Fine-Wire Heat Exchanger Works at Very Low Temperature

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Abstract: *New fine-wire heat exchangers are very effective at very low temperatures (over 25°C) for heating and at very high temperatures (below 15°C) for cooling. This is an environmentally technological breakthrough. A temperature of 25 to 30°C is often available as excess heat, emitted during the production process or available by means of a simple solar collector without the help of a heating pump. A groundwater temperature below 15°C is available till 45 degrees of latitude North and by means of radiation during the night as far as the Sahara when the sky is clear. The idea of the new fine-wire heat exchanger (Fiwihex) originated in France in 1927. After almost 17 years of research it appeared that for very low temperatures to be effective, a large airflow is needed which often means noise. Plants do not seem to be auditively sensitive. This new technology has already been successfully used in 15 ha. of Dutch greenhouses and the first machine factory has already been installed. The Floriade 2012 - the horticulture world exhibition in Venlo, The Netherlands, comprising 18.000 m^2 of greenhouses and expecting 2,5 million visitors, is entirely air-conditioned by means of 'Fiwihex' fine-wire heat exchangers. Although the Fiwihex very-low-temperature technology can be applied worldwide, the seasonal heat/cold storage in the ground may be different and more difficult elsewhere*
Keywords: very-low-temperature heating and cooling, fine-wire heat exchanger, new greenhouse technology, translation into dwellings/offices, breathing-window room ventilation.

INTRODUCTION

Why did it take such a long time to make the fine-wire heat exchanger suited to the market when the calculated output roused such high expectations? How air had to be led through or along the Fiwihex device was unknown and was tested in practice in various prototypes. (Fig. 1) (Fig.2)

The knowledge of weaving textiles had disappeared to low income countries. A weaver had to be found who was willing to invest in an expensive, complicated loom that could weave 1/10 mm copper wire. Why is greenhouse horticulture so slow in switching from natural gas to solar energy? There are at least three reasons:

a. natural gas is very cheap for market gardeners
b. when burning natural gas, CO_2 arises, which the plants use as fertilizer (yielding 20% more output)
c. the unfavourable investment climate does not allow much innovation.

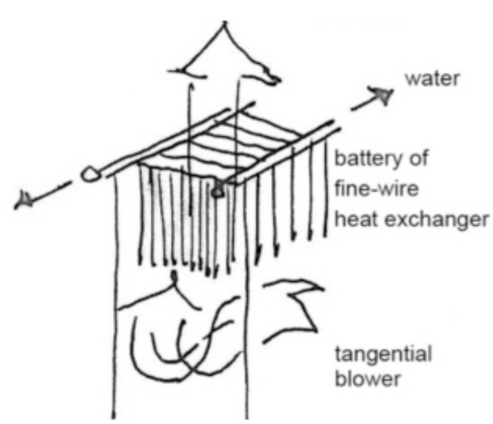

Figure 1: water/air Fiwihex heating/cooling

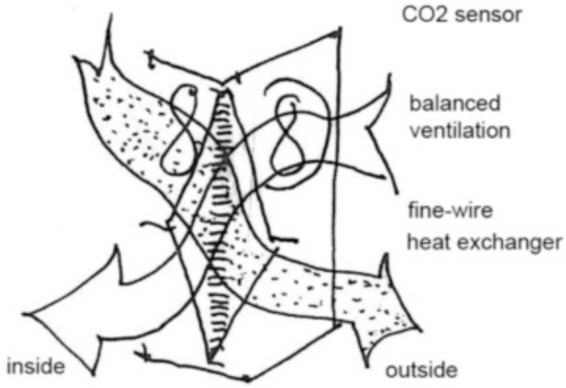

Figure 2: air/air Fiwihex balance ventilation

A foreseeable breakthrough and application is at hand. The seasonal heat and cold storage is generally situated at a depth of 20 to 50 m in the aquifer, a wet layer of sand enclosed between impervious layers of clay. These soil conditions are very often to be found in the Rhine delta of The Netherlands. In brief: This new technology will be applied on a large scale, as it allows Dutch greenhouse horticulture to change from being a wholesale natural gas consumer into a solar energy supplier using seasonal storage in aquifers. The innovator dr. Noor van Andel, a retired director of corporated research of Akzo Nobel, had done his work in his laboratory, situated in a former hairdresser's shop. The only skilled textile weaver and employer was found in the eastern part of the Netherlands, Gerard ter Beek, and after having been a flying-instructor for many years, he was willing to accept the challenge to develop a new loom fit to process copper wire.

Figure 3: The weaving of a 1/10 mm fine wire heat exchanger for very low temperature heating and cooling

HOW TO MAKE A FIWIHEX?

The Fiwihex devices for heating and cooling are woven with a warp of ø 1/10 mm tinned copper wire and a weft of ø 2 mm water-conducting tubes of 9,5 mm centre to centre. (Fig.3) The dimensions of every heat-exchanging mat are: 2 mm thick, 150 mm wide and 300 mm high. Si de by side with an in-between distance of 10 mm the mats are soldered to thicker pipes at top and bottom. The final air-heating element measures 200 x 1050 mm. To this a tangential ventilator is added between the plant tables. This appears to function well in practice and the plants are not hindered by draught. When applied in factories and workshops the Fiwihex fans are mounted high. The shafts have become higher and at the lower end equipped with a streamlined outlet of water-absorbing material to catch possible condensation water collected during the cooling process. The soldered components are glued nowadays (with hot melt glue) and the synthetic main tubes as well to shorten working hours. These Fiwihex devices are tested in practice at max. 2 bar (20 m head of water).

These industrial ventilators have to be transformed for application in private houses. In this phase we go back to an approved very low temperature decentralized air-heating device on the ceiling. Inside a round woven fine wire heat exchanger of ø 0,6 m and 0,2 m high, slowly rotates a fan which keeps moving 1000 m3/h of air. This ceiling air heater has proved to operate free of dust. The first large-scale application will be the new Kramer-laboratory at TU Delft. Fresh air form outside is led to the offices through the fans on the lowered ceiling. A laboratory is extremely well ventilated. Therefore cheap heating is important.

Figure 4: The twinning machine for 1/10 mm fine wire heat exchanger in the breathing window

Maybe a combination of basic radiation heating and a lower temperature air heating is a better solution. We can postulate that when the demand for it arises within a short time, another small silent fine wire air heating element will be developed.

Formulating a problem is meeting its solution halfway. When this paper was written in January 2009, experiments were being carried out with small Fiwihex transparent convectors, driven by small LTV-tangential ventilators. (Fig. 4)

FIRST APPLICATION OF THE GREENHOUSE TECHNOLOGY OF TOMORROW

After many years of development the 'fine-wire heat exchanger' has now reached its first phase of application. (Fig. 5) (Fig. 6) In the Dutch greenhouse horticulture proof has been furnished that by using fine-wire heat exchangers the energy consumption in a greenhouse is reduced from approximately 50 m^3 natural gas/m^2 plantation per year to zero.

Figure 5: Fiwihex heating and cooling in a all year closed horticulture greenhouse

There is even an excess of solar energy that can be stored in the aquifer, i.e. in sand layers at a depth of 30 to 50 m. On an annual basis at our latitude of 52° north, about 7 times more solar heat enters the greenhouse than leaves it due to transmission loss.

It is clear that cooling is no less important than heating. It is customary to whitewash glass roofs to keep out the heat and to open wide the skylights to ventilate by means of fresh air from outside.

In the case of the energy-producing greenhouse such as the one described here, it is taken for granted that the greenhouse is kept closed all year round and in hot sunny weather is cooled by the same water/air heat exchanger which heats up the green-house during the night. Keeping greenhouses closed all the year round has three advantages. Firstly, the relative humidity inside the greenhouses can be kept at a steady level (for example 80%). Secondly, the plants are less troubled by vermin.

The third advantage is vegetation stimulation. In the further development of the energy-producing greenhouse all organic waste matter will be collected and anaerobically converted by means of biogas fermentators, micro turbines or diesel engines to generate its own electricity. The filtered CO_2 will be blown into the greenhouse to manure the plants. Thus a CO_2-neutral greenhouse horticulture arises with approximately 20% more produce at a CO_2 concentration of 1.000 parts per million (ppm) instead of 500 ppm in open greenhouses.

Figure 6: Fiwihex very low temperature heating and cooling device in a machine factory

FLORIADE 2012

The Horticulture world exhibition in Venlo, The Netherlands, has in two years from now, a greenhouse with a landscaped office of 25 m high completed. The metobolism of a sedentary person and an upright plant are different. The inside climate of the greenhouse with 35.000 visitors on peak days is mainly controlled by Fiwihex air cooling and heating. (Fig. 7) The fine wire heat-exchanger already works at very low temperatures. Preparing for the insulation and the outside air temperature to be expected, concrete core activation - cooling floors with water - can also influence radiation heat. The average temperature of air and radiation is the perceptible temperature for humans. There is a clear relation between the inside climate of the greenhouse and the heat and cold storage in the aquifer. A greenhouse of 2 ha. (150 x 150 m) is just big enough for seasonal heat storage (aquifer) to function with edge losses. The heat excess from the greenhouse can provide 8 ha. (i.e. a maximum of 200 passive houses) with heating and cooling. The cooling water from the diesel engine provides the houses with hot tap water. This new greenhouse technology will be introduced into dwellings and offices.

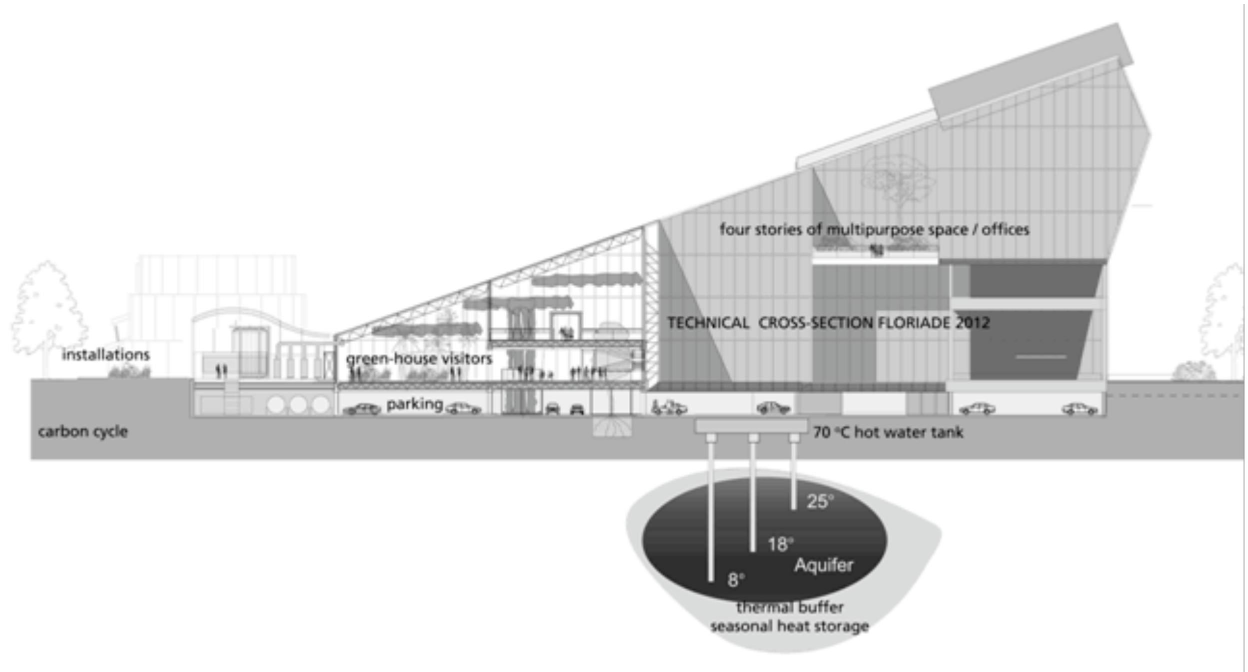

Figure 7: East façade cross section - Floriade 2012 world exhibition glasshouse - integrated design of 40.000 m² with an anearobic waste treatment and seasonal heat and cold storage in wet sand

THE TRANSLATION OF GREENHOUSE HORTICULTURE TECHNOLOGY TO PRIVATE HOUSES

The translation of greenhouse horticulture technology to private houses has not yet been realized. In some houses no well-functioning aquifer can be installed. A minimum roof collector surface of 1 ha. is necessary, assuming that a simple version of a roof collector is 2x more efficient than a closed greenhouse.
Often there is also excess heat of 25 to 30˚C in various forms, even when cooling milk at a dairy farm. This is a new technology, a minimalist approach without the help of heating pumps and fossil fuels.

The electricity consumption of good pumps with little resistance can be kept limited if the diameter of the pipes is wide enough and the conveying height small.

The temperature level inside the house is bound to limits of comfort. Most Europeans find 17˚ to 23˚C comfortable.

Now we have to consider radiation heating, air heating and the preferences of the inmates of the house. Low radiation heating in floors and walls is based on a constant temperature of 19˚C in the living area/room, to which the option is added to use ΔT 3˚C air heating to heat up or cool down the house individually/ automatically. Heating and cooling follow the same procedures.

Is greenhouse air heating suitable for private houses? The air heating installation is too big, makes too much noise and the living room is not free of dust.
There are two main types of fine-wire heat exchangers: the fine-wire water/air heat exchanger and the fine-wire air/air heat exchanger.

BREATHING WINDOW

When you as a university professor at the end of your professoriate unexpectedly receive the Royal/Shell Award in person, what do you do with the tax-free money? According to the chief author of this paper the ventilation in buildings is the weakest link in the building industry. Much money has been spent on this. The list of conditions did not require extrapolation, improving existing techniques, but devising from scratch an optimal ventilation system that is small, user-friendly, intelligent, with hygienic CO_2 control and inaudible. (Fig. 8) In the meantime, in the course of a parallel search for a smart effective decentralized room ventilation device, a new type of fine wire heat exchanger was developed, with the same partners as Fiwihex. We call it a “breathing window”. (Fig. 9) (Fig. 10)

This air/air fine wire heat exchanger is not woven but wound with ø 1/10 mm copper wire on a big rotating drum. This new technology has taken a lot of development time. The air/air heat exchanger measures 16 x 200 x 400 mm. Each heat exchanger consists of a warp of 15 km of ø 1/10 mm diameter copper wire weighing 500 gr. The weft is glued nylon thread with a centre-to-centre distance of 12.5 mm. Its small size makes it easy to take the heat exchanger out of its housing in order to clean it under a shower or in a dishwasher. The stacked wefts must be mutually airtight, forming 13 small air-channels of 2 x 220 mm, each having a width of 16 mm. Due to two counter-current flows evenly distributed by conical air ducts, the channels are alternately hot inside and cold outside.

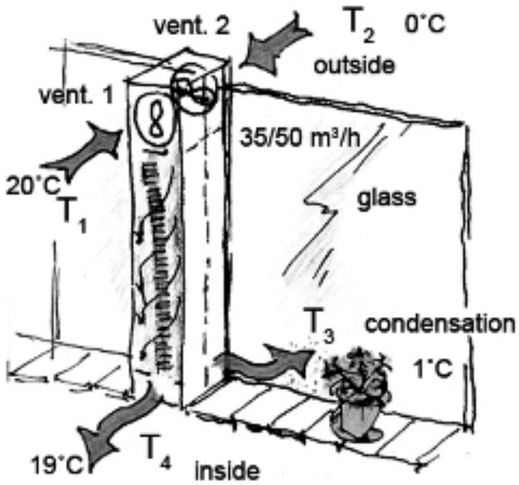

Figure 8: Operation scheme of a Breathing Window

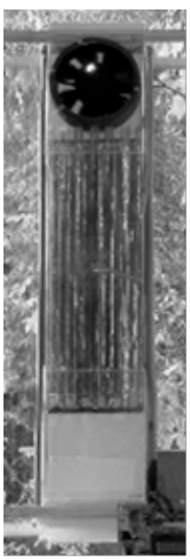

Figure 9 and 10: Prototypes of the Breathing Window (BW)

After 10 years devising and developing it appears that the first Zero-series of breathing windows will be taken into production halfway 2009.

DECENTRALIZED ROOM VENTILATION

The main characteristic of every Passive House ventilation device is that it must be very well balanced because of the perfectly airtight exterior wall.

The decentralized Breathing Window (BW) – one in every room – is characterized by perfectly balanced ventilation in every room with a high percentage of heat recovery. The control system measures the CO_2 concentration of the indoor air in parts per million and reacts on it immediately by adjusting its ventilation rate.

The relative humidity of the indoor air in relation to the outdoor air temperature makes an optimum heat exchange possible without any condensation. A good indoor-air quality in each separate room is ensured. Rooms which are not used are minimally ventilated. One can adjust (program) the maximum and minimum CO_2 concentration. In open country ventilation stops at 450 ppm and in urban areas at 550 ppm. When a room is not occupied or when a window is opened the breathing window also stops ventilating. When a room is used more often the BW will rotate faster to refresh (exchange) more air. Whereas at 50 m3 air/hour (master bedroom) the BW is not audible (< 30 dB) the noise level in the occupied living room can be 40 to 45 dB at a high rotating speed and 250 m3 air/hour, without its being noticed because of daytime noise in the house or traffic noise.

The CO2-controlled ventilation system is highly efficient, unoccupied rooms are not permanently ventilated. However, regular ventilation is desirable in connection with radon and paint smells.

Generally decentralized ventilation as compared with central ventilation can lead to a 2/3 saving in energy with the same indoor air quality.

When in summer doors and windows are open, the BW will not rotate. The relation between humidity and the outdoor temperature ensures that the heat exchanger will never get frozen. By adjusting the rate of recirculation of the indoor air through the 'bypass' the highest possible efficiency is always reached.

CONCLUSION

This paper gives an explanation of two high-tech innovations, which are a turning-point in heating and cooling in sustainable building. This innovation has been 10% inspiration and 90% perspiration, but it is worth improving the human environment.

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