Factsheet Recair Enthalpy

saving energy in comfort


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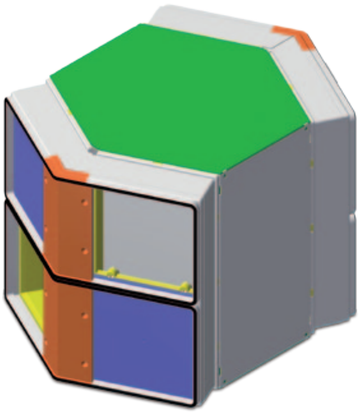
1 Introduction Enthalpy Exchanger

The enthalpy exchanger is able to transfer both sensible heat and latent heat (moisture) from the cooled to the heated flow. The flows can cyclic be interchanged (typical 10 min period) by 4 integrated motorized valves. After changing, the condensing and cooling air will flow through the ducts of the former opposite air, and vice versa. Condensate and ice will evaporate in the opposite flow during the next cycle. If the exchange of latent heat is (partly) unwanted, the interchanging of flows is stopped (or done at asymmetric periods). In cold ambient conditions, sensible and latent heat are recuperated, preventing a dry in-door climate. The sublimation of ice prevents freezing of the heat exchanger. During hot and wet ambient conditions, fresh air is cooled and dehumidified. Waste air will increase in temperature and moisture. Depending on the temperatures and humidity's, the total heat transferred (the enthalpy) may increase by a factor of 2,5 as compared to the sensible heat in a normal heat exchanger.

Figure 1.1 Enthalpy exchanger



The objectives of the enthalpy exchanger are:

- recover sensible and latent heat
- control the amount of recovered latent heat
- prevent freezing of recuperator
- limit the extra pressure loss caused by condensate and ice
- control the humidity in the building

2 Definitions

ambient		fresh air from ambient, or outside
indoor		used air from indoor, air from the building
fresh		fresh air, provided to the building
waste		used air, discharged to outside
flow fresh	[kgh-1]	mass flow of the fresh air
flow used	[kgh-1]	mass flow of the used air
T	[K]	temperature = temperature [°C] + 273,15
RH	[-]	relative humidity between 0 and 1
SP	[Pa]	saturation pressure, the maximum vapor pressure of an air/moisture mixture (@ RH = 1) = f(T)
PP	[Pa]	partial pressure, the vapor pressure of an air/moisture mix-ture = f(T, RH)
MM	[kgkg-1]	mass moisture relative to the mass of air
TC	[K]	temperature of condensation, the temperature a air/moisture mixture starts to condense

Constants

$\rho0_{moisture}$	[kgm-3]	0,8037	specific mass of moisture @ 0 °C, P_{atm}
$\rho0_{air}$	[kgm-3]	1,293	specific mass of air @ 0 °C, P_{atm}
P_{atm}	[Pa]	101325	atmospheric pressure

Calculations

$$\rho(T) = \rho0 \frac{T}{273,15} \tag{2.1}$$

ε_{fresh} [-] generally used definition of the thermal effectiveness (2.2) of the fresh air.

$$\varepsilon_{fresh} = \frac{T_{fresh} - T_{ambient}}{T_{indoor} - T_{ambient}} \tag{2.2}$$

ε_{waste} [-] the thermal effectiveness (2.2) of the waste air.

$$\varepsilon_{waste} = \frac{T_{indoor} - T_{waste}}{T_{indoor} - T_{ambient}} \tag{2.3}$$

(2.4a) for SP gives an accurate calculation for the saturation pressure (2.4b) gives an easier to use approximation.

$$SP = 100 \cdot e\left(17,433 - \frac{19513,7}{T^{1,27095}}\right) \tag{2.4a}$$

$$SP = 1,625 \cdot 10^{-44} \cdot T^{19,11} \tag{2.4b}$$

$$PP = SP \cdot RH \tag{2.5}$$

$$MM = \frac{\rho0_{moisture}}{\rho0_{air}} * \frac{PP}{P_{atm} - PP} \tag{2.6}$$

(2.7a) for TC gives an accurate calculation for the condensation temperature, (2.7b) gives an easier to use approximation.

$$TC = e^{\left(\frac{1}{1,27095}\ ln\left[\frac{19513,7}{17,433 - ln(0,01 \cdot PP}\right]\right)} \tag{2.7a}$$

$$TC = 198 \cdot PP^{0,05054} \tag{2.7b}$$

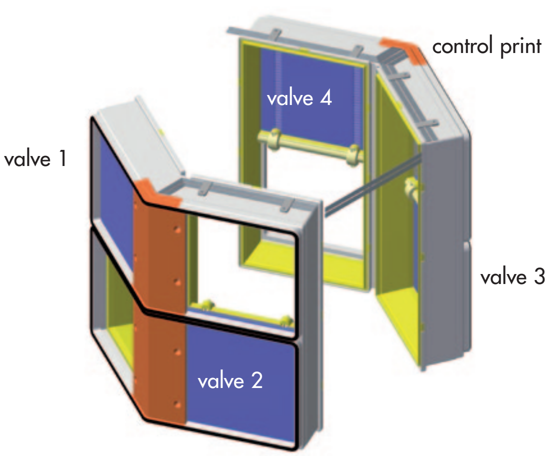
In computer language:

SP	100*Exp(17,433-19513,7*Exp(-1,27095*Ln(T)))
MM	621,5778*(PP/(P_{atm}-PP))
TC	Exp((1/1,27095)*Ln(19513,7/(17,433-Ln(0,01*PP))))

3 Positions of the valves

All 4 valves can be controlled separately. The valves have been numbered to uniquely define their mutual positions, see fig. 3.1.

Figure 3.1 Valve numbering



Depending on the ambient and indoor conditions different positions are preferred. Fig. 3.2 and 3.3 show the positions of the valves and the flow for the most common positions of the enthalpy recuperator. These 2 positions are called the symmetrical positions. The fresh air flow and the waste air flow are symmetrically. In both positions the directions of the flows outside the Recair Enthalpy are unchanged.

In the symmetrical 1 position valve 1 = down; valve 2 = up; valve 3 = up; valve 4 = down.

In the symmetrical 2 position valve 1 = up; valve 2 = down; valve 3 = down; valve 4 = up.

The symmetrical 2 position is the standby position. This is the position which should be used when the switching is off or when no moisture (or a part of) will be recuperated. The condense from the waste air must be discharged when valve 1 is up.

Figure 3.2 Symmetrical 1 position

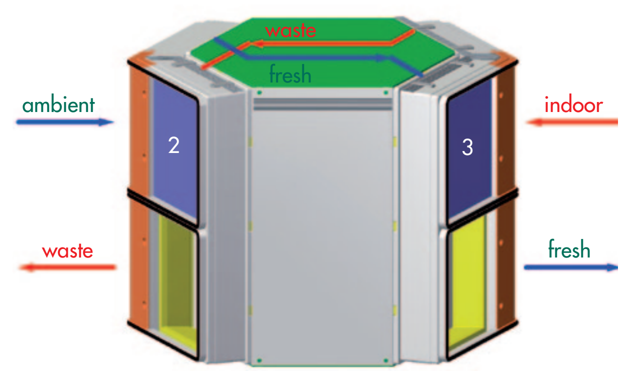
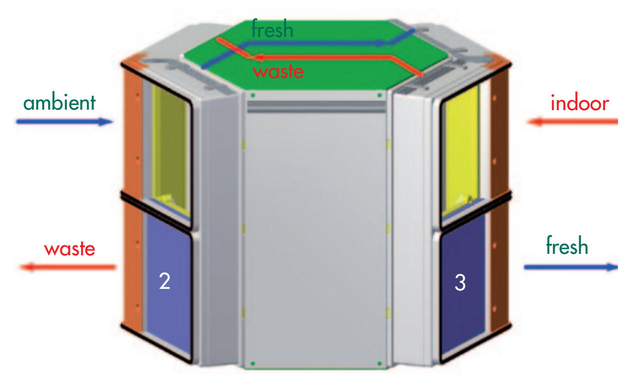


Figure 3.3 Symmetrical 2 position



The asymmetric positions can be used if fresh and indoor are mounted reversed (compared to symmetric) to the recuperator, or waste and ambient are mounted reversed, depending on the positions of the fans. It is possible to change between symmetric and asymmetric positions, in this case the insert and extract from the building is changed. The asymmetrical 2 position should be used when the switching is off or when no moisture (or a part of) will be recuperated. The condense from the waste air must be discharged when valve 1 is up.

In position asymmetrical 1 valve 1 = down; valve 2 = up; valve 3 = down; valve 4 = up.

In position asymmetrical 2 valve 1 = up; valve 2 = down; valve 3 = up; valve 4 = down.

Figure 3.4 Asymmetrical 1 position

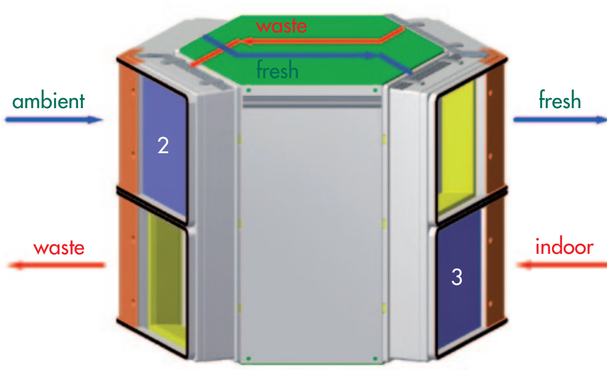
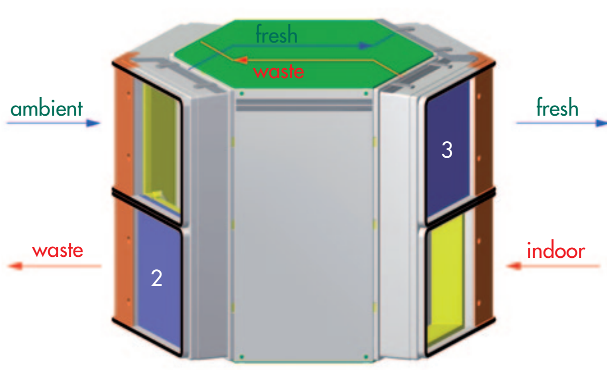


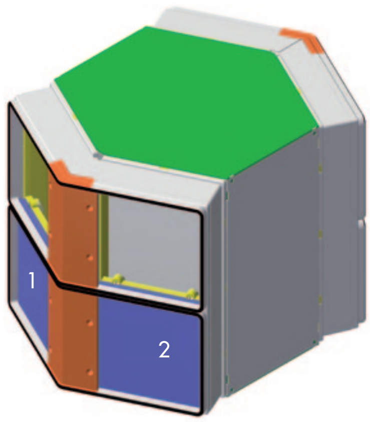
Figure 3.5 Asymmetrical 2 position



3.1 Bypass

To create a 100 % bypass the 2 valves on one side can be positioned both up or down. In this case one or two flows can be completely blocked, and 100 % of the air will bypass the heat exchanger. Fig. 3.6 shows one of the 4 possible bypass configurations.

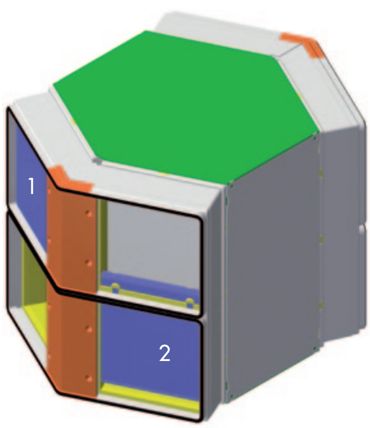
Figure 3.6 100% Bypass position



3.2 Shortcut

All valves can be forced in any position between halfway "up" and "down". This creates a short cut between 2 flows at the same side of the recuperator. For example directly from ambient to waste or from indoor to fresh. This might be useful when a condenser or evaporator of a heat pump is placed between the enthalpy exchanger and ambient, or between the enthalpy exchanger and fresh. Extra air can be forced over the condenser or evaporator, or recirculation of indoor air is possible. This feature is not useful for balanced ventilation units without heating or cooling equipment. Fig. 3.7 shows the recuperator with valve #2 slightly opened.

Figure 3.7 Recuperator with valve #2 slightly opened



4 Control

The control of the Recair enthalpy can be divided into 2 parts:

- winter situations, when the ambient temperature < indoor temperature
- summer situations, when the ambient temperature > indoor temperature

The control depends on the next parameters:

T_{indoor}	[K]	the indoor temperature
RH_{indoor}	[-]	the indoor relative humidity
TC	[K]	the condensation temperature of the waste air in summer situation, or the condensation temperature of the fresh air in winter situation
$T_{ambient}$	[K]	the ambient temperature
$RH_{ambient}$	[-]	the ambient relative humidity
T_{set}	[K]	the preferred temperature
RH_{set}	[-]	the preferred relative humidity

4.1 Winter situation

Independent on the RH_{set} and the RH_{indoor} 2 rules should be obeyed.

1. If the temperatures and humidity's are such that no condensation is possible (equation (4.1)), switching the valves has no influence on the amount of heat transferred.

$$T_{ambient} > TC_{indoor} \quad (4.1)$$

2. To prevent freezing the valves should always be switched when both conditions of (4.2) are true.

$$T_{ambient} < 0 \text{ and } T_{ambient} < TC_{indoor} \quad (4.2)$$

4.1.1 Frequency of switching

The main reason to recover the moisture is to prevent a dry indoor climate and to recover the latent heat. If equation (4.3) is true moisture recovery is necessary.

$$RH_{indoor} < RH_{set} \quad (4.3)$$

Switching of the valves should be started:

1. to prevent an increase of pressure loss due to condensation and/or ice
2. before water will roll down. Water will roll down as soon as the water layer on the walls will be transformed in droplets.

The increase in pressure loss due to condensate in the recuperator is small. Even during extreme (winter) conditions the increase in pressure loss is < 0,1 Pa min-1. Water may flow down when the thickness of the water layer on the walls of the recuperator is > 100 μm. During extreme (winter)conditions the increase in thickness is < 3 μm min-1. To prevent a loss of recuperated moisture due to changing weather conditions the frequency of switching < 10 min is preferred. This results in a changing interval of 10 min for all winter situations.

4.1.2 Asynchronic interval

It is possible to control the amount of recuperated moisture. When the interval is asynchronic (for example 10 – 20 – 10 – 20 min) only a part of the moisture is recuperated. By changing the intervals it is possible to control the RH_{indoor}. The longer period should always be the symmetrical 1 or asymmetrical 1 position. The effect of the asynchronic control compared with an on/off control of the switching is small. The relative long periods of 10 min makes it hard to control the RH exactly.
More frequent switching leads to a narrower temperature and humidity control band, but increases the virtual leak!

4.2 Summer situation

In summer situations it is possible to recuperate moisture from the fresh air flow to the waste air flow.
The amount of transferred energy is higher and the temperature of the fresh air will be lower. Recuperation of moisture is only possible when the ambient air is able to condensate, see (4.4).

$$TC_{ambient} > T_{indoor} \tag{4.4}$$

4.2.1 Frequency of switching

The main reason to recover the moisture is to discard sensible heat and/or dehumidify the indoor climate. Switching the valves is necessary if (4.4) is true and one of equations in (4.5) is true.

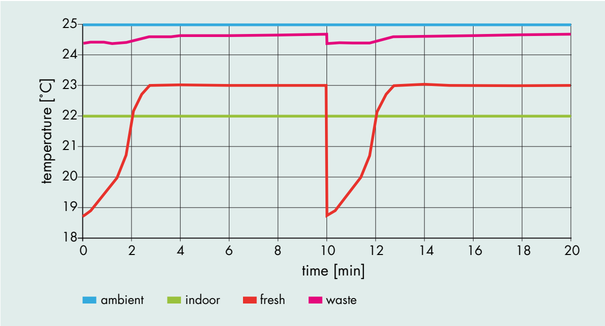
$$RH_{indoor} > RH_{set} \quad \text{or} \quad T_{indoor} > T_{set} \tag{4.5}$$

Depending on the climate, the amount of condensation in summer situations can be much higher than in winter conditions. Switching of the valves should be started:

1. to prevent an increase of pressure loss due to condensation
2. before water will roll down

The increase in pressure loss due to condensate in the recuperator is small. Even during extreme (summer) conditions the increase in pressure loss is < 0,3 Pa min-1. Water may flow down when the thickness of the water layer on the walls of the recuperator is > 100 μm. During extreme (summer)conditions the increase in thickness is < 10 μmmin-1. The amount of evaporation during one period is not constant. The used air will evaporate the amount of condensate during the first part of a period. During the evaporation T_{fresh} will be relative low, even below T_{indoor}. When all water is evaporated, T_{fresh} will increase. Fig. 4.1 shows this effect for a 10 min changing interval (indoor 22 °C 60%; ambient 25 °C 90%). For reasons of comfort the switching frequency should be relative large, every 4 min is recommended.

Figure 4.1 Temperatures in the recuperator



4.2.2 Asynchronic interval

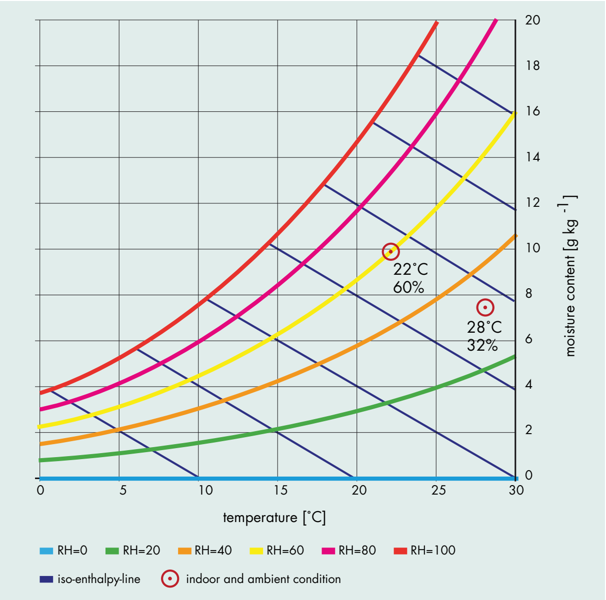
It is possible to control the amount of recuperated moisture. When the interval is asynchronic (for example 4 – 10 – 4 – 10 min) only a part of the moisture is recuperated. By changing the intervals it is possible to control the RH_{indoor}. Asynchronic intervals will be rare. In almost all situations when $T_{ambient} > T_{indoor}$ and $TC_{ambient} > T_{indoor}$ cooling and dehumidification is necessary.

5 Enthalpy effectiveness

The definition according to (5.1) is used in European EN and American ARI norms but useless, all effectivenesses from -∞ to ∞ are possible. For example (fig. 5.1) the enthalpies of indoor and ambient are equal, and the temperatures are different, resulting in an infinite effectiveness!

$$\varepsilon_{fresh\text{-}enthalpy} = \frac{enthalpy_{fresh} - enthalpy_{ambient}}{enthalpy_{indoor} - enthalpy_{ambient}} \qquad (5.1)$$

Figure 5.1 Psychrometric diagram of 2 conditions with equal enthalpy



The amount of energy transferred depends on the indoor and ambient conditions. The sensible effectiveness is defined according to (2.1). To show the effect of the moisture transfer, the enthalpy effectiveness can be defined according to (5.2):

$$\varepsilon_{fresh\text{-}enthalpy} = \frac{transferred\ sensible\ heat + latent\ heat}{potential\ sensible\ heat\ transfer} =$$

$$\varepsilon_{fresh\text{-}enthalpy} = \frac{\dot{m}cp\,(T_{fresh} - T_{ambient}) + \dot{m}\cdot hc(mm_{fresh} - mm_{ambient})}{\dot{m}cp\,(T_{indoor} - T_{ambient})} \qquad (5.2)$$

The nominator is the addition of the recuperated sensible heat and the recuperated la-tent heat. It is divided by the total possible sensible heat. According to this definition the effectiveness may exceed 100 %.

Fig 5.2 shows the sensible effectiveness (2.2) and the enthalpy effectiveness (5.1 and (5.2)) and the amount of recuperated moisture for winter conditions.

The fig. 5.2 shows the results for:

T_{indoor}	20 °C
RH_{indoor}	60 %
$T_{ambient}$	variable
$RH_{ambient}$	80 %
TC_{indoor}	12 °C
flow	150 m3h-1
type recuperator	RE400

$\varepsilon_{fresh\text{-}enthalpy} > \varepsilon_{fresh}$ for ambient temperatures < 12 °C.

Figure 5.2 Effectivenesses and recuperated moisture as a function of the outside temperature for winter conditions

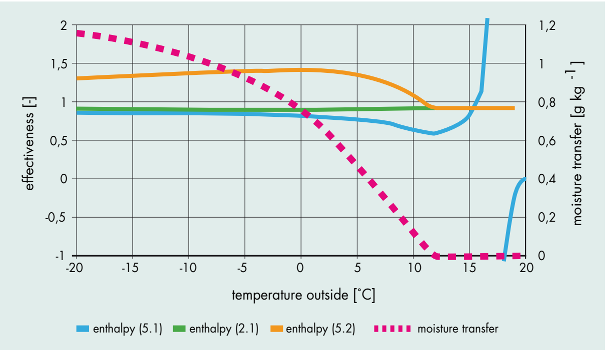
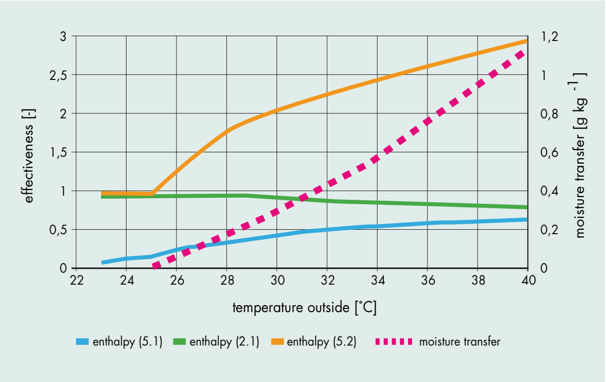


Fig 5.3 shows the sensible effectiveness (2.2) and the enthalpy effectiveness (5.1) and (5.2) and the amount of recuperated moisture for summer conditions. The figure shows the results for:

T_{indoor}	22 °C
RH_{indoor}	50 %
$T_{ambient}$	variable
$RH_{ambient}$	80 %
$TC_{ambient}$	variable
flow	150 m3h-1
type recuperator	Recair enthalpy 400 mm

$\varepsilon_{fresh\text{-}enthalpy} > \varepsilon_{fresh}$ for ambient temperatures > 25 °C.

Figure 5.3 Effectivenesses and recuperated moisture as a function of the outside temperature for summer conditions



Though an effectiveness > 100 % seems odd, this definition shows the difference between only sensible and enthalpy recuperation and resembles the COP used with heat pumps.

6 Leakage

All Recair heat exchangers are tested on leakage.
The average leakage is 0,5 % of the nominal flow. The virtual leakage caused by the switching of the valves is small. In most situations the switching interval is 10 min, switching lasts < 1 s. The volume between 2 valves will leak (~28 l for RE400). The average total leakage (leakage without switching + leakage due to switching) < 0,6 % of the nominal flow. This is small compared to the average leakage of full applications (typical several percent).

7 Pressure loss and effectiveness

The pressure loss and sensible effectiveness are a function of the flow. The enthalpy effectiveness is determined by the indoor and outdoor conditions (see fig. 5.2 and 5.3). Also the sensible effectiveness and pressure loss is slightly influenced by the indoor and ambient. Calculations for special flows and conditions can be performed by Recair. Fig. 7.1 and 7.2 show the effectiveness and pressure loss as a function of the flow for dry conditions.

Figure 7.1 Sensible effectiveness as a function of the flow

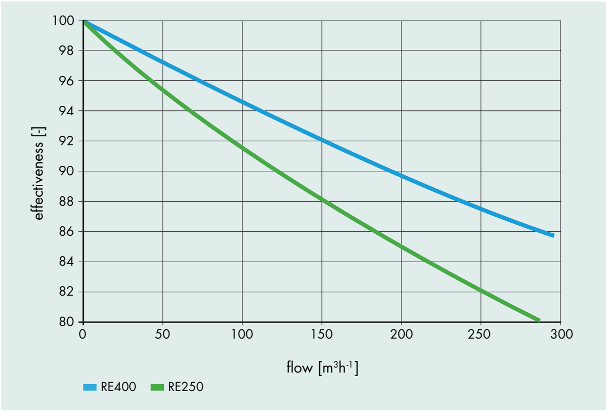
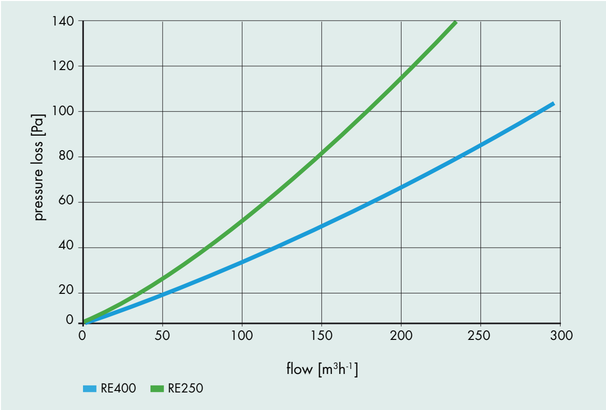
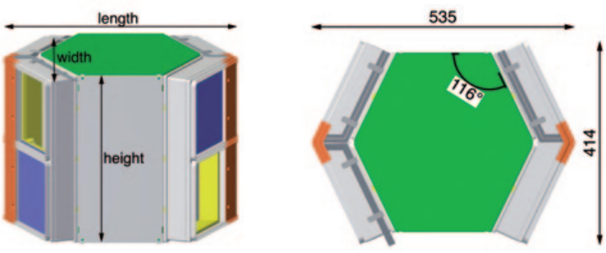


Figure 7.2 Pressure loss as a function of the flow



8 Dimensions

Figure 8.1 Dimensions of the Recair Enthalpy



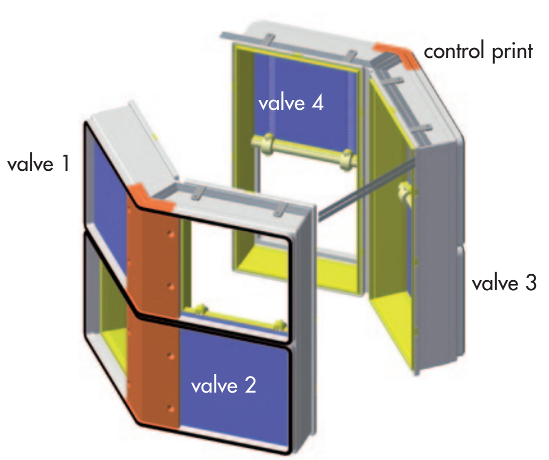
	RE 250	RE 400
height [mm]	250	400
width [mm]	414	414
length [mm]	535	535
weight [kg]	6,41	9

Exact dimensions will be provided on demand in a 3D-dxf –file or IGS file.

9 Connection

The Enthalpy recuperator can be connected in two possible ways, serial and digital. The serial connection gives more possibilities.The valves have been numerated to uniquely define their mutual positions, see fig. 9.1.

Figure 9.1 Valve numbering



The control print is at the side where the control cable leaves the enthalpy recuperator.
A total of 8 positions of the 4 valves are needed to let the enthalpy recuperator function properly. Each valve can be in the bottom position (indicated with down) or in the top position (indicated with up). Further the valves can individually be partially opened for the short cut functions. The recuperator can be symmetrically (fig. 3.2 and 3.3) or asymmetrically (fig. 3.4 and 3.5) or bypassed (fig. 3.6) crossed by the air flows.
The following valve positions are then possible:

Table 9.1 Possible combinations of valve positions, their names and commands

valve 1	valve 2	valve 3	valve 4	position	flow pattern	mode	command
down	up	up	down	1	symmetrical	heating 1	SM 1
up	down	down	up	2 standby		heating 2	SM 2
down	up	down	up	3	asymmetrical	cooling 1	SM 3
up	down	up	down	4		cooling 2	SM 4
down	down	down	down	5	full bypass	bypass 1	SM 5
down	down	up	up	6		bypass 2	SM 6
up	up	down	down	7		bypass 3	SM 7
up	up	up	up	8		bypass 4	SM 8

The positions of the valves after "init" is SM 3.

9.1 Control cable

The control cable (fig. 9.2) consists of 10 lines for power supply, serial interface RS485 and digital interface.

Figure 9.2 Control cable

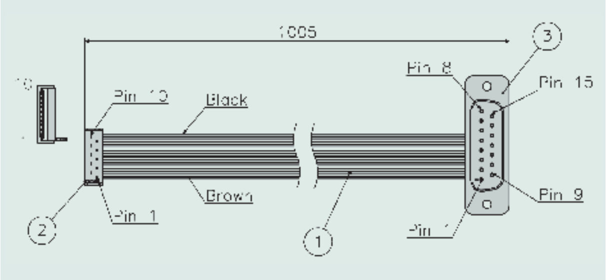


Table 9.2 Main connector cables

Contact	Description	Colour	Contact
1	Usupply 24 V	brown	1
2	Gnd	red	9
3	Data – (B)	orange	2
4	Data + (A)	yellow	10
5	Digital out	green	3
6	Gnd	blue	11
7	Digital in 1	violet	4
8	Digital in 2	grey	12
9	Digital in 3	white	5
10	Digital in 4	black	13

9.2 Communication

Communication via (2-wire) RS-485. Connections Data + and Data (– with common Gnd).

Table 9.3 Command set summary

Command	Function
Init	Initialisation
SM <mode>	Set mode to <mode>
SC <valve> <shortcut>	Set shortcut on valve
POS <valve>	Get position
INPOS <valve>	Get if is in position
MAXOPEN <valve>	Get maximum open position
ISHOMED <valve>	Get result of home
STATE <valve>	Get valve state

Between the command name and the value and between the two values in the shortcut command a space is mandatory. The shortcut value runs from 0...255, corresponding to a closed and half open valve. The shortcut value should be set starting from value 0. The hysteresis is approximately 15.

9.3 Digital inputs

Table 9.4 Digital inputs

in 1 violet	in 2 grey	in 3 white	in 4 black	valve 1	valve 2	valve 3	valve 4	Function mode
L	L	L	L	down	up	up	down	heating 1
H	L	L	L	up	down	down	up	heating 2
L	H	L	L	down	up	down	up	cooling 1
H	H	L	L	up	down	up	down	cooling 2
L	L	H	L	down	down	down	down	bypass 1
H	L	H	L	down	down	up	up	bypass 2
L	H	H	L	up	up	down	down	bypass 3
H	H	H	L	up	up	up	up	bypass 4
X	X	X	H	down	up	down	up	init

H = 15 V, L = 0.....3 V, X = any value

9.4 Digital output

Digital out is active on "set mode" move error. Cleared on next move.

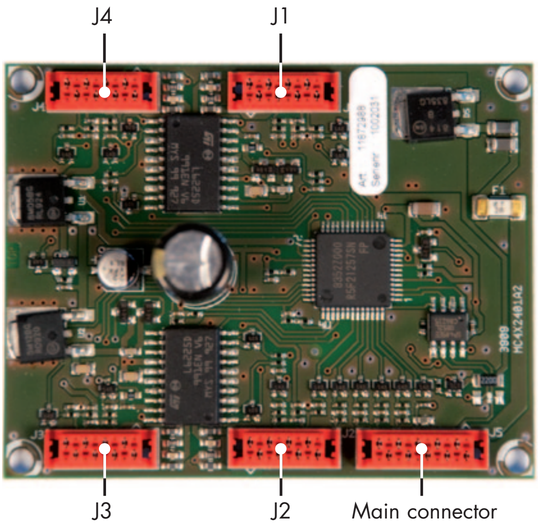
9.5 Power

The power consumption is 1,7 W at 20 °C. The power consumption during switching is 26 W at 20 °C.

10 Connection to the control print

Fig. 10.1 shows the control print of the Enthalpy recuperator, the connector labels are shown in red. The control print is placed at the position of motor 3 and 4 (see fig. 9.1).

Figure 10.1 Control print of the Recair Enthalpy



The main connector cable should be connected to "main connector"
The cable for motor 1 to "J1".
The cable for motor 2 to "J2".
The cable for motor 3 to "J3".
The cable for motor 4 to "J4".

Figure 10.2 Control print at the position of motor 3 and 4

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