Fine-Wire Heat Exchanger can effective heat and cool Houses

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Abstract

The recent development of a fine-wire heat exchanger creates new, possibilities to heat buildings with extremely low water temperatures. The improbably small temperature difference of 3˚C is already applicable. Until recently, waste water of 24 to 25˚C could only be used for heating up buildings by means of a heat pump. Now we cool greenhouses with water of 16 to 17˚C using the same fine-wire heat exchanger. This new technology is applied on a large scale – to transform Dutch greenhouse horticulture from using natural gas to solar energy with seasonal heat storage in the aquifer or wet sand.
Another application of fine-wire technology is a de-centralized, balanced room ventilation with 80–90% heat recovery. Now a twinned air/air heat exchanger is applied, which contains several km of fine copper wire . It reacts on the humidity and measures the CO_2 concentration of the inside air and breathes only when needed. This compact heat exchanger in the outside wall is in development.

Keywords: fine-wire heat exchanger, very low temperature house heating, decentralized room ventilation, breathing window BW, new greenhouse technology

1. Introduction

1.1 New Greenhouse Technology has been proofed

After many years of development the ‘fine-wire heat exchanger’ has now reached its first phase of application. In the Dutch greenhouse horticulture proof has been furnished (fig.1) 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.
The translation of engineering into private houses is not yet finished. A combination of slow floor/wall radiation heat with additional fast decentralized air heating and air cooling seems to be the most logical option.

Fig 1. New heating and cooling system in a closed horticulture greenhouse

2. Seasonal heat storage in the aquifer

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 about 7 times more solar heat enters the greenhouse than leaves it due to transmission loss.

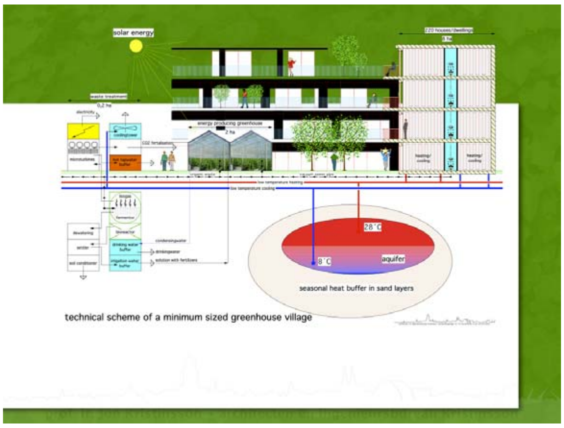

Fig 2. Scheme of 2 ha closed greenhouse scan heat and cool 200 dwellings by means of aquifer storage in sand layer

We have had experience with heat storage in an aquifer for some decades. The trick of the trade is that at the bottom of the aquifer cold is stored during a season, whereas in the upper half of the same aquifer heat is stored. (fig. 2) In the ground there is also heat stratification like in any other big liquid storage tanks above ground.
Cold storage is to some extent fed by groundwater of 11˚C, but more so by nightly radiation towards the clear sky and supported by a cooler/

3. The Translation of Greenhouse Horticulture Technology to application in Private Houses

The translation of greenhouse horticulture technology to private houses has not yet been realized. For a few houses no well-functioning aquifer can be installed. A minimum roof collector surface of 1 ha. is necessary to keep warm or to cool a group of 200 houses ,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 17^{0} to 19^{0} C in the living area, to which the option is added to use ΔT 3˚C air heating to heat up or cool down the house individually or automatically using a thermostat.
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.

4. The New Fine-Wire Heat exchanger for Heating and Cooling

There are two main types of fine-wire heat exchangers: the fine-wire water/air heat exchanger (fig. 3) and the fine-wire air/air heat exchanger (fig. 4).
The first idea of a fine wire heat exchanger (Fiwihex) is French and dates from 1927. The long way of research and production was done by dr. Noor van Andel and his son Eur in their laboratory in a former hairdresser's salon in Almelo in the Netherlands. The main author of this paper got to know the Van Andels in 2002 and together they started the development of a" breathing window' concept (BW).
An enthusiastic, retired textile weaver Gerard ter Beek restarted a closed textile factory in Oldenzaal, weaving. winding, and soldering fine copper wire
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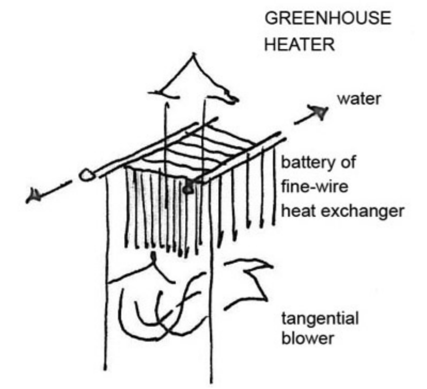

Figure 3: The principle of the fine-wire

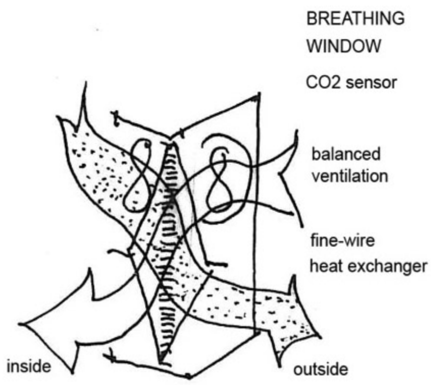

Fig 4. The principle of fine-wire water/air heat exchanger in closed air/air heat exchanger 'breathing window' horticultural greenhouse

5. The Fine-Wire Water/Air Heat Exchanger

For heating and cooling a woven heat exchanger is used with a warp of ∅ 1/10 mm tinned copper wire and a weft of ø 2 mm water-conducting tubes of 9,5 mm centre-to-centre. The dimensions of every heat exchanging mat are: 2 mm thick, 150 mm wide and 300 mm high. Side 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 200x 350 x 1050 mm. To this a tangential ventilator is added between the plant tables. 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 ∅ 0,6 m and 0,2 m high, slowly rotates a fan which keeps moving 1000 m^3/h of air (fig.5).
This ceiling air heater has proved to operate free of dust. The first large-scale application will be the new Kramer-laboratory at TUDelft. Fresh air from outside is led to the offices through the fans on the lowered ceiling.
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.

Fig 5. Prototype of a free-hanging very low temperature ceiling air heater

In the meantime we can use our imagination to redesign the appealing, -already existing 'Jaga' air heating, equipped with some small convectors with a forced heat exchange by means of a battery of small ventilators. In our thoughts we replace the convectors by 'Fiwihex' water/air heat exchangers and the small ventilators by the very relaxed and silent 'Papst" centrifugal fan (fig. 6). To avoid turbulence an air conductor might be needed. Besides all 'Fiwihex' heat exchangers have to be free of dust. Thus a dust filter, F7, as used in cars can also be used in houses. (fig. 7)

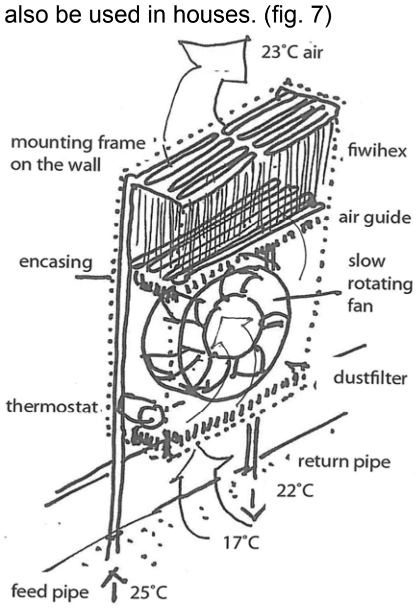

Fig 6. A draft. Open drawing of a low temperature 'fiwihex convector. Silence means bigger axial/radial fan

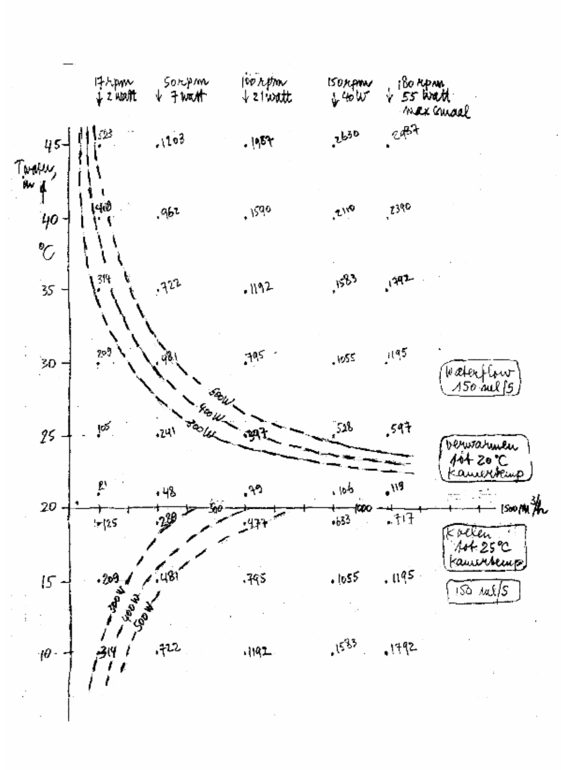

Fig 7. The relation of watertemperature and fan capacity

6. Decentralized Balanced 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 (in ppm) of the indoor air 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. Passive Houses are built with healthy materials with little or no radon pollution and formaldehyde from glue or paint. Rooms which are not used need little ventilation. One can adjust (programme) the maximum and minimum CO_2 concentration. In open country ventilation stops at 450 ppm and in urban areas at 550 ppm.
So when a room is not occupied or when a window is opened the breathing window 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 (25 dB) the noise level in the occupied living room can be 30 to 40 dB at a high rotating speed of 100 to 250 m3 air/hour, without its being noticed because of daytime noise in the house . The usual traffic noise from outside is unknown in a Passive House.

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 (BW) as compared with central ventilation can lead to some 2/3 saving in ventilation energy with a good indoor air quality. When in summer doors and windows are open, the BW will not rotate. Due to the humidity-controlled ventilation in bathrooms and kitchens using a 'turbo' –ventilator for a short time is an improvement.

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. The supply of pre-heated air through underground air ducts, as is customary in Passive Houses, is a very roundabout method in the case of the BW. In practice it means that the regular 80 to 90% heat exchanging efficiency will only be lower during periods of frost and during the night. At ÷ 4˚C outdoor air temperature, 20^0 C indoor air temperature and 30% relative humidity indoors the dew point is $0{,}6^0$ C. The 'bypass' for 50 m3/h needs to be 12,5 m3/h (25%) . For a whole house occupied by six people, requiring 300 m3/h ventilation, a 75m3/h 'bypass' is programmed by the four temperature sensors in each BW.

The 'bypass' also functions as a storm flap in extreme weather conditions or in case of fire. An interesting aspect of the CO2 control is that it can function as a fire alarm when the CO2 concentration inside is rising too fast.

7. The Fine-Wire Air/Air Heat Exchanger

Fig. 8 and 9: Prototypes of the Breathing Window (BW)

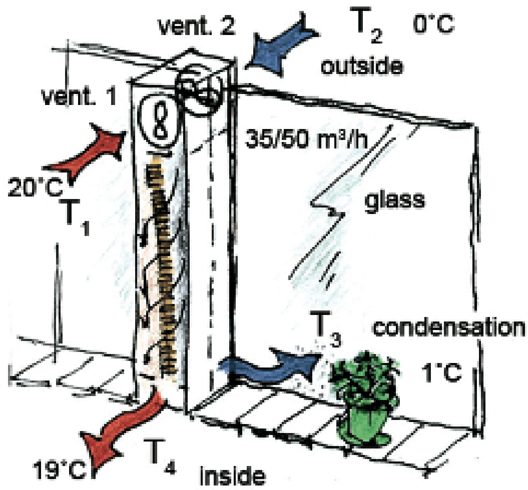

Fig 10. Operation scheme

The air/air fine-wire heat exchanger is not woven but wound with ∅ 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 440 mm. (fig.8, 9, 10)

Each heat exchanger consists of a warp of 15 km of ∅ 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 2x220mm, each having a width of 16 mm.

Due to two counter-current flows evenly distributed by conical air ducts the channels are alternately hot and cold.

The fine-wire warp ensures that the heat exchange is at right angles to the air current. A fine-wire heat exchanger is about 8x more efficient than a plate heat exchanger. Thus this compact heat exchanger has the smallest possible size which can be outside half is cold and the inside warm. When mounted in glass fronts (fig 11) this offers an advantage and also when mounted in vehicles, for example, in caravans and boats. The energy consumption measured for the two ventilators is 2x 8 Watts, the CO_2 meter and control 1 Watt. A small surface of p.v.-cells is sufficient to provide the BW with electricity. The 'BW' can also be built in a wall, for instance an cavity brick wall (fig 12). The name 'breathing window' arose some 10 years ago when a demanding list of conditions was made without knowing what the Breathing Window would look like or considering if all demands were realistic or feasible.

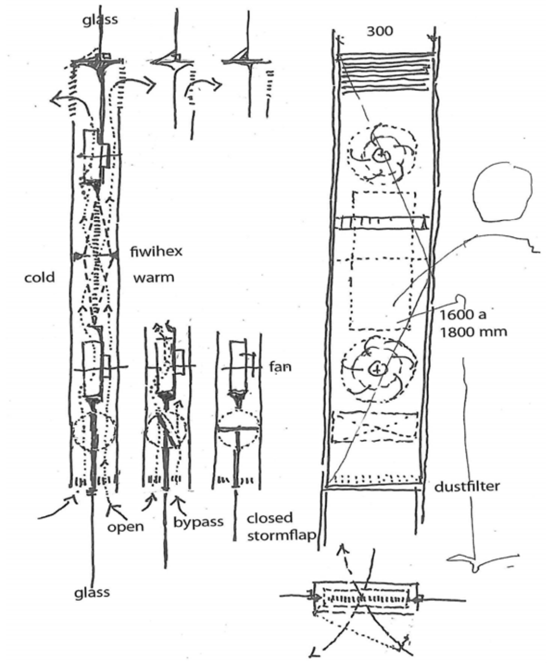

Fig 11. A draft. Breathing window

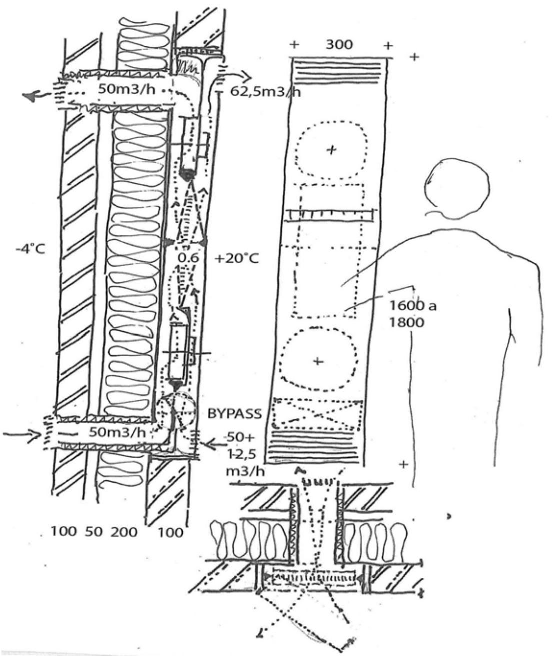

Fig 12. A draft. Breathing window built in an mounted in a glass front. Cross-section outer wall with insulation. showing a 'bypass' in three positions. the inside front can been opened For cleaning purposes

8. Integration of a 'Fiwihex' water/air heat exchanger and a 'Breathing Window' air/air heat exchanger.

Coming to an end-draft (fig 13), knowing no condensation will occur the, up to now, vertically drawn BW can also be used in a horizontal position. This offers us an opportunity to combine the very low temperature heating / cooling and the balanced ventilation.

9. Conclusion

New very low temperature heating and cooling of Passive Houses seems possible. Seasonal heat storage through solar heat or waste heat is getting more important.

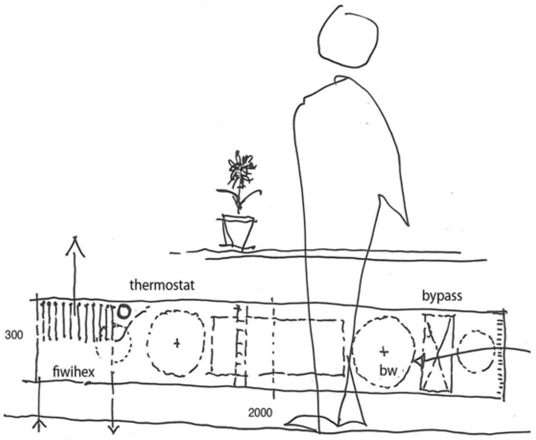

Fig 13. A draft. Horizontal high-tech air. A decentralized CO2-controlled balanced conditioner as an integration of 'Fiwihex' and ventilation is on its way to be applied in 'Breathing Window' test buildings.

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