Eurovent 17/11 - 2015

Guidelines for Heat Recovery

Eurovent 17/11 - 2015

First Edition

Published by EUROVENT
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Foreword

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1. Introduction

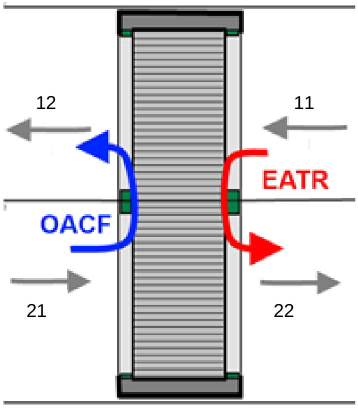
Eurovent Certita Certification rated performance for air-to-air heat exchangers is established with balanced mass flow conditions on the supply and return air side. From a measurement point of view this is achieved at low duct pressure differences around the heat exchangers, which is defined in EN 308 and the Eurovent Certita Certification Operational Manual and Rating Standards. This allows the comparison of technical performance as efficiency and pressure drop between different manufacturers' products. Nevertheless in real air handling systems optimum conditions are seldom met, and depending on the duct pressure differences air leakage needs to be considered during the system design phase.

2. Leakage

2.1. Definitions

Air leakage is defined in prEN 16798-3:2014 by two ratios:

- Outdoor air correction factor (OACF) [ ]
- Exhaust air transfer ratio (EATR) [%]



Outdoor Air Correction Factor (OACF) [-]: Ratio of Supply Air Inlet (21) mass flow divided by the Supply Air Outlet (22) mass flow.

$$OACF = \frac{q_{m,21}}{q_{m,22}}$$

With OACF > 1 more air is transferred from the supply to the exhaust air side and with OACF < 1 more air is transferred from exhaust to supply air side (recirculation of exhaust air). In general OACF is a measure expressing the difference between outdoor and supply mass airflow and is used to correct the Supply Air Inlet mass flow in order to meet the required Supply Air Outlet mass flow to the building (see 2.3.2).

Exhaust Air Transfer Ratio (EATR) [%]: percentage of the exhaust air inlet going back to the supply air outlet. With $q_{m,22,net}$ the portion of the Supply Air Outlet mass flow that originated as Supply Air Inlet (Net Supply Air Outlet Mass Flow), EATR is defined as:

$$EATR = \frac{q_{m,22} - q_{m,22,net}}{q_{m,22}} = 1 - \frac{q_{m,22,net}}{q_{m,22}}$$

EATR is measured by gas concentrations of inert gas and represents the exhaust air leakage to the supply airflow, which is in general described as internal exhaust air leakage.

Internal exhaust air leakage can occur by two different mechanisms:

- Carry-over is understood as the transfer of exhaust air trapped inside the heat exchanger matrix during the pass from exhaust to supply side. A purge sector is commonly installed to reduce carry-over to meet top supply air quality. Carry-over exists only for regenerative heat exchangers (wheels and storage matrices)

- Sealing leakage is defined as air leakage from exhaust to supply air flow and can be prevented by correct pressure set ups in the air handling unit system.

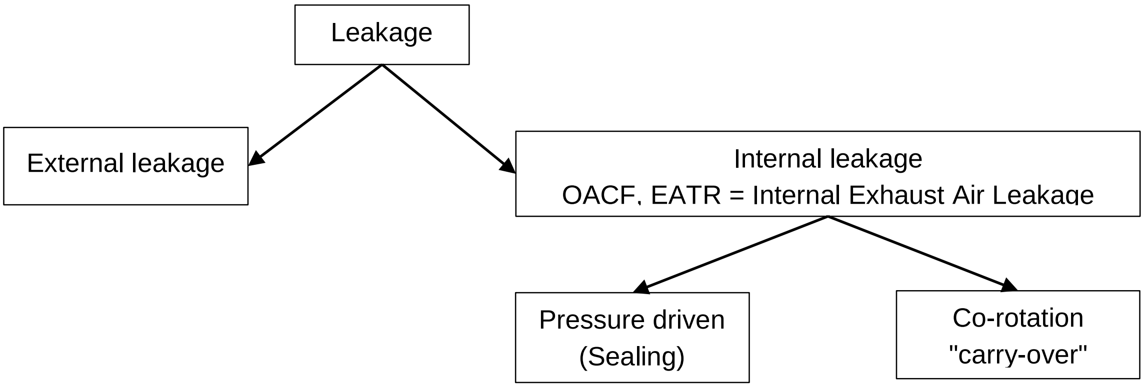


Figure 1: Concept tree of "leakages"

2.2. Where does it come from?

The Outdoor Air Correction Factor (OACF) and Exhaust Air Transfer Ratio (EATR) are depending on the duct difference pressure around the heat exchanger. Following diagram shows the relation of OACF and EATR depending on the duct difference pressure between supply and exhaust air. At negative duct difference pressures OACF decreases below 1,0 and EATR increases as the air leakage flow is directed from exhaust side to supply side. Positive duct difference pressures reduces EATR and increases OACF as air leakage flow is directed from supply to exhaust side. In case a purge sector is installed EATR values drop to very low limits and OACF increases slightly (see 2.6). Optimum operation conditions are reached with a low positive duct different pressures between supply and exhaust side.

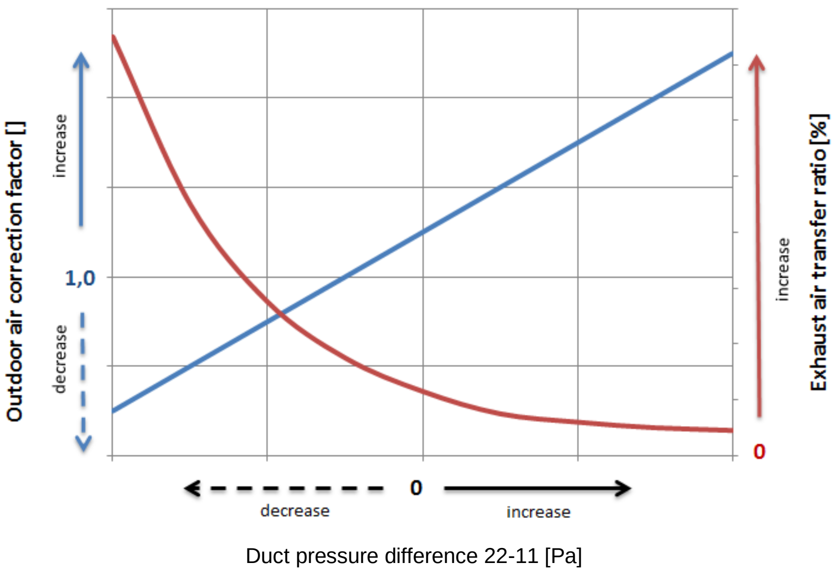


Figure 2: Behavior of OACF and EATR as a function of the duct pressure difference

2.3. Correction of mass flows according to OACF and EATR

2.3.1. Definitions

Net Supply Air Outlet Mass Flow ($q_{m,22,net}$): Fraction of the Supply Air Outlet mass flow that originated as Supply Air Inlet. The net Supply Air Outlet mass flow is determined by subtracting air transferred from the exhaust side of the exchanger from the gross airflow measured at the Supply Air Outlet side of the exchanger (according to AHRI Standard 1060)

Fresh Air Correction Factor (FACF) [-]: Ratio of Supply Air Inlet mass airflow and the net Supply Air Outlet mass airflow.

$$FACF = \frac{q_{m,21}}{q_{m,22,net}} \geq 1$$

By using the definitions of OACF and EATR above, this factor can be written:

$$FACF = \frac{q_{m,21}}{q_{m,22,net}} = \frac{q_{m,21}}{q_{m,22} * (1 - EATR)} = \frac{OACF}{1 - EATR}$$

2.3.2. Correction of Supply Air Inlet mass flow

Correction of Supply Air Inlet mass flow from required Supply Air Outlet mass flow and OACF, regardless the quality of Supply Air Outlet:

$$q_{m,21} = OACF \cdot q_{m,22}$$

Correction of Supply Air Inlet mass flow from required fresh (net) Supply Air Outlet mass flow, OACF and EATR, under consideration of Supply Air Outlet quality:

$$q_{m,21} = \mathrm{FACF} \cdot q_{m,22,net}$$

N.B.: *If this correction is required, this will result in an increased mass flow rate through the wheel with increased pressure drop and different static pressures around the wheel. The real correction only can be found with iterative calculations.*

N.B. bis: *OACF provides a quantitative mass flow correction whereas FACF provides a qualitative and quantitative mass flow correction.*

2.3.3. Correction of exhaust air outlet mass flow

From the mass balance we have:

$$q_{m,12} + q_{m,22} = q_{m,11} + q_{m,21}$$

And with the definition of OACF:

$$q_{m,12} + q_{m,22} = q_{m,11} + OACF \cdot q_{m,22}$$

Thus:

$$q_{m,12} = q_{m,11} + (OACF - 1) \cdot q_{m,22}$$

In the special case of balanced air mass flow rates on the building side ($q_{m,11} = q_{m,22}$) we have:

$$q_{m,12} = OACF \cdot q_{m,11}$$

Or

$$\frac{q_{m,11}}{q_{m,12}} = \frac{1}{OACF}$$

N.B.: *a definition of "net Exhaust Air Outlet mass airflow rate" analogue to supply air does not make sense.*

2.4. Correction of temperature efficiency and pressure drop

For an ideal heat recovery system the efficiencies are defined as follow:

$$\eta_t = \frac{t_{22} - t_{21}}{t_{11} - t_{21}}$$

and:

$$\eta_x = \frac{x_{22} - x_{21}}{x_{11} - x_{21}}$$

Leakage can influence temperature and humidity efficiency in sections 11, 12, 21 and 22 depending on the pressure situation around the wheel.

2.5. How to define leakages according to Regulation n°1253/2014?

Annex V of Regulation n°1253/2014 defines the following:

> *From 1 January 2016, the following product information shall be provided:*
>
> *[…]*
>
> *a) declared maximum external leakage rate (%) of the casing of ventilation units; and declared maximum internal leakage rate (%) of bidirectional ventilation units or carry over (for regenerative heat exchangers only); both measured or calculated according to the pressurisation test method or tracer gas test method at declared system pressure; […]*

Definition of 'internal leakage rate' in the regulation is as follows:

> *(7) 'internal leakage rate' means the fraction of extract air present in the supply air of ventilation units with HRS as a result of leakage between extract and supply airflows inside the casing when the unit is operated at reference air volume flow, measured at the ducts: the test shall be performed for RVUs at 100 Pa, and for NRVUs at 250 Pa.*

Therefore 'internal leakage rate' as defined in European Regulation n°1253/2014 on Ventilation units corresponds actually to the 'Internal exhaust air leakage' defined in EN 308 and to EATR defined earlier (not to be mixed with the internal leakage as defined in EN 308 which includes carry-over and sealing leakages).

The newly defined, Eurovent-certified and controlled values EATR and OACF together with the underlying differential pressure (taken for calculation of OACF and EATR) completely define the internal exhaust air leakage.

2.6. Impact of purge sector

The purge sector triggers the purging of the exhaust air existing in the heat storing mass ducts by the outdoor air. No exhaust air can get into the supply air.

A complete separation of outdoor air and exhaust air for regenerative rotary heat exchangers is ensured only with a functioning purge sector.

In devices without purge sectors a small portion of the exhaust air can be transferred to the outdoor air by carry-over. If this is not acceptable, then the carry-over can be eliminated by using purge sector systems.

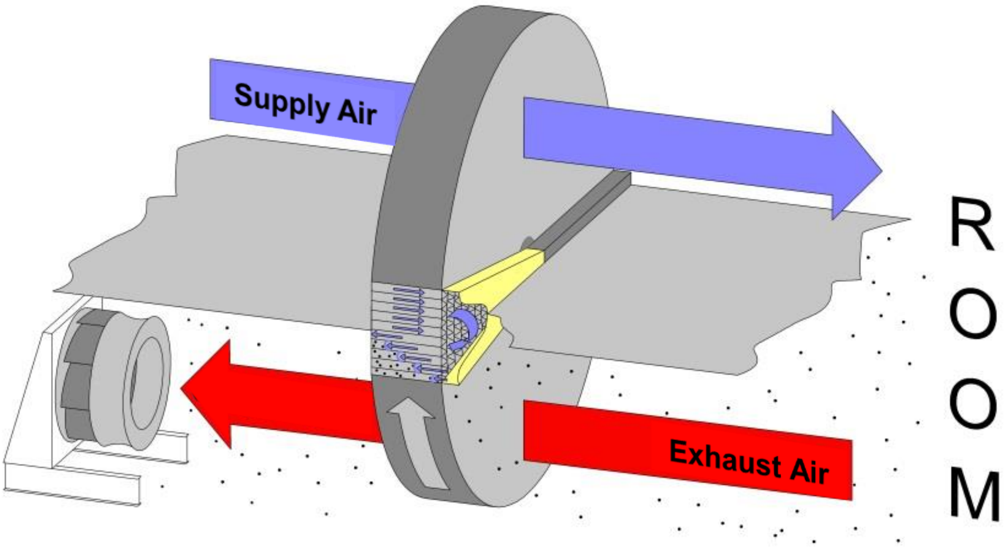


Figure 3: Arrangement of purge sector

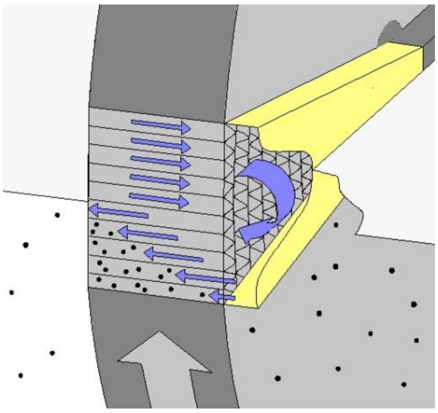


Figure 4: Operating principle of purge sector (detail)

Precondition for a purge sector function is a sufficient overpressure in the supply air. A sufficient overpressure in the supply air is achieved by appropriate placing of the fans.

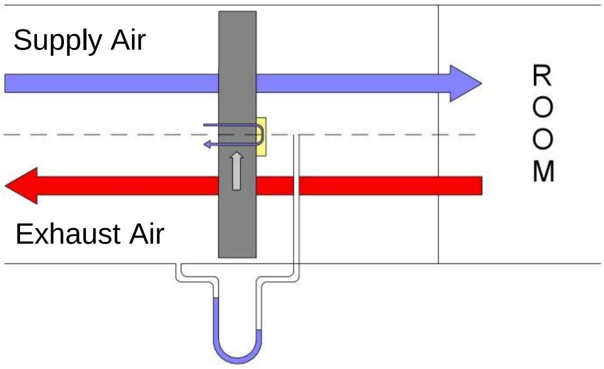


Figure 5: Correct pressure potential for installation of purge sector

The purge sector fulfils its function only then when the pressure potential of the supply air is greater than that of the exhaust air.

Beyond this a correct execution of a purge sector depends on the different construction principles (sealing systems, manufacturing tolerances, number of revolutions etc.) of different manufacturers.

Impact of purge sector on EATR and OACF:

- Rotary heat exchanger with purge sector = High OACF and low EATR
- Rotary heat exchanger without purge sector = Low OACF and high EATR

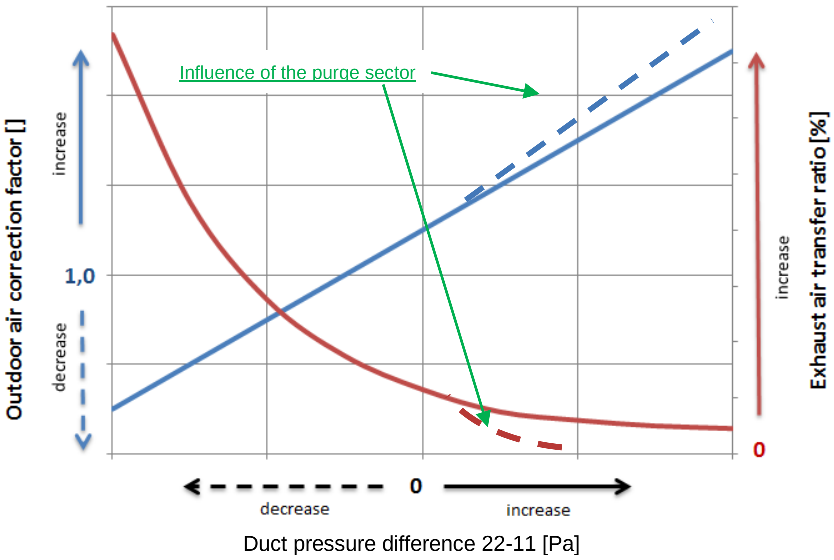


Figure 6: Influence of the purge sector

2.7. Internal leakage sources and how to decrease the leakages?

Internal leakage occurs when the pressure difference between the two streams is bigger than zero. It increases with increasing pressure difference.

It is difficult to completely eliminate leakage, but its effect can be reduced by taking the following actions:

- Decrease differential pressure between air streams
- Use a stable sealing system

2.7.1. *To decrease the differential pressure by Fan positioning*

Fan positioning can be designed to keep pressure difference as low as the system allows. This method allows getting the lowest leakage available for that system (see section 3.1).

2.7.2. *Use a pressure resistant / better / more stable sealing system*

Another way to reduce the leakage is to use a more stable sealing system that allows low leakage even at high pressure differences.

By combining the above mentioned solutions the leakage can be reduced to very low values and assure a tight system.

3. Design

3.1. Impact of the positioning of fans

The fans can be arranged in four different combinations and every combination has benefits and disadvantages. The fan arrangement will influence the factors EATR and OACF.

The EATR and OACF are important factors for the assessment of heat exchangers and the fan arrangement has an influence on both factors. In the examples below the different fan positions for a system equipped with a rotary heat exchanger will be described. The same assessments can be given for other types of heat exchangers.

We assume the following:

- Heat exchanger pressure drop: 100 Pa
- Filter F7 (supply side): 100 Pa
- Filter M5 (Extract side): 80 Pa
- Available external pressure drop supply side: 300 Pa
- Available external pressure drop extract side: 200Pa

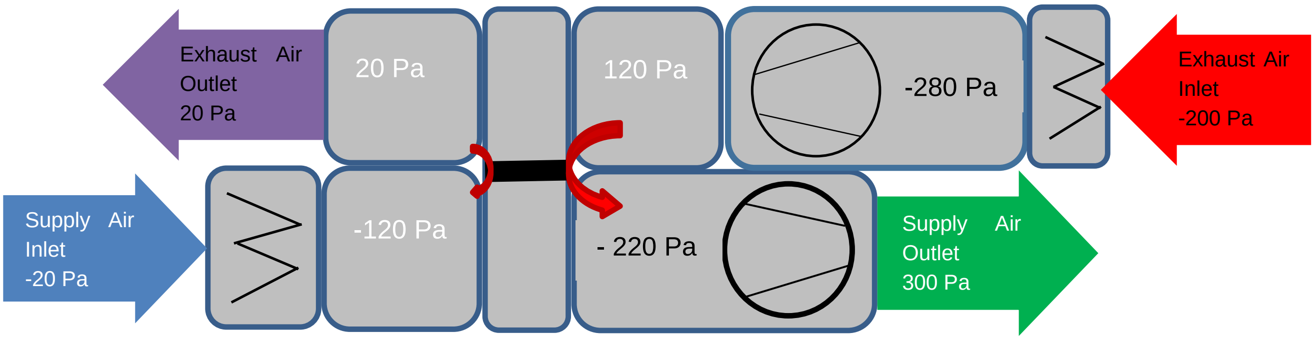


Figure 7: Both fans on the building side

In the first picture, the fans are arranged on the warm side of the rotary heat exchanger or on the building inner side. This arrangement of fan will lead to an air transfer from the extract air flow to the supply air flow, causing a high EATR and low OACF.

The position of the extract air fan is the reason for the air transfer, because the extract air fan pushes the air through the rotary heat exchanger and the supply air fan drawing the air through the rotary heat exchanger.

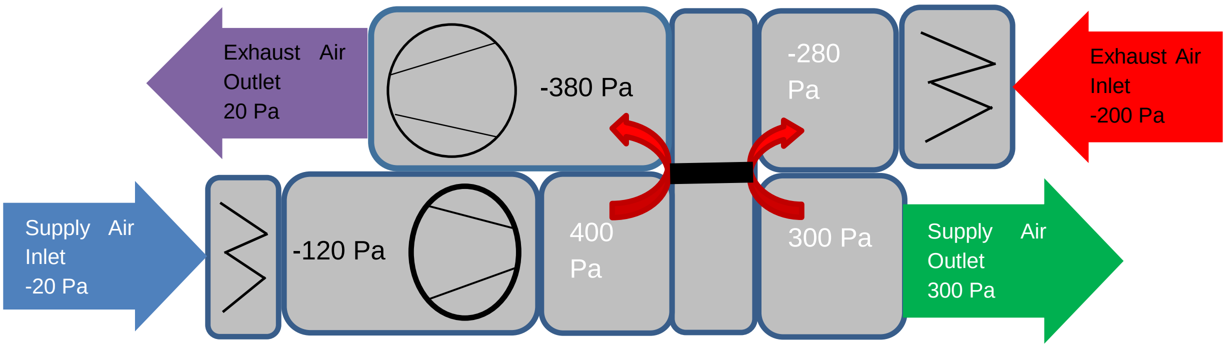


Figure 8: Both fans on the outer side (cold side) of the building

The outdoor fan push the air through the rotary heat exchanger. The large pressure difference between the floors will lead to a high OACF and low EATR. This setup have the highest pressure difference between the floors of all four combinations that result in a very low risk of leaking air from extract to supply.

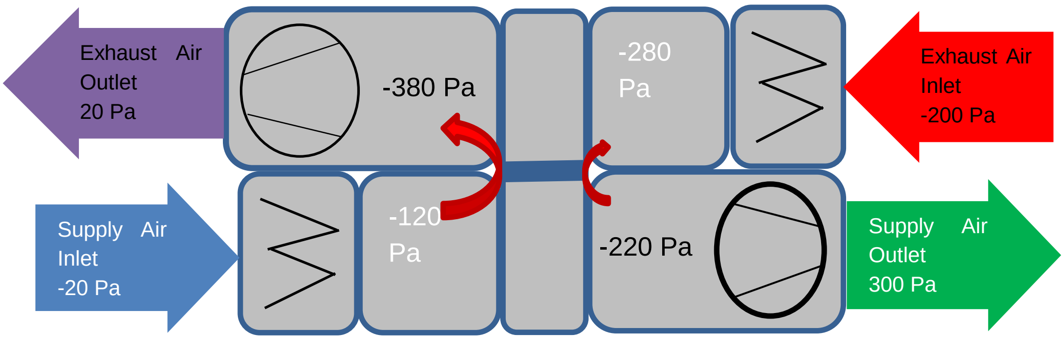


Figure 9: Ideal fan position - both fans drawing the air

This arrangement is the most common setup of AHUs and is ideal for the rotary heat exchanger, because both fans draw the air through the rotary heat exchanger. Due to the beneficial pressure difference the leakage from extract to supply can be kept low. EATR is low while the OACF is higher.

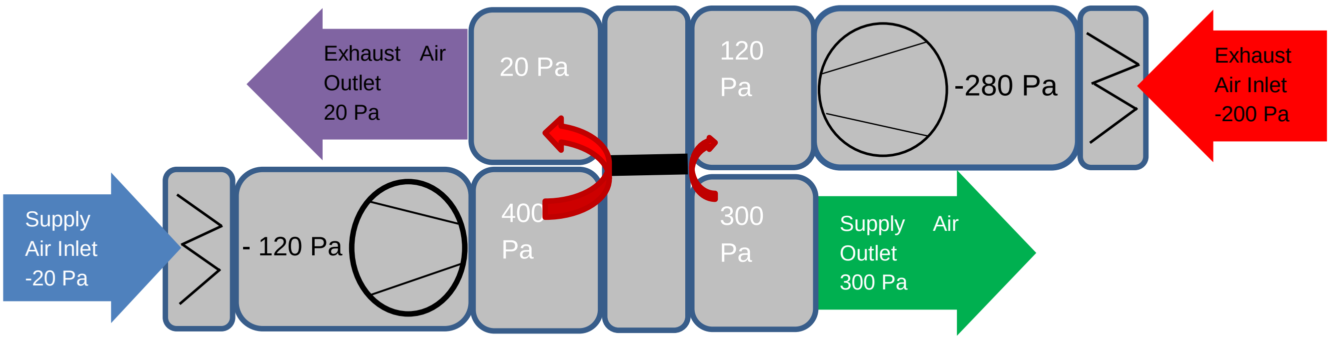


Figure 10: Both fans pushing the air

This arrangement pushes the air through the rotary heat exchangers. The large pressure difference between the floors will lead to a high OACF and a low EATR. This setup will have a low risk of leaking from extract to supply.

4. Total energy recovery systems (sensible and latent)

4.1. Why is it important to look at the humidity efficiency?

Energy recovery covers two fields: sensible heat recovery (temperature) and latent heat recovery (humidity).

While most systems only recover temperature some systems are also capable of recovering the humidity of air. This results in much higher transferred power as humidified air at same temperature has higher enthalpy. For comparison: Evaporating only 1 kg/h of water into the air reflects 700W of power (!).

Therefore, recovering temperature and humidity opens an additional field of energy saving.

High efficient humidity recovery opens a new opportunities for energetic and investment advantages:

- In mechanically cooled buildings the needed cooling power can be reduced by up to 50% (depending on conditions and technique) by use of sorption technique. This is possible because in summertime the humidity transfer dries the outdoor air. Due to this the cooling section can be reduced as less power is necessary to achieve the same temperature. This results in lower investment costs with even better air conditions. In the same time the needed energy is reduced also. This saves not only energy and money it also protects the environment.

- In the wintertime a lot of buildings have to be humidified to have a healthy air condition. In this case the needed energy for evaporating water or additional heating (due to the adiabatic cooling effects of the water) can be mostly saved due to the humidity recovery.

- In cases of freezing danger the humidity transfer reduces (and with high efficient humidity transfer in most cases even avoids) the building of condensate on the extract air side. Therefore freezing is either not happening or is at least massively reduced. In this case no capacity reduction of the heat recovery is necessary during the cold period - the heat exchanger does not freeze.

4.2. Techniques to recover humidity

The most popular systems are:

- Regenerative heat exchangers with sorption coating (e.g. sorption wheels)
- Plate heat exchangers with humidity transfer
- Regenerative heat exchangers with hygroscopic coating (hygroscopic wheels)
- Other regenerative heat exchangers (e.g. condensation wheels)

Sorption wheels and plate heat exchangers with humidity transfer are capable of transferring humidity constantly the whole year through (not only in wintertime).

Hygroscopic wheels are less efficient than sorption wheels during summer time.

Condensation wheels are mainly capable of transferring humidity when condensation occurs (that is during winter time only). They should therefore only be used for applications without cooling or humidifying.

5. Literature

[1] ANSI/AHRI: Standard 1060 Standard for Performance Rating of Air to Air Exchangers for Energy Recovery Ventilation Components – 2013.

[2] ASHRAE: Handbook, Chapter 25.6 – Air to Air Energy Recovery Device.

[3] Eurovent Certita Certification: OM-8-2015 Operational Manual for the Certification of Air to Air Plate and Tube Heat Exchangers – January 2015.

[4] Eurovent Certita Certification: RS 8/C/001-2015 Rating Standard for the Certification of Air to Air Plate and Tube Heat Exchangers – January 2015.

[5] Eurovent Certita Certification: OM-10-2015 Operational Manual for the Certification of Air to Air Regenerative Heat Exchangers – January 2015.

[6] Eurovent Certita Certification: RS 8/C/002-2015 Rating Standard for the Certification of Air to Air Regenerative Heat Exchangers – January 2015.

ANNEXE A. CALCULATION OF LEAKAGE INDICES AND RECIRCULATION FACTOR ACCORDING TO VDI 3803/PART 5

A.1. DEFINITIONS

<u>Leakage index extract airflow</u>: $L_1 = \frac{\dot{m}_{11}}{\dot{m}_{11} - \dot{m}_{1-2}} = \frac{\dot{m}_{11}}{\dot{m}_1}$

<u>Leakage index outside airflow</u>: $L_2 = \frac{\dot{m}_{21}}{\dot{m}_{21} - \dot{m}_{2-1}} = \frac{\dot{m}_{21}}{\dot{m}_2}$

where

$\dot{m}_1$	leakage-free extract airflow
$\dot{m}_2$	leakage-free outside airflow
$\dot{m}_{1-2}$	circulation air leakage from extract airflow to outside air flow
$\dot{m}_{2-1}$	short-circuit air leakage from outside airflow to extract air flow

<u>Recirculation factor U</u>: $U = \frac{\dot{m}_{1-2}}{\dot{m}_{21} - \dot{m}_{2-1}} = \frac{\dot{m}_{1-2}}{\dot{m}_2}$

Translation table between VDI 3803/Part 5 and this document:

VDI 3803/Part 5	Eurovent
$\dot{m}_{11}$	$= q_{m,11}$
$\dot{m}_{22}$	$= q_{m,22}$
$\dot{m}_2$	$= q_{m,22,net} = q_{m,22} * (1 - EATR)$
$\dot{m}_{1-2}$	$= q_{m,22} * EATR$
$U = \frac{\dot{m}_{1-2}}{\dot{m}_{21} - \dot{m}_{2-1}} = \frac{\dot{m}_{1-2}}{\dot{m}_2}$	$= \frac{q_{m,22} * EATR}{q_{m,22,net}} = \frac{q_{m,22} * EATR}{q_{m,22} * (1 - EATR)} = \frac{EATR}{1 - EATR}$
$L_1 = \frac{\dot{m}_{11}}{\dot{m}_{11} - \dot{m}_{1-2}} = \frac{\dot{m}_{11}}{\dot{m}_1}$	-
$L_2 = \frac{\dot{m}_{21}}{\dot{m}_{21} - \dot{m}_{2-1}} = \frac{\dot{m}_{21}}{\dot{m}_2}$	$= \frac{q_{m21}}{q_{m,22,net}} = f = \frac{OACF}{1 - EATR}$