"BreathingWindow"
Highly effective room ventilation system for all earth climates

Jon Kristinsson, prof. ir.
Architecten- en Ingenieursbureau Kristinsson bv, Deventer, The Netherlands
arch@kristinsson.nl and www.kristinsson.nl
Emeritus professor Faculty of Architecture, Delft University of Technology The Netherlands
jon@kristinsson.net and www.breathingwindow.org

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SUMMARY
The "breathing window" (BW) is a smart, decentralised balanced ventilation system in the skin of buildings. The BW is not yet on the market although the experimental zero-production has started. The winding process of 15 km copper thread on the "fine-wire heat exchanger" is a challenge. This new air/air heat exchanger weighs 1.05 kg and is compact enough to be cleaned in a dishwasher. It also measures and acts on the CO_2 concentration inside the room; it could even act as a fire alarm. The h/w/d dimensions of the first generation BW are 750/200/180 mm, respectively. The BW can be mounted in a window post or in an outer wall. After having tested prototypes in Iceland and in the Netherlands the predicted 95% heat-transport efficiency seems attainable. At a 20˚C difference between inside and outside air temperatures two 4W fans exchange some 50 m3/h making the thermal energy saving 320 thermal Watts . Traditional power plants have an efficiency of about 40% resulting in a net energy saving of the BW of 300 W. Therefore, the "overall energy efficiency" of the BW is 89%. The fine-wire heat exchanger has only a 18 Pa pressure difference. The fans in our current BW prototype cause 30 dBA noise, which needs to be addressed in the next prototypes.

1.1 Indoor-air quality

An investigation into the indoor-climate quality of private houses in the Netherlands has yielded some remarkable results worth mentioning. Research worker ir Evert Hasselaar attached to OTB of the Delft University of Technology investigated 500 houses in various categories. Two thirds of the housing stock had mechanical ventilation. Non-subsidized houses had a balanced ventilation with heating regenerative for the purpose of a low EPC. After some years the ventilation capacity was halved, a reduction of some 10% per year due to dirt. Besides because of the noise nuisance caused by the engine sometimes the whole mechanical ventilation had been simply shut off. Another discovery was that in 4/5 of the houses with natural ventilation the relatively small master bedroom was slept in by two people. 29% of these houses did not have a window open even at night due to traffic noise. The CO_2 concentration was far too high. Much fine dust and house dust mite was found. The bathroom which was used for showers three times a day generally had too little ventilation to get dry. This led to mould visible as black spots. There was no significant difference between built-in bathrooms or bathrooms with a window in the outer wall. Tiling bathroom walls up to the ceiling simplified cleaning.

1.2 Present installations

Studies on present ventilation in house-building and commercial and industrial buildings in the Netherlands, show an incredibly great difference between the results intended and what is effected in practice.
Factors are: concept, design, saving, execution, control, adjustment, use and maintenance.
In every phase mistakes can be made and are made, which are camouflaged by over-dimensioning. FIG 1

In the conceptual (draft) phase the architect should design the overall indoor-climate in a cross-cut fashion, phrase this and explain it to the principal and the installation consultants. In practice it usually does not work out this way. The help of experts is called upon.
Albert Einstein said: “We cannot solve problems with the same thinking that created them”.

Generally one does not choose adjustment of insights, such as the integral designing of a building and its installations, but goes on. Without affecting the layout all heating, ventilation and air-conditioning systems are drafted by consultants and usually concealed in lowered ceilings. The internal thermal mass of the building is for the greater part put out of action. Lowered ceilings in order to conceal air ducts claim 15% building volume. FIG 2

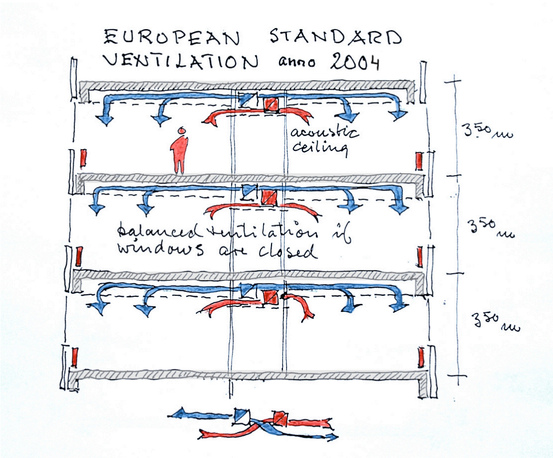

Fig. 1: Standard installation – cross section
lowered ceilings = 0.6 m

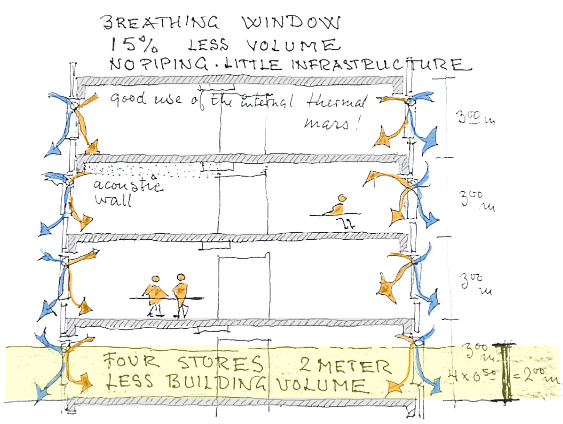

Fig. 2: ventilation in the skin of building –
15% less volume built

At the building-costs estimate before or after public tender the ventilation is sometimes curtailed. The suddenly required extra fire compartmentalizing is a well-known phenomenon in the last phase before the building permit is granted.

1.3 Installations reviewed

Gradually we have arrived at a turning point in thinking about installations.
The current installations in houses appear in practice not to be appreciated by its inhabitants.
The main reasons are noise nuisance and the quickly soiled heat exchanger behind a steel hatch in the attic. It belongs to another world compared with the familiar thermostat of the central heating installation.

The bigger installations are usually maintained, but take up a lot of space and render much thermal mass of buildings useless by lowered ceilings and facing. This means less comfort, higher building costs and higher peak loads of cooling and heating. Installations have a short writing-off period and are thus relatively expensive.

1.4 Use and maintenance

When everything has gone well, a long period of use and maintenance follows. According to research it appears that heat exchangers in houses with a balanced ventilation system are hardly maintained and get clogged up with dust. It also appears that two thirds of the mechanical ventilation as prescribed in the regulations are not achieved in draught-free newly built houses. The average user generally has no idea of technical installations. In large buildings which are mechanically ventilated, the sick-building syndrome was found. People felt locked up in non-compliant technology. This complaint is sufficiently remedied by opening windows, but the question arises: shouldn’t we look for fundamentally different ventilation systems?

1.5 New highly efficient ventilation

We start again from the very beginning – only a building is sustainable architecture – installations are silent, clever guests. As an architect I have been brooding for years on the idea of making a breathing window. How this is to be achieved and what form it is going to have is now (February 2005) not entirely known yet. Optimization of heat recovery to around 95% seems to be feasible.

The worldwide search in literature for the best heat exchanger took many years and to my great surprise ended on a website showing a fine-wire heat exchanger designed by someone who lives 40 kilometres away from where I live. The inventor, dr. ir. Noor van Andel, needed only a few months to convert the original water/air heat exchanger into an air/air heat exchanger. FIG 3 and FIG 4 (Three years ago he received an honorary doctorate from the University of Amsterdam). Being preoccupied by the name of breathing window, I chose the dimensions of a window-frame with a depth which is standard for the cavity wall + insulation of a traditional outside brick wall.

The breathing window has 3 main components:

1. a balanced ventilation system with two fans
2. a smart control system
3. a fine-wire counter-current heat exchanger

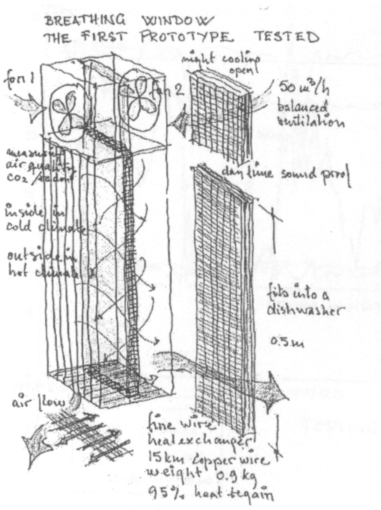

Fig. 3: First generation prototype design

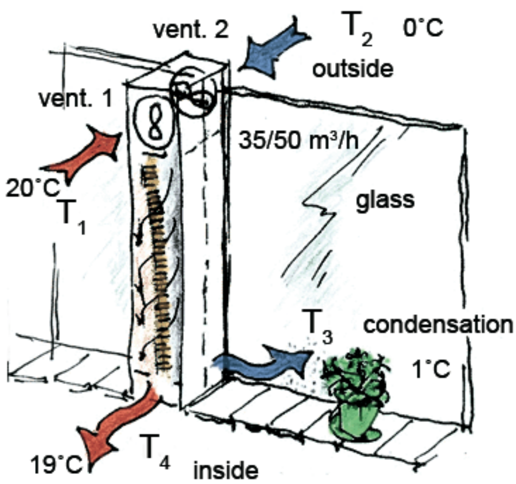

Fig. 4: The breathing window can be a jamb mullion or built in a wall

The prototype got a compact transparent synthetic counter-current heat exchanger of 80/180/480 mm, consisting of 15 km (length) and 0,1 mm (diameter) copper wire weighing a little over 1 kilogram. The winding of the prototype on a washing drum took three days. The fine-wire heat exchanger fits easily into a standard dishwasher.

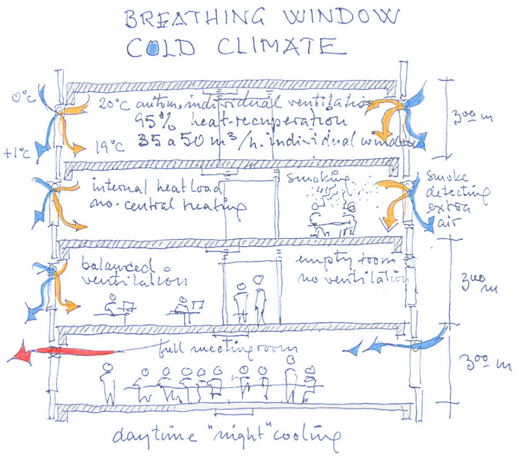

Fig. 5: Schematic cross-section of a building in the Dutch situation; on a winter day

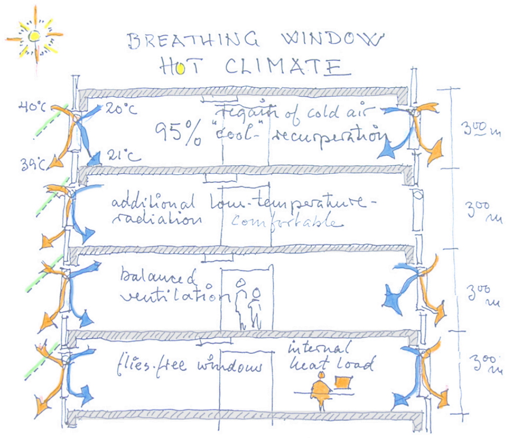

Fig. 6: using the breathing window in combination with chilled surfaces is more efficient than air conditioning

1.6 Breathing window - technical specifications

To make a prototype preliminary draft agreements must be made.

What dimensions, outward appearance and ventilation capacity the breathing window will have is still being discussed. The dimensions of the first-generation prototypes are 750/200/180 mm.

The breathing window functions well beside natural ventilation, hybrid or completely mechanically balanced ventilation. The CO_2 sensor (Sense air Sweden) starts automatically at 500 ppm (parts per million) when an addition to natural ventilation is needed, but also gives a light signal at 1200 ppm (MAC value). On reaching 1700 ppm CO_2 a sound signal will be heard. This means that doors and windows have to be opened to keep a healthy indoor climate.

What should be the driving force, what energy consumption is reasonable, and what noise level belongs to a certain air velocity? It looks as if the ventilators need to have a capacity of 4 Watts each, and that the noise level can stay below 30 dB.

The larger the vent hole, the lower the air velocity; the noise production decreases, but the wind effects increase in high-rise buildings. When turning on the hood, or switching on the light in toilet or bathroom, the balanced ventilation should be slightly skewed and so causes the necessary overpressure resulting in an extra air supply.

Two small reversible computer ventilators could not cope with the extreme differences in air pressure (100-150 Pascal) The ventilation systems in large tall buildings also tend to lose their balance during a storm, the director of a great ventilator factory told me.

Jón, de ventilatoren die er nu inziten, met meegekromde schoepen, kunnen dat wel, hoewel ze niet reversible zijn. Maar bij 150 Pa maken ze wel veel lawaai. Hoeveel, heb ik nog niet gemeten.

Fig. 7: Testing results in Iceland 2003 Fig. 8: First prototype

He advised to close the horizontal air supply and exhaust ducts with heavy winds, because in these circumstances there will be enough natural ventilation anyway.
According to calculations the prototype should have an average heat recovering efficiency of 95%.
The prototype tested in a kitchen window on the coast of Iceland in 2003 usually had a heat-recovering efficiency of over 95% - the uppermost line - due to leakage in the fine-wire heat exchanger. FIG 7
The four thermometers which regulate the temperature of the two balanced air flows by means of the reversible ventilators work very well. One can notice the extreme rotation speed (and noise) during storm peaks, both windward and later leeward. And thus we have arrived at the realisation aspects.

1.7 Realisation

The basic idea behind the breathing window, as we call it, is a smart local ventilation system which has almost all the qualities of large centralised ventilation systems with a minimum of disadvantages. FIG 8 It is no hopeless task to re-design and minimize most parts of a ventilation system. It is my personal opinion that minimum technology can always be realised.
The second, a redesigned prototype is devised from the point of view of a producer and a consumer.

The industrial-design student, Yannic Dekking, of the University of Delft, received this assignment as his final project, which was rewarded with a 9 as the final mark FIG 10. In broad outline the dimensions of the second prototype look like those of its predecessor. Yannic Dekking succeeded in optimizing the feeder channels of the fine-wire heat exchanger in his prototype and to fit it for installation in a weaving machine. In the space left vacant a handle could be made to take out the heat exchanger to clean it in the dishwasher FIG 9. All types of ventilators were included in this research.

There are three different construction possibilities in several types of building: as part of transparent glass, as a vertical window frame, or, which seems to be the most probable solution, as part of a closed panel/wall in existing buildings.

The breathing window functions well beside natural ventilation, hybrid or completely balanced mechanical ventilation (air-conditioning).

To cut a long story short : we can mention general major characteristics, subject it to a SWOT analysis and draw up some calculations to test its viability.

1.8 Main characteristics

1.8.1 new healthy ventilation

- no airshafts
- fine-wire heat exchanger
- balanced ventilation
- 95% performance
- compact size
- intelligent multifunctional control
- functions with open window
- little or no icing – sublimation
- capacity output from 35 to 50 m^3/hour
- new building technology
- building-cost reduction

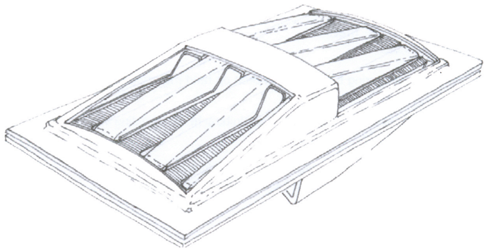

Fig. 9: compact counter-current fine-wire heat-exchanger fits into a dishwasher

1.9 Breathing Window SWOT analysis

1.9.1 strength

- decentralised energy-saving ventilation
- personal control over air quality
- 15 km copper-thread heat exchanger
- balanced ventilation, no air-tunnels
- no lowered ceilings needed
- floors can be used as internal thermal mass
- no installation space needed
- minimum infrastructure with intelligent
- control, contact through electricity grid acts on
- wind, temperature, time, CO_2 (possibly radon)
- warning by clocking, quick change and extreme
- resistance

1.9.2 improved sanitation:

no air recirculation
heat exchanger easily cleaned by dishwasher
insect-proof / dust filter
no traffic noise
no draught (almost no temp. difference)
light warning at an air quality of 1200 ppm CO2
sound warning at 1700 ppm CO2
fire alarm at source time
at CO2 from less than 500 to 700 ventilation
stops automatically, depending on location:
countryside or town

1.9.3 weakness

- noise due to wind pressure
- heat exchanger/dust filter fragile
- several power-supply and
  waste-water points needed
- 3 – 7 units per house

1.9.4 opportunities

unique innovation with definite USPs
new products in existing market
patented innovation
energy saving on heating new houses 35%
less building-volume in offices 15%
reduction of building costs by ≥ 10%
global market for several licence holders

1.9.5 threats

- lack of acceptation caused by unconventional product
- users have no experience
- reliability not proven
- investment in production is high
- no market for a long period of time (app. 2-3 years)
- product is to be mounted in the outer skin of the building
- building regulations

1.10 Some calculations

Calculating energy saving
There are 5080 degree hours in the heating season in the Netherlands. Between October and May the outside temperature measured is 4.8˚C (before the global warming?), the inside temperature 20˚C. The 'breathing window' ventilates on average (ranging from 25 to 50) 40 m^3/hour with a heating regenerative efficiency (85 to 95)of 90% volume metrical heating capacity, that is 1212 joules/m^3°K.
Saving 5080 x 40 x 1212 x [20 - 4.8] x 0.9 = 3.37 gigajoules / 'breathing window' per year.

Heating cost reduction per house
Expressed in energy equivalents: one m^3 natural gas is 32 megajoules in the heating efficiency of a 90% High Efficiency boiler, that is 3.370.000.000 / 32.000.000 x 0.9 = 117 m^3 natural gas/'breathing window' during the heating season.
With 3 to 5 breathing windows in one house, its average multiplied by: 4 x 117 = 468 m^3 natural gas or 13.5 gigajoules. At the end of 2004 the price of natural gas was € 0.416/m^3.
Thus the calculated saving is 41.6 x 468 = € 195/year per house.

Footnote: 1 m^3 natural gas corresponds energetically to 1 litre of petrol, therefore the saving of 468 m^3 natural gas per house is comparable to 5000 kilometres in a luxury car.
Around the world in eight years = 40.000 km.

Electricity consumption
Besides the savings of the heat exchangers the primary energy consumption of the two ventilators should be deducted. At an outside temperature of 0˚C and an inside temperature of 20˚C and 50 m3/hour ventilation per 'breathing window', the two ventilators use 8 Watts, but now with 95% heating regenerative efficiency. The thermal (low-calorie) energy saving is now: 50 / 3600 x 1212 x [20-0] x 0.95 = 320 Watts.
The high-quality 8-Watt electricity is produced by a traditional power station (not connected to district heating), with 40% efficiency amounting to 8 : 0.40 = 20 thermal Watts.
The energy saving is 320 – 20 = 300 thermal Watts , therefore the net efficiency of the 'breathing window' is 300 / 320 x 0.95 = 89%, which is close to the 90% average efficiency assumed earlier.
The electricity consumption of the CO_2 meter and the intelligent control is to be neglected.

Air resistance and noise
Even when two ventilators work reversibly to control the even current of air, they can be very inefficient. The heat exchanger in the 'breathing window' has an air-pressure resistance of 18 Pascal at 50 m^3/hour ventilation. The two ventilators produce a net energy of: 2 / 3600 x 50 x 18 = 0.5 Watt ventilation energy.
Due to this modest air resistance in the heat exchanger little electricity appears necessary, but even so the indoor ventilator produces a 30 decibel noise and that is audible in the silent hours of the night.
We aim at 25 decibels. The simplest solution: when you halve the depth of the heat exchanger, the heating regenerative will still be 85%. A sirocco type ventilator with a spiral case underneath is also thought of.

Questions and answers
1. What will the 'breathing window' look like?
   More or less as shown in the picture.
2. What are its dimensions?
   bxdxh: 240x140x800 mm.
3. What is the price of a 'breathing window'?
   The first estimations are:
   the first 1000 handmade units: € 650 to € 700 each, excluding VAT
   the next 10,000 semi-manufactured units: € 350 to € 450 each, excluding VAT.
4. What noise problems are to be expected?
   The 'breathing window' will not be put on the market before the noise problem is solved (>30 dBA).
5. What happens to condensation and glazed frost?
   Condensation water must be drained and frost hardly occurs.

6. What kind of control system is used?
 Whatever you like
7. What is the primary heating regenerative?
 300 thermal Watts per ‘breathing window’ at 0˚C. in wintertime.
8. How much energy is saved?
 3370 megajoules per ‘breathing window’ per year.
9. How much natural gas is saved?
 468 m^3, or € 195/year per dwelling with 4 breathing windows.
10. Can you turn off the ventilation?
 Yes, but at a CO2 level of 500-700 ppm it stops automatically, dependent on the location; countryside or town.
11. How does the CO2 check work?
 At a CO2 level of 1200 ppm a light starts burning and at 1500 ppm there will be a sound signal. This also happens in case of fire.

1.10.1 Breathing window takes care of your health when you forget it.

1.11. Conclusion

Although the breathing window is still in the making (statu nascendi) it seems to be the right answer to the question of desired customized ventilation. Time will prove.
A coincidental, unforeseen advantage compared to the usual plate heat exchangers is that the fine-wire heat exchanger hardly gets frosted up. The explanation is not simple. Is it sublimation? Is the frost evaporation time so short that the forming of ice does not take place?
Applied in hospitals the fine-wire heat exchanger can easily be renewed to prevent infection. The range of applications is wide. For instance it fits into a specific small mounting space in boats, caravans and mobile homes. The CO2 meter is also a very accurate smoke detector, which signals fire even before any smoke develops. Bigger separate fans make night-cooling in office buildings a real issue in summer, using the same smart control system.

1.11.1 Finally I will make a wish: give all of us a silent positive displacement ventilator.

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