Natural air conditioning: what are we waiting for?





BEN BRONSEMA
PhD, BEng, Bronsema Consult/TU Delft, Faculty of Architecture Dept. Architectural Engineering+ Technology;
bronconsult@planet.nl

RONALD VAN LUIJK
MSc, Green Building Engineering;
ronald.vanluijk@greenbe.nl

PETER SWIER
MSc, ABT Consulting Engineers;
p.swier@abt.eu

JAAP VEERMAN
BEng, RoyalHaskoning DHV Consulting Engineers;
jaap.veerman@rhdhv.com

JOOST VERMEER
BEng, Van Delft Group Mechanical Contractors;
joostvermeer@vandelftgroep.nl

Air conditioning is expensive and very energy inefficient. We cannot live without it, nor do we really like it. Sometimes, it is even bad for our health. But there is hope: a natural air conditioning concept is now ripe for large-scale application in existing and new buildings. Fan noise, draughts and dry throats and eyes will all become a thing of the past, and the air quality is just as good as outside. And as for energy consumption? The most stringent European standard is easily exceeded by a factor of ten. What are we waiting for?

The following essay is based upon the doctoral research of the main author as published in his thesis "Earth, Wind & Fire – Natural Airconditioning" (Bronsema, B. 2013). It explains and stresses the importance of this disruptive concept, which probably can be considered the most important innovation since the invention of air-conditioning at the beginning of the 19th century. At the end of 2018 hotel BREEZE in Amsterdam, the first naturally air-conditioned building in the world, will open its doors, and the time is right to start an offensive in the HVAC community to promote the EW&F concept in the engineering practice. Academics are invited to have a look at my thesis, but this essay is in the first place meant for HVAC practitioners as they form the clear majority in the REHVA member associations.

Introduction

The invention of air conditioning at the beginning of the last century[1] and its subsequent further development has brought many benefits to society. Comfortable indoor environments have significantly improved the well-being and productivity of people at their work. Nevertheless, many people are unsatisfied with the indoor climate at their workplace. There are many complaints about annoying fan noises, air quality, draughts and dry throats and eyes, which are notorious phenomena of the so-called sick building syndrome. Furthermore, the high energy consumption of air conditioning systems is increasingly becoming an issue, particu-

[1] Willis Carrier, 1902

larly in the light of the energy-neutral built environment that must become a reality soon.

The responses to these challenges vary.

- 'We promise to improve'[2], said the manufacturers and installers of HVAC systems, and the authors did their best to contribute. Regrettably, this only made things more complicated in practice, which was the last thing people wanted.
- 'We need to get rid of air conditioning', some building physicists called, and they put forward a case for natural ventilation. Of course, this was a step in the right direction, but it was not good enough! Were we going to accept that employees would have to sit and sweat in their workplaces? Could we accept the loss of productivity in hot weather?
- The authors are proponents of Buckminster Fuller's[3] approach to problem solving: "*You never change things by fighting the existing reality. To change something, build a new model that makes the existing model obsolete.*"

Modern air conditioning

But first, let us start by examining the essence of modern air conditioning. **Figure 1** is an exploded view drawing of a modern air handling unit, a beautiful product of Dutch industry (OC Verhulst). This is a 'bidirectional ventilation unit (BVU), which produces an air flow between indoors and outdoors and is equipped with both exhaust and supply fans'.[4] Air is sucked in and conditioned in the bottom of the unit and exhausted from the top section. The sections are connected by a heat wheel that exchanges thermal energy between the two air flows. The essence of the air handling unit lies in the elements for heating (1) and cooling (2) in the supply side. Here, the air is sucked through the fan (3) at a speed of approx. 2 metres per second. We do not want too much fan noise in the workplace, nor outside the building, so a silencer (4) is installed. The fan must compensate for the resistance of this silencer, and so it consumes more energy and produces more noise. This in turn must be compensated by the silencer. An air filter (5) is installed to prevent the elements for heating (1) and cooling (2) from becoming fouled with dust from the outdoor air and impeding the operation of the system. The fan must also compensate for the resistance of this air filter and, so, it consumes more energy and produces more noise that again must be compensated by the silencer. At the end of the lowest section, you can also see a compartment that ensures air humidification (7) during the heating season. A fan (3) is also required for air extraction, for which another silencer (4) is installed. To limit energy use, a heat wheel (6) has been installed in the air handling unit. This device does not only cause a considerable amount of air resistance, it is sensitive to fouling too. Another air filter (5) is installed to prevent this. Its resistance must also be compensated by the fan, which results in more energy use and noise. The fans use a lot

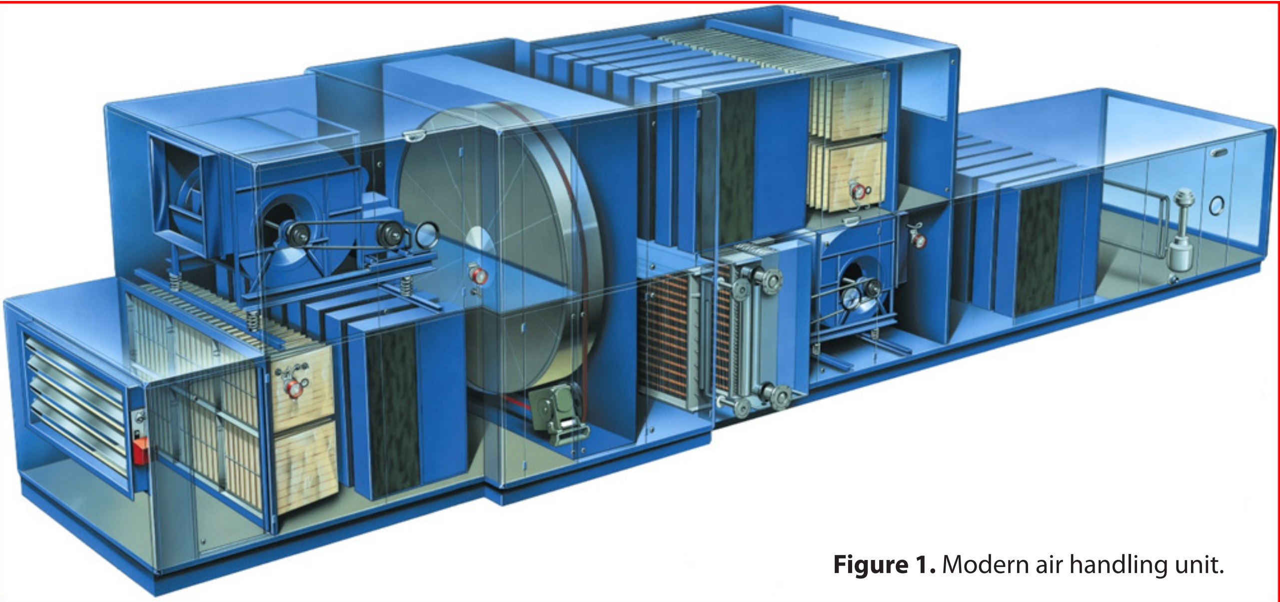

Figure 1. Modern air handling unit.

2 'Let's make things better!'

3 American architect, systems theorist, writer, designer, and inventor (1895-1983)

4 Technology based on EC regulation 1253/2014

of energy, but that is not the only problem. Although the noise produced is reduced by the silencers, they only effectively dampen the high frequencies. The low frequencies penetrate the workplace, where they are heard as a low hum, which many people find very annoying. As for the air filters, they filter the dust out of the air, but they become fouled after a time and when not replaced timely will emit odours. Although these odours occur only in low concentrations, this means that the air inside is less fresh than outside. Finally, in addition to transferring thermal energy, the rotating wheels of the heat wheel can also transfer odours from the exhaust air to the supply air. Many indoor climate experts say that heat wheels contribute to the degeneration of indoor air quality.

Conclusion

The primary functions of ventilation (3), heating (1) and cooling (2) are the only essential functions of air conditioning. All other functions, which are largely responsible for the bulkiness of HVAC systems and the use of energy, are solely used to control the undesirable side effects (except for the heat wheel).

A new model that makes the old one obsolete

Figure 2 displays a conceptual cross section of a building with natural air conditioning. This building does not have an air handling system installed. Instead, the building itself functions as an air conditioning *machine* using the sun, wind and gravity. This means it must be designed in close cooperation with the architect. This is climate-responsive architecture!

Just as with the air handling unit, the system is based on separate sections for air supply and extraction.

Air supply is provided by the climate cascade (2), which is a structural shaft. Outside air flows into the building at roof level and into the climate cascade by way of the overpressure chamber (1). Cold water with a temperature of 13°C is sprayed at the top of the cascade, so that in the summer the air is cooled to approx. 18°C and in winter it is preheated to approx. 7 or 8°C. Cold is extracted from the ground using a TES (Thermal Energy Storage) system.

The hundreds of thousands of droplets in the spray together form a heat exchanger with a very large surface area, so that the system can generate tiny temperature differences between water and air. This heat exchanger has no air resistance, and in fact produces pressure. This is because the specific mass of the water/air mixture in the cascade is considerably larger than that of the outside air, so that pressure is built up at the base of the climate cascade which is used to distribute air throughout the building by means of the vertical supply shaft (3).

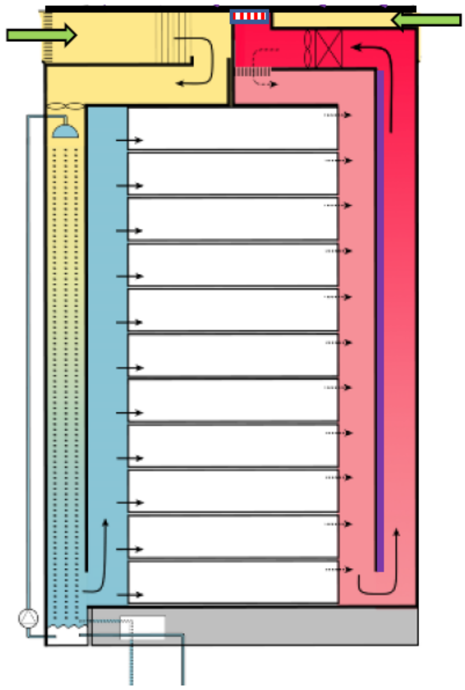

Figure 2. Earth, Wind & Fire 2.0 Natural Air Conditioning[5]

Due to the high level of contact between the spray spectrum and the air, various matter carried by the outside air – possibly including particulate matter – is absorbed by the water and so improves the air quality. In the summer, the air is dried somewhat due to condensation of water vapour on the cold-water droplets. In winter the air is automatically humidified. The spray water must of course be thoroughly cleaned and disinfected.

This *'silent air conditioning'* concept does not require fans and, hence, also no silencers. The odour-enhancing spray spectrum replaces air filters. Air humidification is inherent to the system. Finally, the energy use of the spray pump is only a fraction of that of the fans use in traditional air conditioning.

The ventilation air is extracted through the exhaust/recirculation shaft (8), which is connected to the base of the solar chimney (4), a structural shaft provided with

[5] Figure 2 illustrates the EW&F 2.0 concept. The original EW&F 1.0 concept had a Venturi roof system for ex-tracting air. An EW&F 3.0 concept with wind turbines on a convex roof is currently under study.

insulating glass and installed on or in a south-facing wall. The air in the solar chimney is heated by solar radiation, and the resulting thermal draught functions as an *extraction fan* for the air.

A heat recovery system (5) at the top of the solar chimney recovers heat from the building and the sun. The heat is either used directly in the building or transported by the TES system to the ground to restore the thermal balance. During business hours, the used air is exhausted from the roof. The air is recirculated by the extraction shaft (8) to recover solar heat outside business hours, for example during the weekend.

Auxiliary fans (6) ensure that air circulation is maintained under all circumstances. The energy for the fans is supplied by solar panels on the roof and in the solar chimney (7).

The Earth, Wind & Fire concept described above was developed as part of PhD research in a joint venture involving TU Delft, TU Eindhoven and external partners. This research demonstrated that the system is suitable for application in practice[6].

Climate-responsive architecture

The integration of the solar chimney, climate cascade and air distribution system in the structural design requires close cooperation with the architect, who will, therefore, play a key role as technical and artistic co-designer of the climate system. In principle, the intensive cooperation between the architect and the climate engineer should improve the quality of the building while, at the same time, reducing the failure costs.

Energy consumption

EU Regulation 1253/2014 has set 'ecodesign requirements' on ventilation units (air handling units). As of 1 January 2016, the maximum internal specific fan power (SFP_{int_limit}) is 900 $W.(m^3.s^{-1})^{-1}$ and will be reduced to 800 $W.(m^3.s^{-1})^{-1}$ as of 1 January 2018. In practice, these requirements can only be satisfied by using much lower air velocities in the air handling unit. Experts assume that this may result that the space required for the system will increase by approx. 20%.

The energy use of a natural air conditioning system based on the EW&F concept is largely caused by the spray pump and to a lesser extent by the auxiliary fans.

The system can be very energy efficient by using several spray units which are switched on and off depending on the outside temperature (in summer) or the desired relative humidity in the room (in winter). Depending on the height of the climate cascade, the spray water flow rate and the infrastructure used for the air distribution system, the system could exceed the levels set by EU Regulation 1253/2014 by a factor of 10!

The climate cascade and the solar chimney generate only a modest pressure difference for air transport. This means that the air supply and exhaust system must have larger dimensions than a traditional air conditioning system. This system can best be made as an integrated part of the building, for example by using the spaces above suspended ceilings and under raised floors. Hollow-core slab floors and hollow structural components can be installed in new buildings or as part of major renovations. The cooperation of the architect in the integration of the climate system is an essential element of the concept.

The supply shaft (3) and the exhaust shaft (8) are dimensioned for an air velocity of approx. 3 ms^{-1} and, therefore, need to be considerably large. For traditional air conditioning, a higher air speed of approx. 6 ms^{-1} is required but the gross shaft space needed to accommodate the air ducts is usually double the cross section of the duct. This means that the two climate systems have similar spatial footprints.

The three Ps of sustainable development are harmoniously combined in the Earth, Wind & Fire Natural Air Conditioning System:

People → A better indoor climate

Planet → Less consumption of energy and materials

Profit → Lower costs – less sickness absence

See also the overview for Hotel BREEZE **Figure 3**.

People – Planet – Profit Hotel BREEZE

Hotel BREEZE in Amsterdam IJburg will be the first building in the world with Earth, Wind & Fire Natural Air Conditioning[7]. EW&F helps the building to achieve an high energy performance level. The concept

[6] *Earth, Wind & Fire – Natuurlijke Airconditioning*, Uitgeverij Eburon, Delft, ISBN 978 90 5972 762 5.

[7] We applaud Maarten Quist (director of Dutch Green Company), the developer of Hotel BREEZE and initiator of the first practical application of the EW&F concept in the construction industry.

The Earth, Wind & Fire concept in perspective

Hotel BREEZE 25.000 $m^3.h^{-1}$

ASPECT	TRADITIONAL AC	EW&F NATURAL AC
Space requirement plant-room 2 AHU's	220 m^2 (EN 13779)	50 m^2
Cross-section of shafts Air velocity	2,5 m^2 ≈ 6 $m.s^{-1}$	2,5 m^2 ≈ 3 $m.s^{-1}$
Energy consumption EU 1253/2014-$SPF_{int-limit}$	50 $MWh.a^{-1}$ 0,8 $kW.(m^3.s^{-1})^{-1}$	10 $MWh.a^{-1}$
Maintenance KISS factor - simplicity	Very extensive low	Little extensive high
Average life span	15…20 years Mechanical facilities	40 years Architectural facilities
Construction costs Excluding solar chimney	Neutral	

Figure 3. The EW&F concept in perspective.

has been adapted to the specific requirements of a hotel. The hotel has applied for BREEAM innovation credits for the climate cascade and the solar chimney. **Figure 3** compares a few parameters with those of traditional air conditioning. It is important to realise that a hotel has a higher specific energy use than an office building. The reasons for this are the relatively high-pressure loss of the air distribution system due to the complex infrastructure and the requisite fire and constant flow valves usually applied in hotel rooms.

What does this mean for the climate industry?

The introduction of natural air conditioning may have impact on the scale of the HVAC industry, but the overall effect will certainly not be dramatic. In the first place, the *Earth, Wind & Fire* concept is primarily intended for climate systems in high rise buildings, these could be offices, schools, residential buildings etc. This means that plenty of areas of application will be needed for traditional air conditioning. Secondly, natural air conditioning will always be combined with systems for heating and cooling. Finally, installing the *Earth, Wind & Fire* concept requires various HVAC and hydronic equipment, such as pumps, pipes, spray-water treatment, control technology and the entire thermo-hydraulic infrastructure, including Thermal Energy Storage systems. ■

Reference

Bronsema, B. 2013 -TU Delft Repository Earth, Wind & Fire: "Natuurlijke Airconditioning"[8]

[8] Some sound advice: Never Stop Reinventing Yourself: 'Who wants to just "retire"? Banish that word from your vocabu-lary. You've got to constantly reinvent and take a chance on something you've always wanted to do — it's what keeps you alive. You're never done.'(Jack Welch (1935-) – former CEO of General Electric)