*Nat***Vent**

Overcoming technical barriers to low-energy natural ventilation in office type buildings

Overview of investigated buildings

Edited by D. Ducarme
Division of Building Physics and Indoor Climate
Belgian Building Research Institute

Research funded in part by
THE EUROPEAN COMMISSION
in the framework of the
Non Nuclear Energy Programme

The NATVENT project

Overcoming technical barriers to low-energy natural ventilation in office-type building in moderate and cold climate

Participants to the project

Co-ordinator

Building Research Establishment
Environmental Engineering Division

Contact person: Earle Perera
Tel: +44 1923 664796
Fax: +44 1923 664095
e-mail: pererae@bre.co.uk

Main Contractors

Belgian Building Research Institute
Division of Building Physics and Indoor Climate

Contact person: Peter Wouters, David Ducarme
Tel: +32 2 653 88 01
Fax: +32 2 653 07 29
e-mail: ducarme@bbri.be

Danish Building Research Institute
Energy and Indoor Climate

Contact person: Soren Aggerholm
Tel: +45 42 86 55 33
Fax: +45 42 86 75 35
e-mail: soa@sbi.dk

TNO Building & Construction Research
Department Indoor Environment

Contact person: Willem de Gids
Tel: +31 15 2 60 84 72
Fax: +31 15 2 60 84 32
e-mail: w.degids@bouw.tno.nl

Associated Contractors

J&W Consulting Engineers AB
Division of Building Physics and Indoor Environment

Contact person: Johnny Kronvall
Tel: +46 40 10 82 00
Fax: +46 40 10 82 01
e-mail: johnny.kronvall@malmo.jacwid.se

Delft University of Technology
Laboratory of Ref Eng and Indoor Climate Tech

Contact person: Dolf van Paassen
Tel: +31 15 278 66 69
Fax: +31 15 278 72 04
e-mail: a.h.c.vanpaassen@wbmt.tudelft.nl

Willan Building Services

Contact person: Peter Willan
Tel: +44 161 973 1234
Fax: +44 161 969 53 45

Norwegian Building Research Institute

Contact person: Jorn Brunsell
Tel: +47 22 96 55 00
Fax: +47 22 96 57 25
e-mail: jorn.brunsell@byggforsk.no

Sulzer Infra Lab

Contact person: Peter Kofoed
Tel: +41 52 262 47 45
Fax: +41 52 262 00 02
e-mail: sinfra@dial.eunet.ch

About the NATVENT project

Objectives

This seven nation pan European project aims to reduce primary energy consumption (and consequently CO_2 emissions) in buildings by:

(a) providing solutions to barriers which prevent the uptake of natural ventilation and low-energy cooling in countries with moderate and cold climates, and

(b) encouraging and accelerating the use of natural ventilation and 'smart' controls as the main design option in new-designs and major refurbishments of office-type buildings.

This project is targeted at countries with low winter and moderate summer temperatures and where summer overheating from solar and internal gain can be significantly reduced by low-energy design and good natural ventilation. Natural ventilation solutions to buildings in urban areas where external air pollution and noise levels are regarded as being high, is also a priority.

Technical approach

The work is divided into three work packages. The first, led by the Danish Building Research Institute, is aimed at identifying perceived barriers to natural ventilation through in-depth structured interviews among leading designers, architects, building owners and developers in all the seven EU Partner countries. A European wide questionnaire has been produced with input from all nine Partners within the NATVENT consortium and interviews in all the seven countries have been carried out. The responses are currently being analysed and a report will be produced comparing country-specific barriers.

The second work package is led jointly by the Belgian Building Research Institute and Sulzer Infra Laboratory. Its aim is to evaluate the performance of existing ad-hoc buildings designed and constructed specifically as energy-efficient naturally ventilated buildings. Eighteen such buildings within the seven EU countries have been identified for monitoring and details of all these buildings are given in this brochure. The intention is to identify any shortcomings and the advantages from such strategies as well as specifying the overall design and construction conditions required for achieving successful natural ventilation. Parameters such as temperature, humidity and ventilation rates will be measured during both winter and summer periods to identify the efficacy of the different ventilation strategies used for each period.

The Building Research Establishment in the UK is leading the third work package, with the aim of developing 'smart' naturally ventilated technology systems and component solutions to overcome barriers identified. This is being done through laboratory tests, field measurements and simulations in the following specific activities:

(a) Activity 1: Air supply components (led by Willan Building Services, UK) - to develop specifications and design solutions for natural ventilation air supply components for use with high external pollution and noise loads;

(b) Activity 2: Constant (natural) air-flow inlets (led by the Netherlands Organisation for Applied Scientific Research) - to identify and specify conditions under which newly-developed natural ventilation 'smart' constant air inlets can provide acceptable indoor air quality for occupants health and comfort in offices;

(c) Activity 3: Advanced natural ventilation system as with heat recovery (led by the Norwegian Building Research Institute)- to develop systems which can provide natural ventilation in cold climates and to recover heat without incurring an acceptable high energy consumption;

(d) Activity 4: 'Smart' components and 'intelligent' controls for optimal night cooling (led by the Technical University Delft) - to develop natural ventilation systems and controls suitable for optimal night cooling; and

(e) Activity 5: Integration of 'smart' systems for year-round performance (led by J&W Bygg & Anlaggning AB, Sweden) - to address and define robust performance specifications for integrated performance of 'smart' systems for optimum year-round performance.

Expected achievements and exploitation

Effective and widespread dissemination and communication of the results is a key activity. Results will be disseminated to a wide spectrum of the construction industry, to building designers, architects, researchers and services engineers through OPETs and other organisations and to standards setting organisations such as CEN. Conferences and workshops will also be targetted for dissemination of results. A NATVENT International Conference will be held at the end of the project to promote the results of the findings and encourage uptake of the natural ventilation solutions. Specific major achievements will be a Guide book and a promotional non-technical video for energy efficient natural ventilation and a computer simulation model for developing and evaluating natural ventilation strategies in office buildings. Other achievements will include technical and case study reports, guide books, and papers at national and international fora.

Why natural ventilation in office buildings ?

Achieving good indoor climate conditions and at the same time an energy efficient and environmentally friendly office building is a clear challenge. This is valid for new buildings as well as for retrofitting activities. Creating a good indoor air quality and a good thermal comfort is certainly an important aspect. Full air conditioned systems were in the past considered as the ultimate choice. Today, a more balanced view is found in many countries and among many people.

Increased concern over the adverse environmental impact of energy use has encouraged the design and construction of energy efficient buildings, many of them suited to natural ventilation. It can provide year round comfort, with good user control, at minimum capital cost and with negligible maintenance. Also, nowadays there is a better understanding of natural ventilation in buildings. Furthermore there is a common feeling that many mechanically ventilated and/or air-conditioned buildings do not behave as well as could be expected.. As a result, there is an increased interest for natural ventilation strategies and much attention is being given to the development of such systems with better performances. The NATVENT project aims to contribute a better understanding of the barriers and possibilities for applying natural ventilation in office buildings.

What is 'natural ventilation' ?

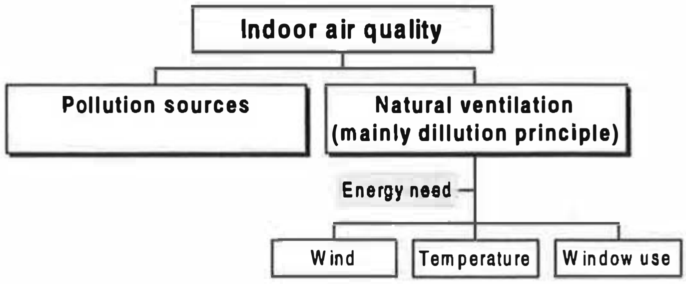
The expression 'naturally ventilated building' covers the following two concepts:

- Ventilation may be linked to the control of the indoor air quality: natural ventilation in this case means providing specific provisions (eg trickle ventilators) aimed at achieving an acceptable indoor air quality. Such design may include natural supply openings and mechanical extract fans.
- Ventilation may be linked to the control of temperature in summer and the avoidance of overheating. In this context, the natural ventilation is generally applied at night time and the aim is then to use the relatively cold outside air as the heat sink for cooling down the building thermal mass.

The NATVENT project is looking at these methods of natural ventilation provision in office buildings in both moderate and cold climates.

Natural ventilation and IAQ

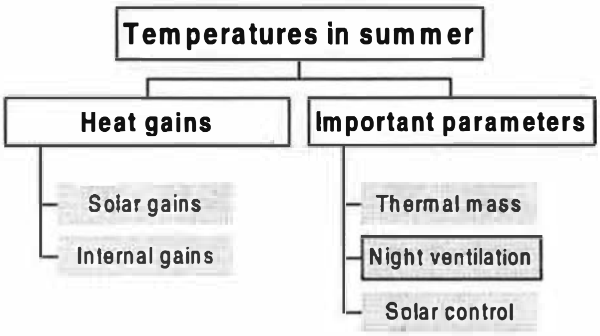
Natural ventilation as a strategy for achieving acceptable indoor air quality is essentially based on the supply of air to a space and by dilution reducing the pollution concentration in the space. No fan energy is needed (unless mechanical extraction is applied) but during the heating season is energy needed for heating up this air. The natural air flow rates varies as function of time and depend on wind and temperature conditions. Likewise the user can have a substantial impact by window use. Therefore, optimisation is essential so that good indoor air quality and a low energy demand can be combined. Keeping the air flow rates in a certain range is very important.



Natural ventilation for IAQ control

Natural ventilation and thermal comfort in summer

In case of natural ventilation for thermal comfort in summer, the situation is completely different. Natural ventilation can be applied at daytime and especially at night-time when the outdoor air is relatively cold. The aim is then to have a maximum exchange of heat between the building structure and the outside air. This is achieved by creating large openings in the building envelope allowing to realise high air flow rates.



Natural ventilation and summer temperatures

Whereas for IAQ control, the resulting indoor air quality is linked in a rather simple way to the pollution source strength and the air flow rate, a much more complex relation is found for temperature control in summer. Influencing parameters are the thermal gains (internally, solar gains), the building characteristics (especially thermal mass and insulation level), the use of the building and the natural ventilation.

Control of the air flow rates is on itself not so important : *'the higher the better'* as long as this does not give unacceptable conditions, e.g. draught problems or undercooling in the early morning hours.

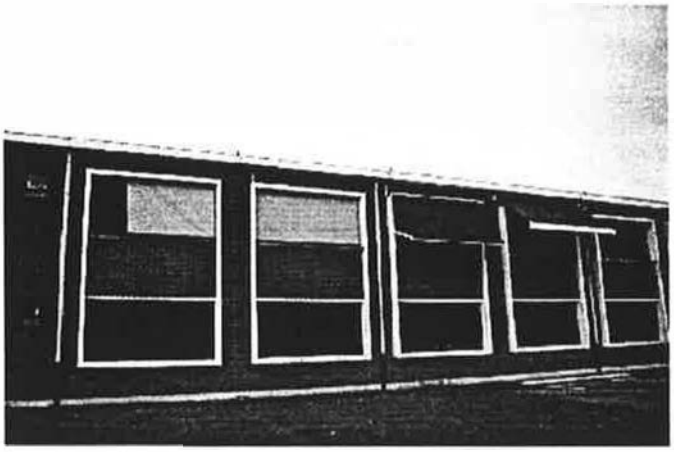
The required air flow rates for IAQ control are of a totally different order of magnitude than the air flow rates for contributing to better thermal comfort conditions in summer time. As a result, the openings are also of a totally different size.

Belgium BE1	The PRO*BE* building Pragmatic Renovation of Office Building for Better Environment

The PRO*BE* building was completed in 1975. It is a 2 storey office building situated in the countryside at about 25 kilometres Southeast of Brussels.

Serious problems of overheating were observed in summertime as well as IAQ problems during the heating season. Indeed, no specific attention was paid to the overheating prevention in the design phase and no ventilation provisions were foreseen.

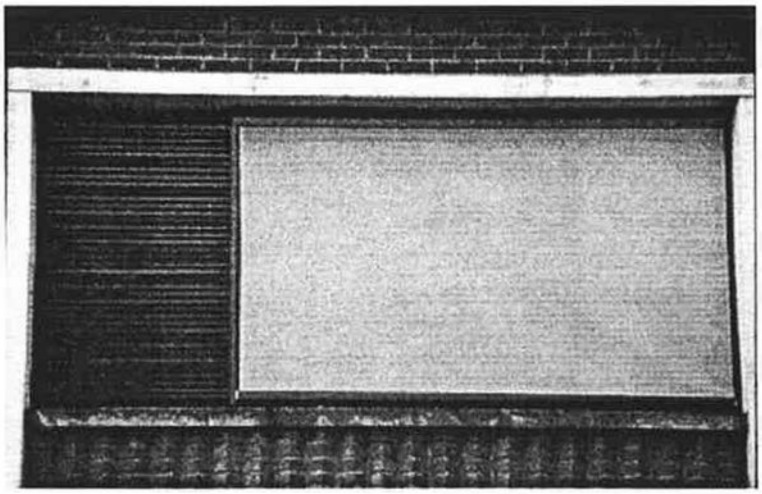
A pragmatic renovation of the whole building started in 1994 and is expected to be finalised in the beginning of 1997. It includes the following measures : thermal insulation of the roof, demand controlled mechanical ventilation, external solar shading system, large louvres for passive night cooling in each room and (probably) demand controlled lighting system.



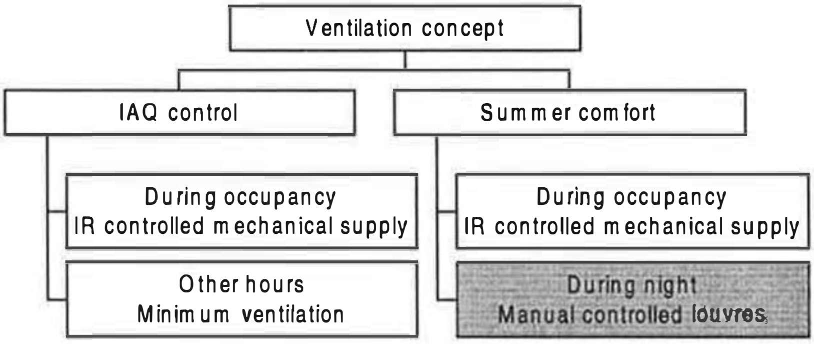
West facade of the PROBE building. Various shading devices were tested including a combination of screens and ventilation louvres (left upper window)

The IAQ has improved substantially in winter and the first experiences during the summer of 1996 indicate good thermal comfort due to the combination of shading and night ventilation

Night ventilation often makes use of chimneys for increasing the stack effect and the wind effect. In this case, it was not evident to add chimneys without closing the building to employees for a certain period of time. Given the fact that there is a large building stock with similar problems as this one and that it was expected that a substantial improvement can be achieved without having chimneys, only external shading and large louvres were installed for improving the summer comfort. The size of the louvres in each office is about 1.2 x 0.8 m^2 with a net section of about 0.6 m^2. Even with doors closed, the impact on the thermal comfort is substantial. It is important to stress that a hybrid ventilation concept is used, combining mechanical ventilation with natural ventilation (see scheme below)



Louvre and external solar screen

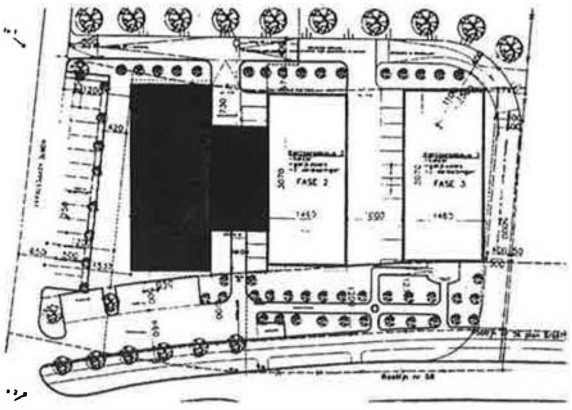


Overall concept for ventilation

Architect for renovation	Building physics consultant
Y. Wauthy, Brussels	BBRI, Brussels

Belgium BE2	New office building built by a promoter near a highway Aalst

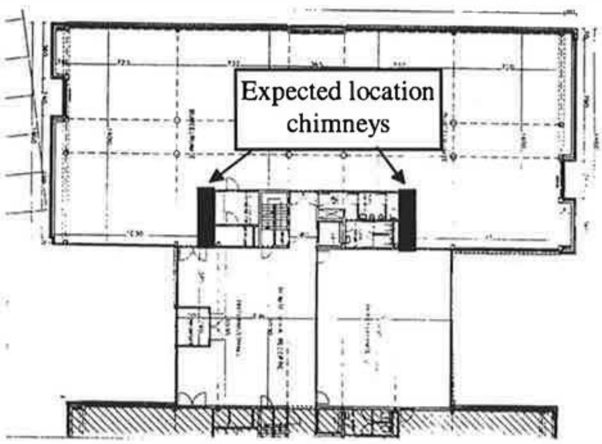
This building will be constructed in Aalst, close to the highway between Brussels and Ghent. The distance to the highway is less than 100 m. It counts three floors and has a total floor area of about 3500 m².



Site plan for new building

This building was not originally designed to be a naturally ventilated building. The promoter was however uneasy in his mind about the fact that it would be impossible to open windows at daytime due to the noise coming from the very close highway. His concern that the users should be able to open the windows without acoustical complaints was based on the assumption that overheating would occur in summertime and that window airing during the day would be necessary. After a number of discussions, he agreed to evaluate the possibilities for adding a number of features to the design (solar protection, better accessibility of thermal mass, energy efficient lighting, night time ventilation,...) in order to prevent overheating and eliminate the need for window opening at daytime.

BBRI started to study this project at the end of August 96 whereas the foundation work started in the middle of August. It is clear that the time constraint was very important. The building should be finalised before the end of April 1997.



Floor plan new building

As the clients that will hire parts of the building are not yet all known, the placement of the internal walls will not take place during the construction. Likewise, there might several clients per floor. In these conditions, it is not easy to implement night ventilation through facade louvres and roof chimneys because it impacts very much on the building layout (eg internal air paths). The first studies and the discussions with the building promoter and architect have resulted in a design with 2 relatively large chimneys (about 3 m² in total) in combination with facade louvres for the ventilation of the upper floor only, where it is less disturbing the building layout. The other floors can be ventilated (cross and single sided ventilation) through large louvres placed in the facades.

It is clear that a very important boundary condition in this project is the cost aspect. The promoter has a strong interest in the concept of a building with good indoor climate conditions at low energy cost but he should be able to recover the cost increase by a higher renting rate. Part of BBRI tasks is to provide him with (scientifically correct) information allowing to convince potential renters of the benefits of this building.

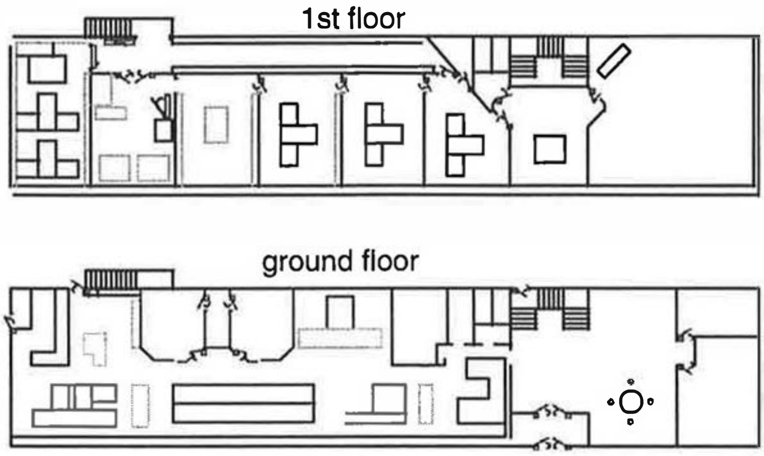
As already indicated, the timing for this project is extremely tight. This is to a certain extent a disadvantage for the planning phase but we believe that it is rather close to the daily design practice for ordinary office buildings. We believe that a lot of information with respect to the potential barriers can be obtained.

Promoter	Architect	Structural design	Building physics consultant
Keppekouter n.v., Aalst	Declercq E., Kortrijk	Pluys R., Brussels	BBRI, Brussels

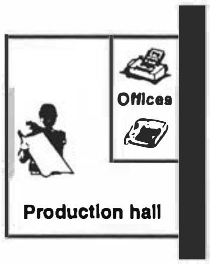
Belgium BE3	Renovation of an office building for a better thermal comfort Waregem

This 2 storey office building is located in Waregem, about 70 km north-west of Brussels. Frequent overheating problems were observed before renovation and it was even necessary to install a small AC system in the drawing room.

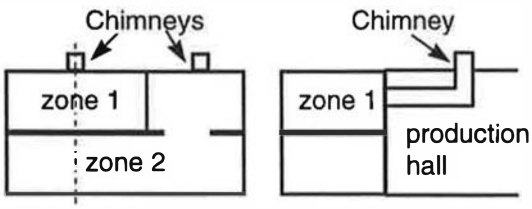
The main objective of the renovation project is to create a better thermal comfort in summer time. Besides, some other aspects like the improvement of the insulation level are also studied.



Storey plans



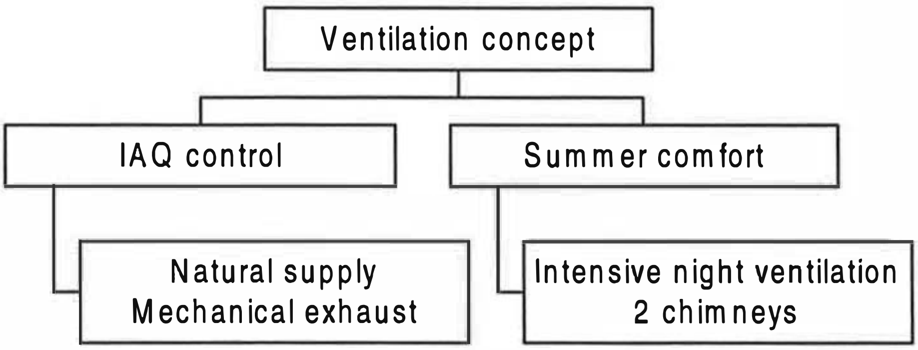
Site top view



Two chimneys for two zones

As one can notice on the site plan, the building is in contact with a large production hall which means that cross ventilation is not possible to implement. Therefore, it was decided to make use of 2 large chimneys to drive intensive ventilation at night time. Each chimney takes care of a specific zone in the building (see drawing). The cool outside air will be drawn into the offices through large louvres in the façade.

The control of Indoor Air Quality also calls upon natural ventilation. Small adjustable ventilation grilles are placed in the window frame. They supplies outside air to the offices while a central mechanical extraction takes place in the corridor. The renovation work will be finalised around April 1997.



Overall concept for ventilation

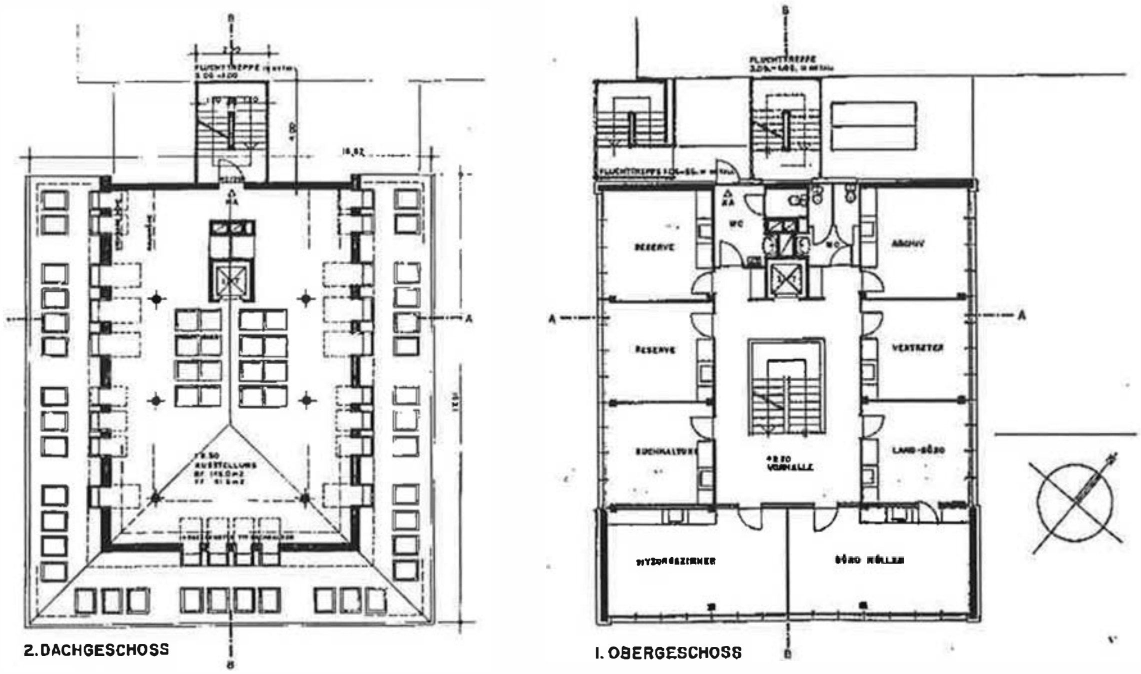
Owner	Building physics consultant
RENSON n.v., Waregem	BBRI, Brussels

Switzerland CH1	The VELUX building TRIMBACH

Outside view of the building

The Velux building was renovated in 1992. The former flat roof was topped by two additional floors with tilted outside walls resulting in the new roof shown in fig. 1. The basement and the two lower floors consist of cellular offices and the two top floors are designed as an open plan office (3rd floor) and a show room (4th floor) respectively. Attached to the back of the building (NW side) is a production hall for window fittings located. The building is located in a quiet industrial zone at a low frequented road at the edge of a river. Noise and pollution are therefore not considered as a problem.

In the early summer of 1996 most of the windows (four windows in the basement, every second window in the 2nd and 3rd floor and the top roof windows) were furnished with electronic attenuators. Because of the open architecture of the staircase of the building, the stack effect is considered to provide a sufficient strong force for ventilation. Rain, temperature and wind sensors as well as a timer are installed to supply a decentralised building management system with the necessary information to operate the attenuators. Security issues (no automatically opened windows on the ground floor, secured windows in the basement) as well as flexibility guided the ventilation concept. The user is still able to modify his indoor climate by manually operating the unautomatized windows and the external shading devices. The design is characterised by relatively low investment costs and the possibility of incorporation during a renovation. It relies on natural ventilation only. Night cooling is foreseen for the summer season and a static heating system is installed for the cooler days.

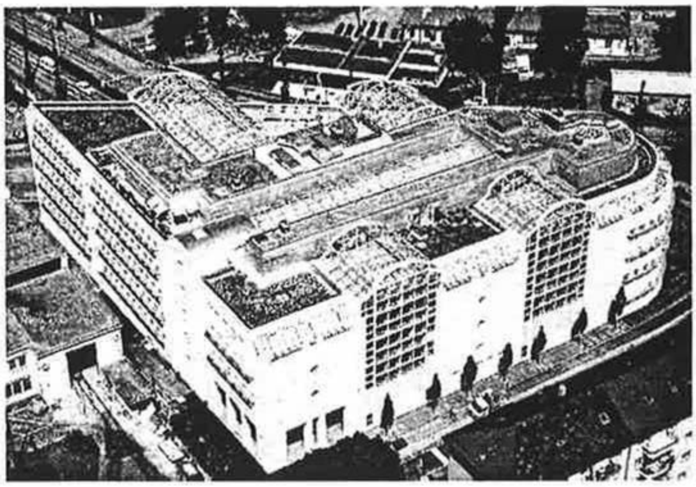


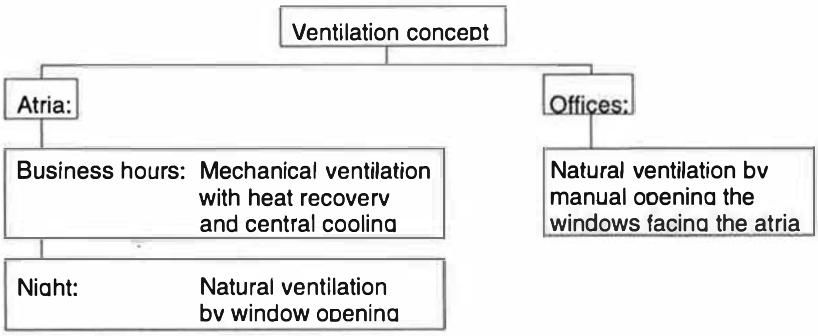
Floor plan of the 4th (open plan, left) and the 2nd (cellular office, right) floor

Architect	Window design
W. Thommen, AG Trimbach	Window Master, Trimbach

Switzerland CH2	The EWZ building Zürich

The EWZ building (see fig. 1) was completed in 1994. It is a 5 storey building (with 2 basements) with a floor area of 15600 m^2 in an urban area of Zürich. The main design guideline was a minimal overall energy consumption of the building. A two step hybrid ventilation concept, described in fig. 2 was chosen to meet energy and comfort demands. The mechanical ventilation system is equipped with a central heat recovery unit for the heating season and a cooling machine with an ice stack for the cooling season. The atria are mechanically ventilated during the working hours.





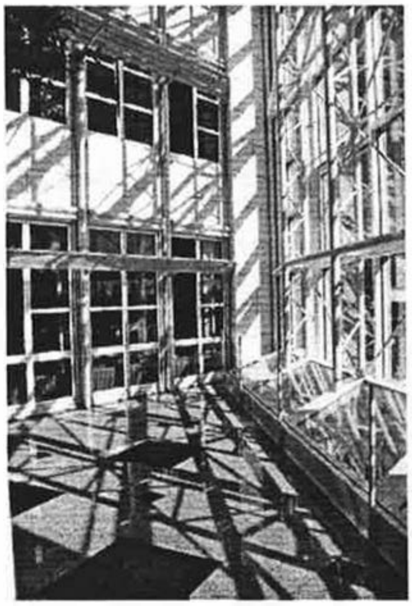
Overall concept for ventilation

Most of the offices are facing the atria and naturally ventilated by manually openable windows towards the atria. The other offices (i.e. left side of fig. 1) are facing the outside of the building and therefore mechanically ventilated. The heavy traffic on three sides of the building with its noise and pollution is the main reason for this design.

The mechanical system provides a good indoor climate in the atria with respect to noise and pollution, because the air inlet is located on the roof. Also this concept is cheaper than having ventilation ducts in every office. Other features of the building are:

- massive walls with good thermal insulation
- exposed ceilings for heat storage
- district heating
- day light guiding system to compensate atria losses
- artificial lighting is guided by daylight sensors
- trees in the atria
- mixing fan below the atria roof to reduce the thermal stratification, to provide also acceptable temperatures on the top floor

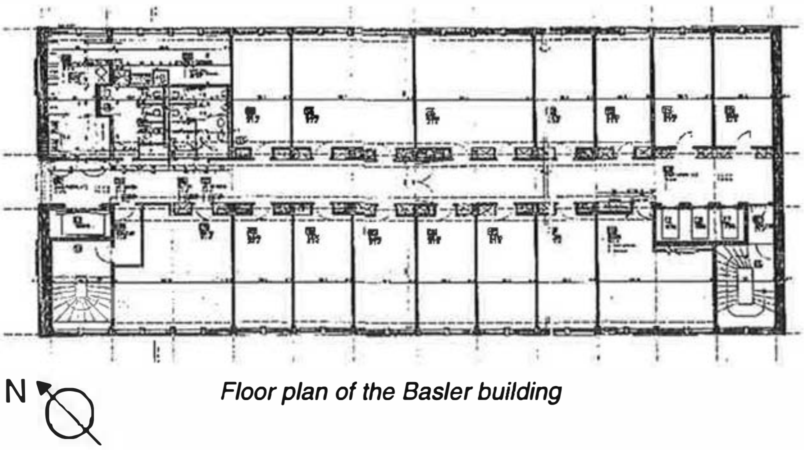
First results are available for the energy consumption: In the first year the heat energy demand was as low as 168 MJ/m^2 which was very close to the design value of 162 MJ/m^2. Currently an optimisation team is analysing the performance of the building in order to further reduce of the total energy consumption.



Inner view of one atrium with the air outlets in the floor. In the back are the office windows with the solar protection discernible.

Architect	HVAC engineers
U. Wüst, K. Hangartner, Atelier WW, Zürich	Gruenberg & Partners AG, ZUERICH

Switzerland CH3	The Basler Versicherungen building Basel



Floor plan of the Basler building

The Basler Versicherungen building is located in the town centre of Basel. Two main roads are in the close environment of the building. The ten floor building (+ 2 basements) was constructed in 1951 without any mechanical ventilation apart from the toilet rooms. The floors are made from massive concrete and the facade is made of a concrete glass construction. All the offices are ventilated by manual window opening only. In wintertime, the building is heated by means of static radiators under the windows.

Outside view

Instead of refurbishing the building with a HVAC system, the owners decided for a very pragmatic approach for improving the indoor climate. By educating the users on using their external stores against solar radiation and opening of the windows for cooling, they could considerably improve the working condition. On the SW-side of the building, opening of the windows in the morning (the facade is still in the shade) and closing the windows and pulling down the solar protections and opening of the door to the corridor on sunny afternoons is promoted. For the offices facing NE, the opposite strategy is suggested.

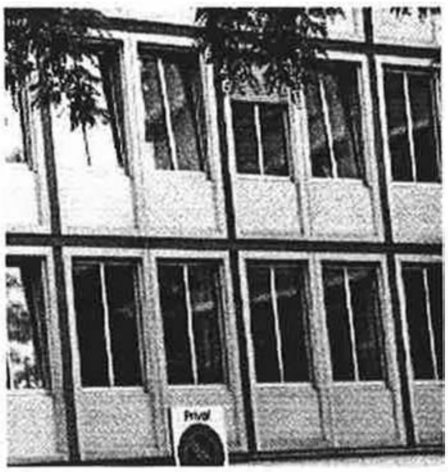
In terms of the NATVENT project we are interested in the performance of this building. Since the occupants are directly responsible for their own indoor climate, they are motivated in following the suggested strategy. We believe that the performance of this building is close to the optimum that can be achieved without any technical ventilation installation.

Two issues are thereby of a special interest:

- How good is the user discipline in using the means they have to influence the indoor climate and what is achievable in terms of performance?
- Does the great range of influence the occupants have on their indoor climate, increase their degree of contentment?

By comparing the Basel results with other monitored buildings, we are looking for a possible improvement in user satisfaction of the different technical solutions relative to the CH3 building.

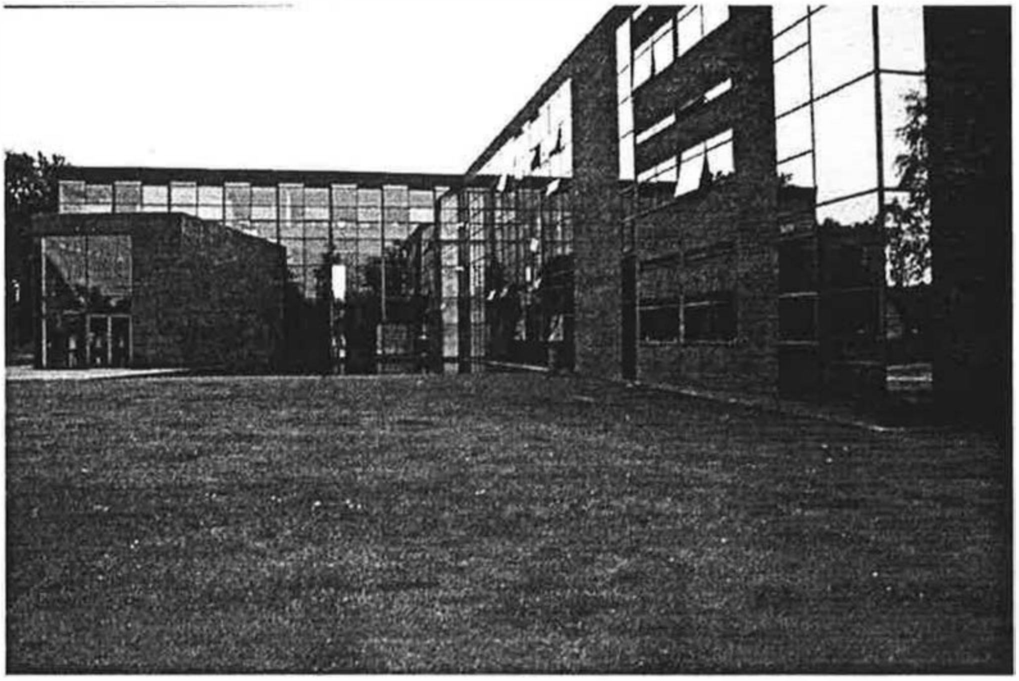
In the heating season, the main focus is set on the indoor air quality.



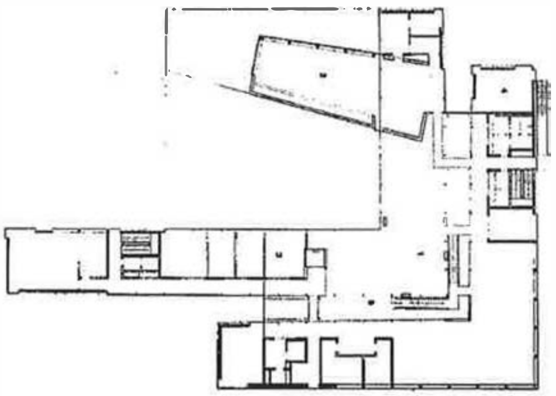
Detail of the facade

Architect
Wenk & Bauer Architekten AG, Basel

Denmark DK1	E. Pihl & Søn AS headquarters Copenhagen



Outside view



Ground plan

The office building is the headquarters of E. Pihl & Søn AS which is a major contractor in Denmark. The building, was built in 1993/94, and it is situated in suburban surroundings approximately 10 km north of Copenhagen City.

In concept, the building is a one-sided, three storey office building in which the corridors are formed as a panopticon space and angled in a diagonal symmetry in which the sides of the angle reflect each other. There are skylit galleries and the two-storey main hall has a large glazed facade facing south-west.

Detail skylit galleries with openeable windows

The office building is specifically designed for natural ventilation (except for the toilets, cloakrooms, service area and air supply through slots in the floor along the glazed facade in the main hall and exhaust in the adjacent entrance). All the rooms have openable windows. Besides large panorama windows, all the offices are equipped with thin, high window bands with specially designed multiposition ventilation openings. The openings provide the ventilation and makes nightcooling possible. In the skylit galleries there are openable windows. Also, in each of the rooflights an exhaust system is incorporated. In case the natural ventilation proves insufficient the mechanical exhaust systems will assist in ventilating the building. Even in the very hot summer of 1995 the mechanical systems were not activated.
In general the ventilation is computer controlled by the socalled 'intelligent house concept'. Solar protection consists of internal blinds and reflecting glass.

Denmark DK2	BRF Kredit building Lyngby

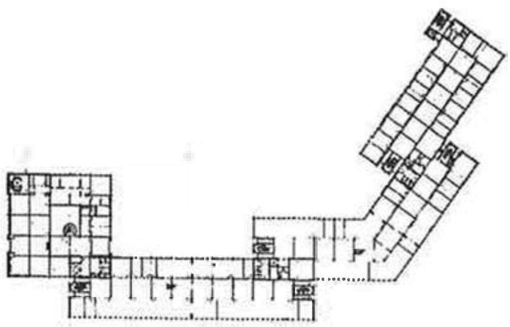
Outside view

The BRF-kredit Headquarters is the office building of a Danish financing institute for property mortgages. It is situated in urban area in Lyngby 10 km north of Copenhagen City. The building was finished in 1986, and it is now the place of work for about 600 people. The building consists of a four-storey main building and three four-storeyed office blocks. The four sections of the building are linked together.

At the planning of the design of the building, it was emphasised by the client that lighting should largely be provided by daylight instead of electric light. As a consequence, the use of central overglazed spaces is a dominant feature of the building. All of the sections have a glass covered central room for circulation. In the main building there is a quadratic shaped atrium, and in the office blocks there are arcade rooms stretching lenghtwise between the two ends of the block.

The figure shows the plan of one of the floors. The atria are open through the 1st, 2nd and 3rd floor, whereas there is no access of daylight to the circulation area of the ground floor. The offices receive daylight through the windows in the facades. There are no windows between the offices and the atria.

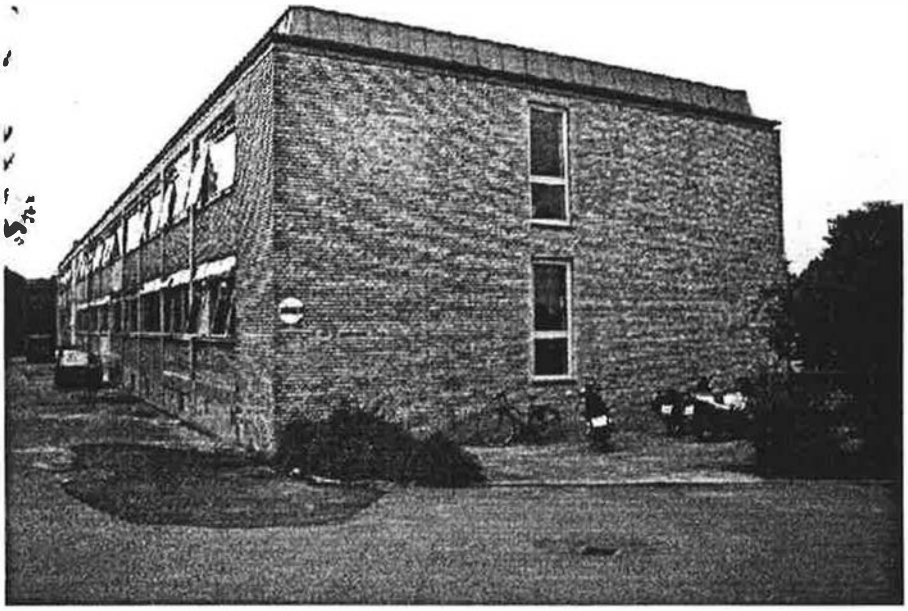
Detail upper gallery



Ground plan

Mechanical ventilation is provided only in meeting rooms, toilets, canteen and the central computer room. Ventilation in the rest of the building is promoted through multiposition windows in the offices and openable windows in the rooflights. Nightcooling is possible. In order to prevent overheating due to excess solar radiation exterior blinds are mounted at the top of the rooflights. The activation of the blinds is controlled automatically by the use of light sensors.

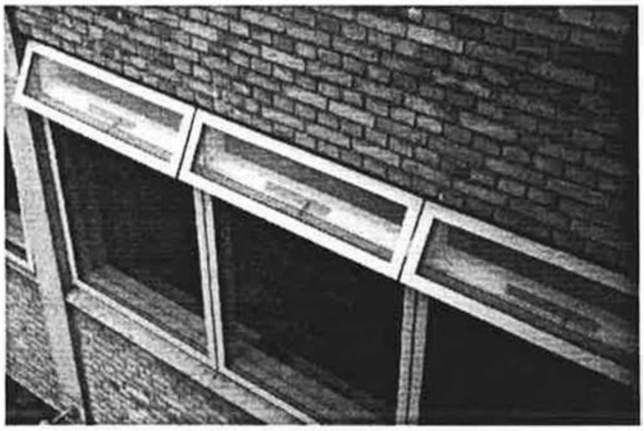
Denmark DK3	The WindowMaster Headquarters



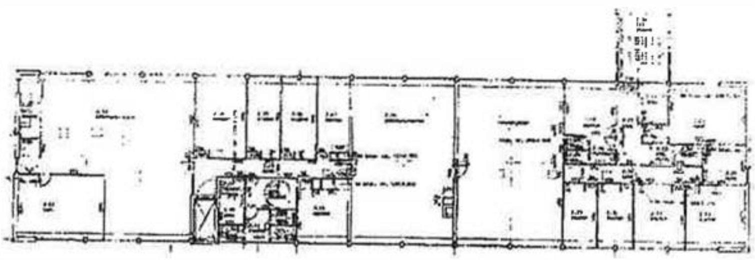
Outside view

WindowMaster headquarters is a renovated factory building consisting of three storeys, the bottom storey being partly below ground. This floor includes the canteen, storage rooms and workshops. The offices are on the two top floors where there are both single cell offices and open plan offices.

The building, situated in suburban surroundings 18 km north of Copenhagen City, was renovated in 1995. In connection with the renovation preparations were made for future installations of control systems for handling of window opening, night-time cooling, solar shading etc.



Motor-operated window

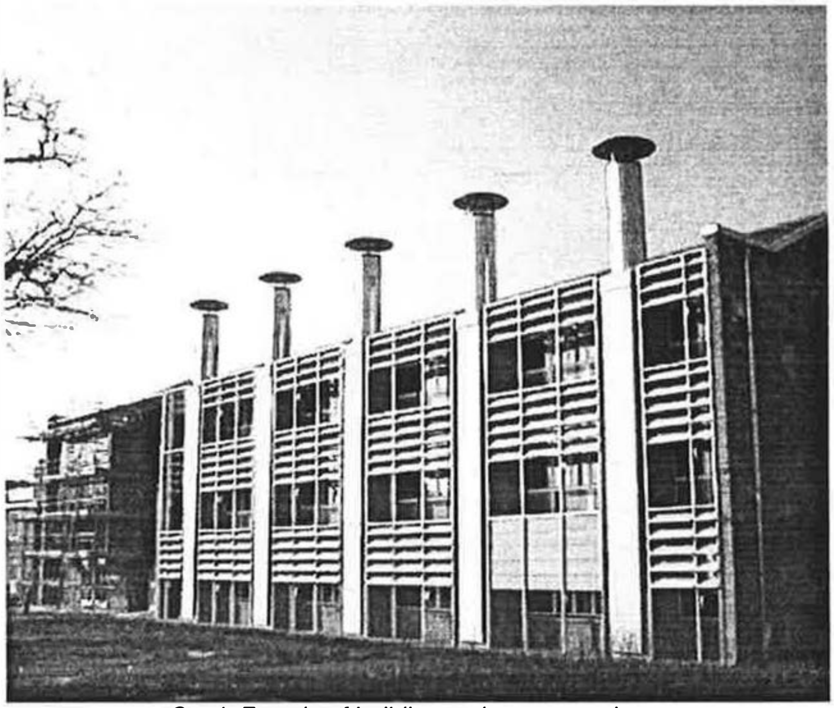


Ground plan

At present the outdoor air supply to the offices is provided through user controlled motor-operated windows. In addition there are high positioned window bands. Room thermostats are controlling the opening of these windows which can be left open during nighttime. Air is extracted through skylights in the two staircases. The skylights can be left open over night. Solar shading is user controlled motor-operated internal blinds.

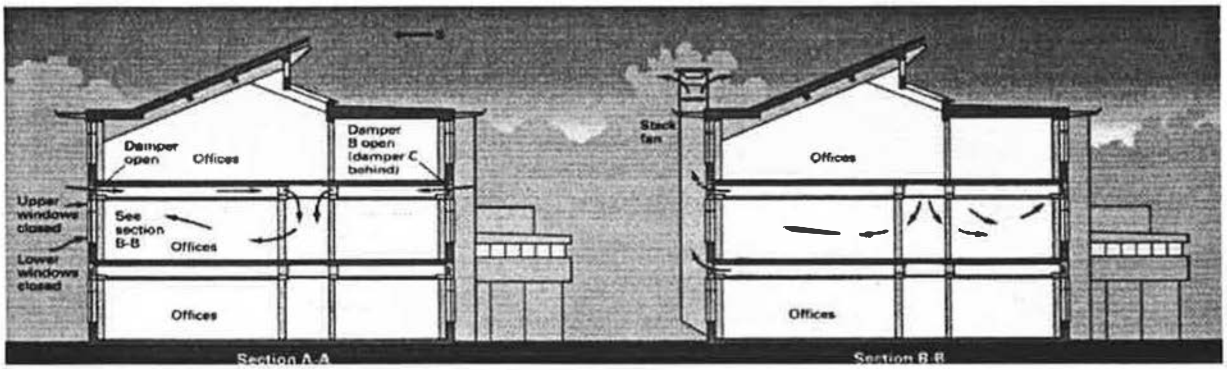
Great Britain GB1	BRE Energy Efficient Office for the future

The BRE Energy Efficient Office of the Future (EOF) is a new office block being built at Building Research Establishment, Watford, 20 miles from central London. Set to be occupied in 1997, the building has three floors and covers a gross area of 2000m^2 with an energy performance target of 20-30 kg CO_2/m^2/year. It is intended to represent best practice at the year 2000 and will meet the energy and environment targets currently anticipated in the early part of the 21st century. It will also be a working office housing the Fire Research Division of BRE. The building also includes a lecture theatre and conference facilities.



South Facade of building under construction

The building is naturally ventilated using a combination of single, cross and passive stack ventilation. The design also includes a sine-wave floor, which has two purposes: firstly to increase the surface area and thus thermal mass of the building's ceilings, and secondly to provide air pathways for cooling and ventilation. During the heating season, background ventilation is provided through trickle ventilators. In addition, low or upper windows can be opened by the occupants. For the summer, large areas of openable glazing are incorporated on both sides of the building to provide through draughts. Although these will be controlled by the BEMS, the occupants will be able to manually open windows in their local area. When there is not enough wind to drive ventilation in the building, pressure different will be created by the ventilation stacks attached to the south side of the building. If the solar generated stack effect is insufficient, fans inside the stacks will be activated. The ventilation paths in the sine-wave roof will be used during the night to provide pre-cooling.



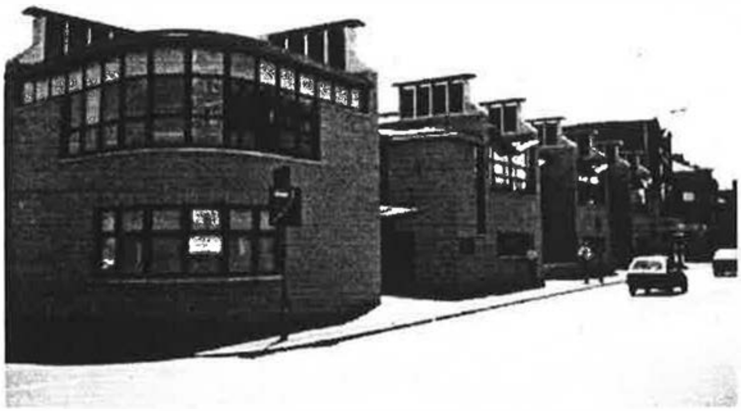
Building section with the ventilation strategy marked

Architect	Service Engineer	Structural Engineer	Quantity Surveyor
Fielden Clegg Design	Max Fordham & Associates	Buro Happold	Turner and Townsend

Great Britain GB2	Canning Crescent Centre

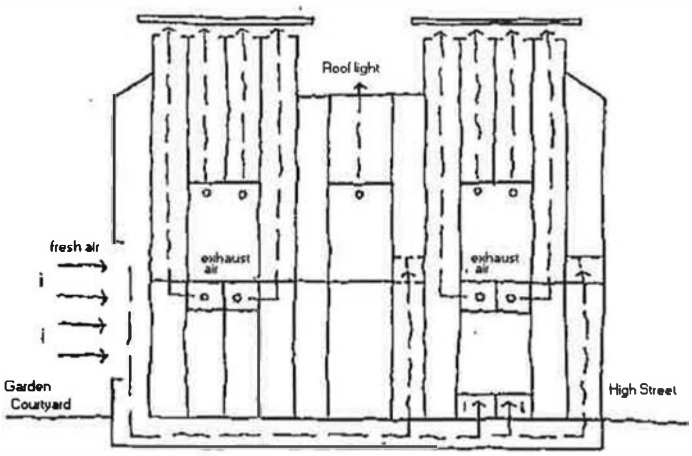
The Canning Crescent Centre, is a purpose built centre, comprising of two separate day-care units with some shared facilities. Completed in 1994 at a cost of £1.3 million, the centre is built on two storeys and has a gross floor area of 1350m^2. It is situated in the heart of Wood Green, a London urban area, adjacent to a very busy high street. The construction is steel frame with brick external walls. Thermal mass is provided by the exposed masses of brick and the ground floor concrete ceiling.

Due to budget restrictions it was decided not to incorporate any mechanical ventilation in the building; but to provide a purely natural ventilation system. However, openable windows were not really an option due to the projected loss of privacy combined with the noise and poor air quality from traffic pollution from the high street. The solution was to create diaphragm walls where each room is connected to a vertical 'outlet' chimney to exploit the stack and wind effects and thus achieve a variable level of exhaust ventilation. The rooms on the noisy high street side of the building have a air inlets at low level, fed through a supply duct routed within the footings to allow clean air to enter silently from the courtyard side, displacing CO_2 and contaminants up towards the outlets.



Exterior view

At the top of each chimney, but within the insulated envelope of the building, an opposed blade volume-control damper controlled by the occupants and by a central control system allows the passive effects to be optimised without compromising energy efficiency in winter (when the stack effect is most effective).



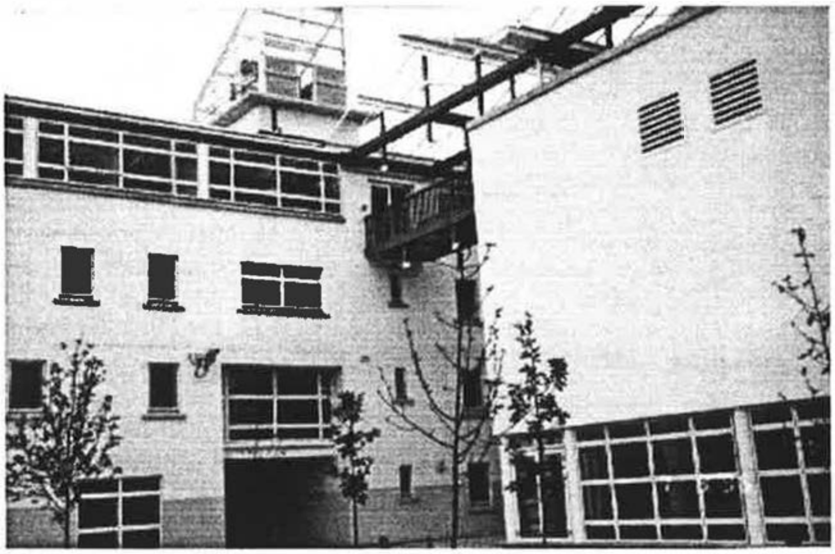
Ventilation strategy (section)

The chimney type outlet was decided on the grounds that functions are independent of wind direction. The glazed clerestory at the chimneys serve two functions, one as an access panel to the damper at the head of the shaft and the other as a solar accelerator, which adds heat at the top of the shaft in the summer and increases the updraught when wind stack effect are slight.

Interior view

Architect	Service Engineer	Structural Engineer	Quantity Surveyor	Main Contractor
Mac Cormac Jamieson Prichard	Atelier Ten	SMP Atelier One	Walker Richardson	DJ Higgins & Sons

Great Britain GB3	Portland street building Portsmouth



View from the courtyard

The building houses the Built Environment Faculty of Portsmouth University and was completed in June 1995. The design brief called for energy conservation and the creation of a stimulating and life enhancing environment for educational purposes. It is a four storey E-shaped building in plan enclosing a quite courtyard; the central bar of the 'E' accommodates a lecture theatre with a coffee bar below. The southern wing extends almost twice as far as its northern counterpart. Extending the full length north-to-south between the wings is the 'forum' a four-storey space with a glazed roof and solar shading. The ground floor contains staff offices, seminar rooms and, west of the 'forum' and opposite the cafe, the resource centre and two lecture theatres. The first floor contains staff and seminar rooms and the main lecture theatre over the cafe. Staff and studio rooms occupy the second floor with IT rooms flanking the resource centre. The top floor contains architecture staff and studio spaces, with a lecture review room above the lecture theatre. In the wings, the rooms are arranged at either side of a central corridor with five staircases for vertical circulation.

Interior view of the 'forum'

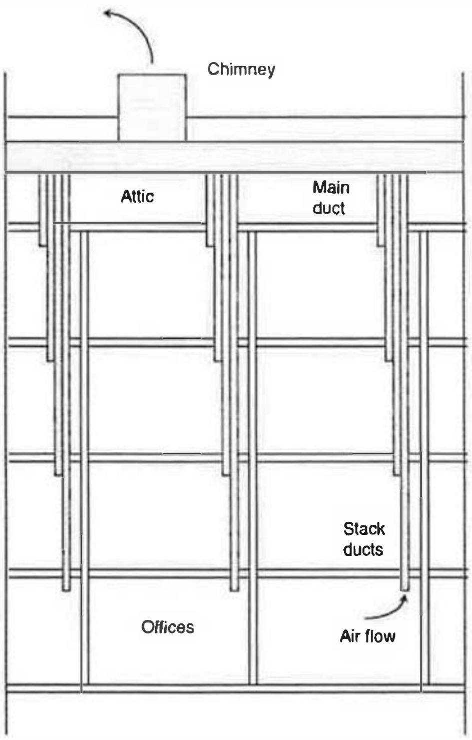
The building is naturally ventilated apart from the lecture theatre. The five staircases are glazed at the top to act as solar chimneys while fans are activated when the pressure difference created passively is not enough to create the required air movement. Extract grills along the central corridor via a ceiling plenum provide the air connection between the office and the staircase.

Heating is provided by an underfloor hot water system. During the winter background ventilation is provided through trickle ventilators located at the upper part of timber finished window frames. During summer, cross ventilation, assisted by the passive stack on hot still days will provide the required cooling. Exposed concrete columns and ceiling in some of the rooms provide the thermal mass for night ventilation pre-cooling.

Architect	Service Engineer	Structural Engineer	Quantity Surveyor
Hampshire County Architects Department	HCAD	Buro Happold	Currie & Brown

Norway NO1	The administration building of the Ulleval hospital Oslo

Outside view



Principle of the ventilation system

The administration building of Ulleval hospital in Oslo, Norway, was completed in 1924. The building has 4 floors and a basement. Total floor area is approximately 14000 m², with 870 m² on each floor. The room height is 4 m. The building has a large thermal mass, with masonry walls and concrete floors. There are about 160 employees in the building, occupied mainly with office type work in 120 cellular offices.

The building is situated in the centre of Oslo, with much traffic on a road just in front of the building.

The heating system is based on hot water circulating in radiators below the windows.

Originally, the building had radiators based on steam, but this was changed in 1964, when the building was refurbished. There is no special night cooling or any other cooling system in the building.

Air outlets

The building was designed for natural ventilation, based on thermal buoyancy in vertical shafts from each of lice room. The size of the shafts are not known. The ventilation system has not been changed, except for a few rooms with much electronic equipment, where water- cooled fan-coil units are installed. Each room has inlets in the outer wall and an extract terminal on the inner wall.m

The occupants say the temperatures often are too high in summertime, but apart from that there have not been special complaints on indoor air quality or thermal comfort.

Norway NO2	Office building - Pfizer as Oslo

The Pfizer office building

External ventilation inlets

The building is situated just outside the centre of Oslo, between a highway and the seashore. The building was completed in 1982. Total area is 3070 m², and there is about 80 employees in cellular office rooms. The building has concrete floors and semi-heavy external walls with wooden, insulated framework and a brick cladding (see pictures).

The heating system is based on direct electric heating, with panel ovens beneath the windows (see pictures). The building has mechanical extract ventilation system, with extract terminals in each office. The air inlets are located below the windows, behind the panel ovens (see pictures). This ensures a preheating of the ventilation air. The inlets are also specially designed to give sound attenuation.

Panel ovens for heating in cellular offices. The ventilation air inlets are located behind the panel ovens to ensure preheating. The inlets are designed to give sound attenuation

There is no heat recovery in the ventilation system.

The building has external Venetian blinds for sun shading.

There have been no special complaints from the occupants concerning indoor air quality or thermal comfort.

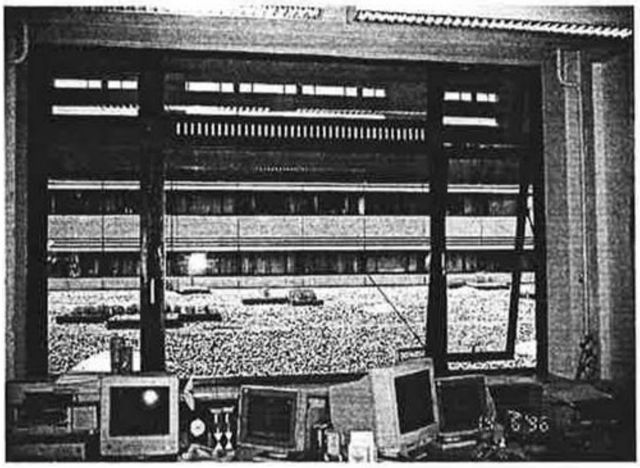
The Netherlands NL1	The European Patent Office Rijswijk

The European Patent Office was built in 1972.

It consists of a square lower part (37 * 37 m) of 4 floors and a tower of 86 m (25 floors) . The diagonals of the building point respectively North-South and East-West. It is a heavy building. The rooms are situated around the inside and outside circumference of the lower part (a square ring) and are separated by a corridor. In the tower the office rooms are situated along the four sides. The whole building is naturally ventilated except for the computer rooms, the archives, the restaurant and the meeting rooms, which are fully air-conditioned, and the toilets, which are mechanical ventilated.

The European Patent Office in Rijswijk

The office rooms measures 3.5 * 5.5 * 2.75 m (w*d*h). The glass area above the parapet consists of fixed view and day-lighting windows (respectively. 1.80 * 1.20 and 0.35 * 1.20) and upper and lower outside turning flap windows (respectively 0.70*35 and 0.70*1.20 m) on each side of the fixed windows. Between the fixed windows is a ventilation grill. On the outside around the building are fixed sunshades and on the south-east and south-west facade manually operated outside venetian blinds.



View from an office room

Reason to choose this building:

- This is a typical naturally ventilated office building with cell like office rooms on every side of the facade.
- The occupants are satisfied with their workplace. Only in extreme summers are there some complaints about the indoor temperature.
- A new BMS has been installed; so that continuous monitoring is possible. Furthermore also the outside climate is measured.
- The influence of natural night cooling in a hot summer day can be investigated.

The Netherlands NL2	The Town Hall of Zevenhuizen-Moerkapelle

Built in	1987
Floor area	1.400 m²
Storeys	2
Volume	4200 m³
Thermal mass	heavy
Occupants	50

Ventilation system: Input of fresh air via manually openable windows; the exhaust ventilators have two capacities: 1000 m3/h for minimum ventilation in the winter and 5000 m3/h for night cooling in the summer.

Winter strategy: Minimum ventilation during working hours of 1000 m3/h. Intake of air via infiltration.

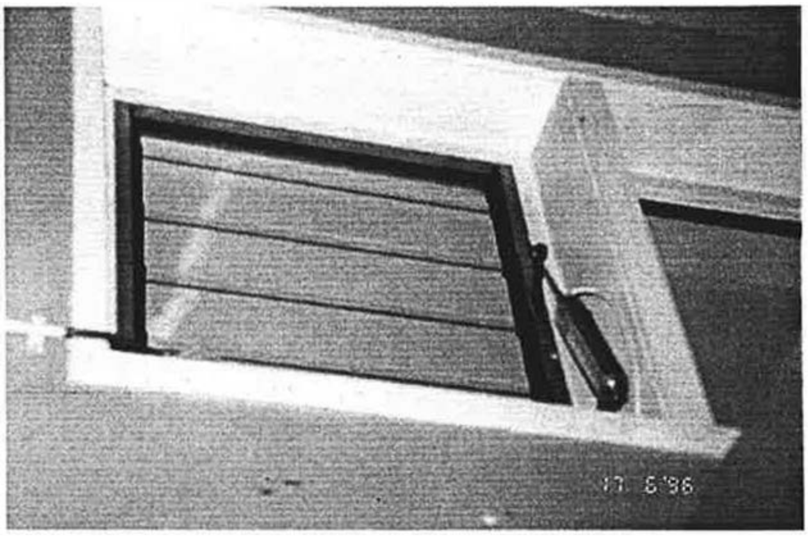
Summer strategy: Normally the ventilation system is off in the autumn, spring and summer. However, when a cool situation occurs: the indoor temperature is above 21 0C and the temperature difference between indoor and outdoor is more than 3K, the night cooling is started: after office hours the ventilation system runs at full speed and the Louvre window is open.

The Townhall of Zevenhuizen-Moerkapelle

The occupants are very cooperative and when it is very hot, the windows are closed at 10.00 in the morning during ohhi.

Reason to choose this building:

With a very simple control strategy for night cooling, only indoor sun shades and an ACH of 1.5, it is possible to obtain a sufficient low indoor temperature. The results can be used to determine simple design rules for small offices.

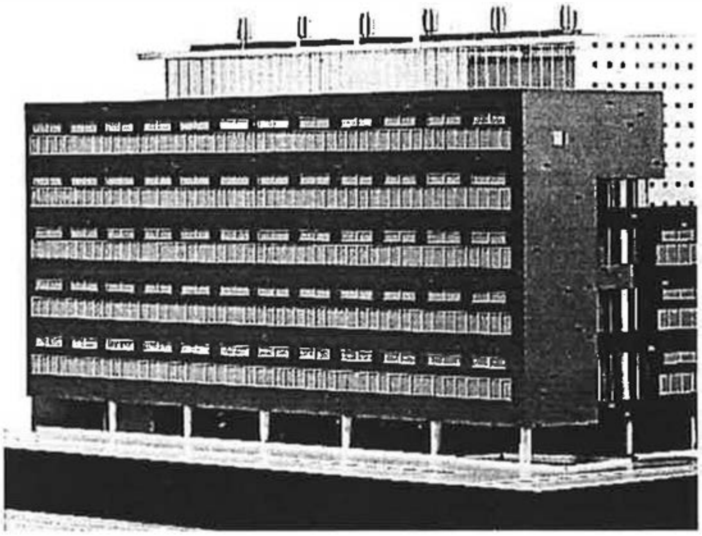


The louvre window for night cooling. It is automatically opened when the ventilator runs at full speed

Architect	Owner
Groen & Bregman	The Municipality of Zevenhuizen-Moerkapelle

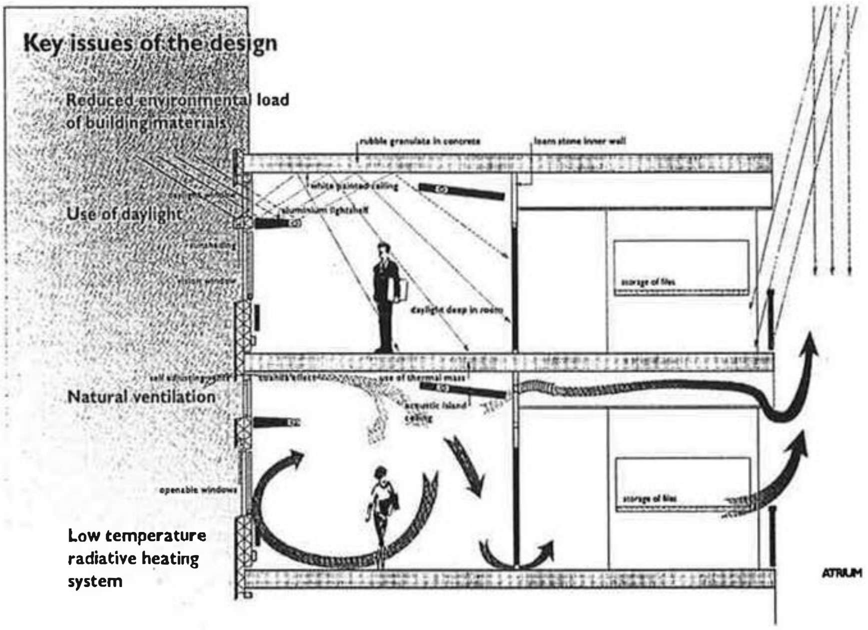
The Netherlands NL3	The Tax Office of Enschede

This building is a Therme EC2000 project. It makes maximum use of passive and active solar energy for heating and day-lighting. The building is situated near a railway station and is wholy natural ventilated. The office rooms have manually openable inside turning trap windows for summer ventilation and double vent dampers integrated in the wall, just below the ceiling. To make optimal use of the building mass, the office rooms have half open lowered ceiling. On this way optimal use of the Coanda effect and of the building mass is obtained. In the winter only one damper is used for minimum ventilation and in the summer both dampers are used for night cooling. On the railway side noise reducing dampers are used. The office rooms are situated on both sides of an atrium. Six huge chimneys on top of the atrium take care of the natural ventilation flow through the building. Participation of the occupants is expected to open the windows and both dampers for night ventilation.



Outside view

Occupation	200 people
Floor area	4300 m^2
Floors	5
Ready	Second half of 1996



Optimal use of daylighting, natural ventilation and night cooling will realise an expected energy consumption of 17 m3 gas equivalent of primary energy.

Reason to choose this building:

This is a modern low energy building with optimal use of daylight and natural ventilation and night cooling based on the latest views on this field in The Netherlands. Optimal results depend on occupants behaviour.

Owner	Design and Indoor Climate	Building physics consultant	Consultant	Daylight consultant
The Government Building Agency	The Government Building Agency	Peutz & Associés	Woon/Energy	Esbensen

Sweden SE1	Small office building with cheap ventilation

The building was completed and the users moved in during spring 1996. It is a small two stories office building situated in windy surroundings right at the harbour quay in Malmö, southern Sweden. The users of the building are also the architects, and thus a great deal of effort was made to adjust the internal environment of the building to the demands of the users.

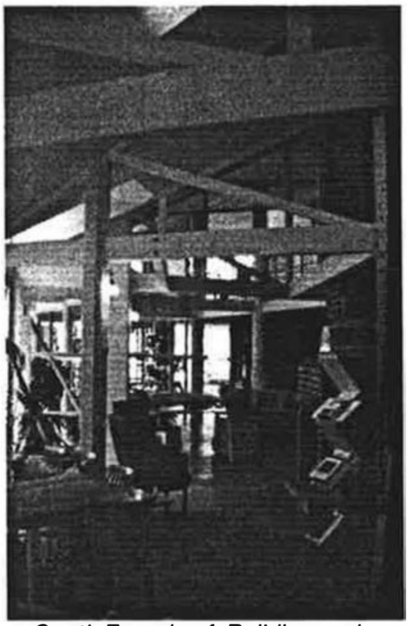
Northeast façade

The ventilation concept is the same all year around: Outdoor air supplies are through poppet valves and open windows. Air is exhausted through open windows and three small manually operated exhaust fans. The internal environment is to a high degree dependant of the interaction with the users, i.e. opening/closing windows and adjusting the air flow rates with the fans. The ventilation system is a hybrid concept, combining natural ventilation with user controlled mechanical exhaust ventilation.

The external solar shading system of the glazed south façade consists of large green plants growing in an green house attached to the building. The south façade is also protected by a covering roof. The building is heated by underfloor heating.

According to the users the indoor climate has been pleasant during the short period the building has been occupied.

The ventilation concept is the same for both IAQ control and summer comfort:



South Facade of Building under construction

Outdoor air intake	Indoor air outlet
• Temperature controlled poppet valves • Manually openable windows	• Manually openable windows • Manually operated exhaust fan

Overall concept for ventilation

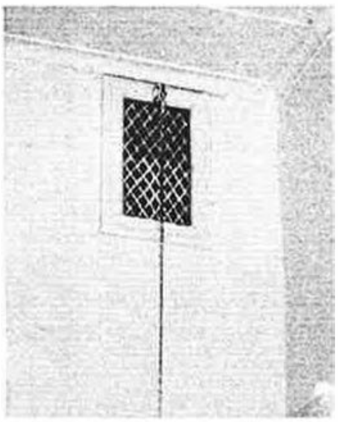
Architect and owner
Tage Møller Arkitektbyrå

Sweden SE2	Old building with passive stack ventilation

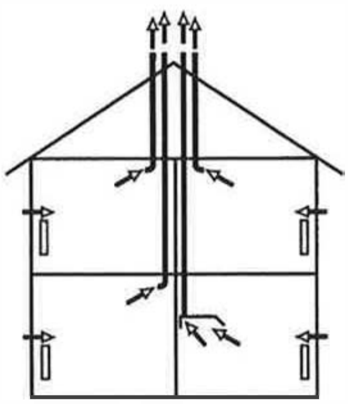
This object is a three-storey building with a basement. It is situated in the centre of a small town in southern Sweden. When it was built by the turn of the century, typical for the time period with a heavy construction and a passive stack system, it was as a school. In the beginning of the seventies it was transformed into an office building. At this stage changes were made to the layout of the building, it was renovated, and, unfortunately, the air supply devices in the façade were covered.

East façade

The ventilation system is arranged with a passive stack system, and thus depending on the thermal forces. By the windows on the top floor and in the basement there are air supply devices giving the building its air supply, while on the other floors air comes in only through openable windows and wall leakage. In those rooms air supply devices will be installed during the autumn 1996. These new air supply devices will be operated by the outdoor air temperature and close when the outdoor air temperature sinks below a specific temperature The exhaust air runs through passive stacks in every room. There is one separate passive stack for each room, running vertical through the thick walls. The corridors have no ventilation devices but depend on the ventilation of the office rooms.



Air exhaust devices



Ventilation system

As solar protection there is solar-protecting film glued to half of the windows and on the southern façade there are awnings protecting the windows.

The building is heated by district heating through radiators beneath the windows.

The ventilation concept is the same for both IAQ control and summer comfort.

Outdoor air intake	**Indoor air outlet**
• Temperature controlled air supply devices by the windows	• Passive stacks
• Manually openable windows	• Manually openable windows

Overall concept for ventilation
