will not solve the problem.

Another source of heat that may be recovered is the waste gas from the boiler. This may be mixed with extract air prior to ducting onto the high temperature side of the heat recovery unit.

Mechanical Ventilation with Heat Recovery is so effective at controlling humidity that the washing machine need not be vented to outside.

Chapter 11

RECOMMENDATIONS FOR FURTHER RESEARCH

The optimum system for recovering heat from the flue gases of fossil fuel boilers.

The cost analysis of Mechanical Ventilation systems including a heat exchanger only, a heat pump only, both and local extract.

The mathematical models of H. Hens[24] have yet to be verified by practical experiment.

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The Air Infiltration and Ventilation Centre is a project of the International Energy Agency (IEA). Their address and telephone number are given below.

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