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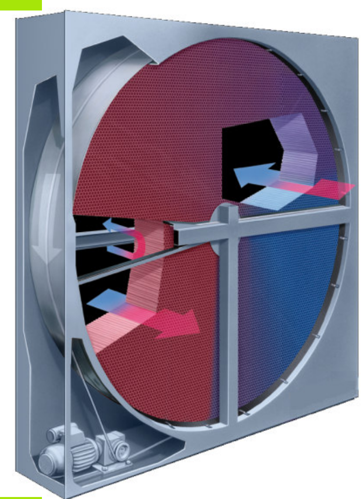
Technical Information

The rotary heat exchanger

Introduction

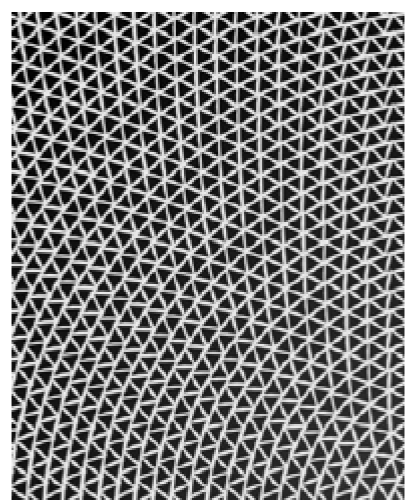


The rotary heat exchanger is classified as a **storage regenerator**.
The principle is to recover the calories in the « warm » air by passing this heat through the storage regenerator. This regenerator will then be crossed by « cold » air and will give this heat by convection.
This calories transfer produces temperature variation on the both airflows (decrease of temperature on the « warm » air side and increase on the opposite side). In the contrary to others heat recovery systems such as plate exchanger, wheel can transfer humidity. The airflow yielding its calories can also give a part of its humidity, that will be absorbed partially by the opposite airflow.

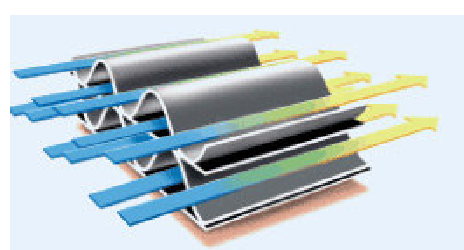
The rotary regenerator is defined by its **heat recovery** capability and also by its **humidity recovery** potential.

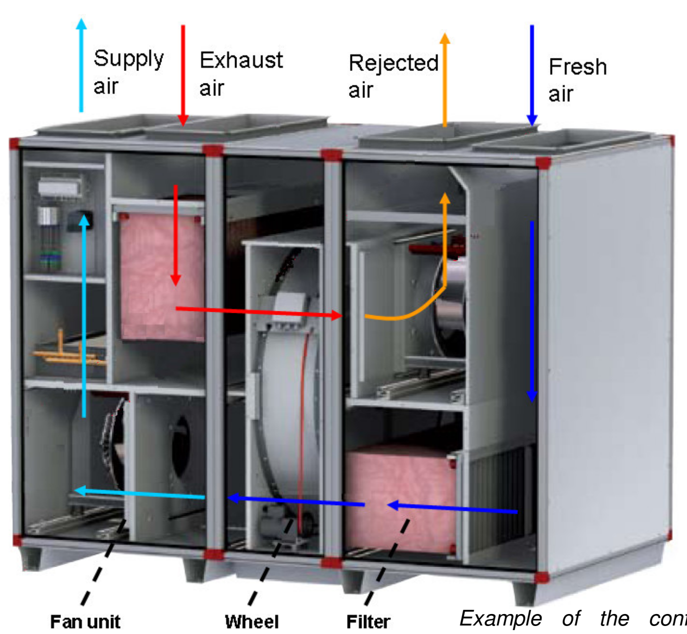
Principle

A wheel is a **cylindrical regenerator** composed of a storage mass. This **storage mass** is constituted by narrow, triangular air channels in axial direction. The mass can be made of stainless steel, in ceramic or in synthetic material; but aluminum is the most common material in the ventilation application due to its high conductivity and thermal capacity.
The wheel can also be covered up by an epoxy treatment (protection painting) allowing its use in the corrosive environment, such as the chlorinate atmosphere of a swimming pool.



Example of the storage mass shape





Example of the configuration of an air handling unit with a rotary heat-regenerator wheel

Principle

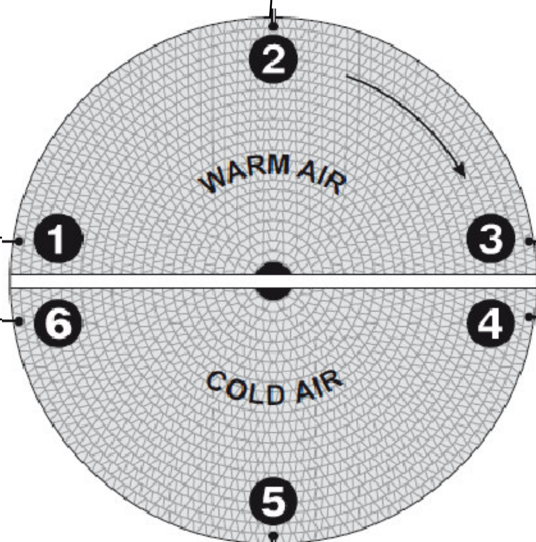
Thanks to its axial air channels, the wheel is used as a storage mass. When one half side is pre-heated by the « warm » air that gives its calories and humidity, the other half side is cooled by the « cold » air. Consequently, the surface temperature varies according to the **rotation angle**.

Evolution of the heat exchange according to the rotation angle :

ZONE 1
The wheel meets the « warm » air.
The mass temperature is close to the « cold » air temperature.
The « warm » air gives its heat to the cold mass.
The heat exchange is high in this zone because of the high temperature difference. The condensate generation can thus be important.

ZONE 2
The half way in the « warm » air side is done: the mass is warmer than in zone 1. Consequently, the heat exchange decreases.
The presence of condensate is possible only if the difference of water content is high between « cold » air and « warm » air.

ZONE 3
In zone 3, the mass temperature is close to the « warm » air temperature.
The quantity of the heat exchange becomes low.



ZONE 6
The mass surface temperature is close to the « cold » air.
The heat exchange is almost null.
This is the end of the cycle. The wheel will go back to zone 1 and the cycle will start again.

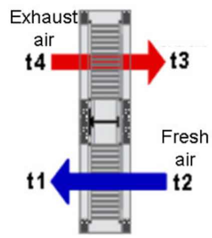
ZONE 5
The half way in this second part is done: the temperature difference between air and mass is decreasing, and the heat exchange reduces too.

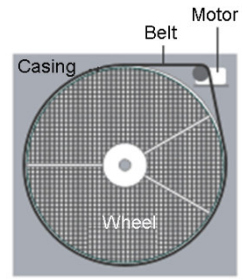
ZONE 4
The « cold » air passes through the warm mass.
The heat transfer rate is very high, due to the great temperature difference.
The « cold » air absorbs a part of the calories and humidity given by « warm » air.

Principle

The wheel in a slow rotation (from 5 to 20 tr/min) is driven by a step-by step motor. The electrical consumption is low. The pressure losses generated by the air passing through the air channels are by 100 to 300 Pa, according to the selected frontal velocity. These low pressure losses are an advantage for this type of exchanger selection.

Both airflows run in counter flow, each airflow crossing a half of the wheel, in opposite direction.





If the system runs in parallel flow, the wheel can be quickly clogged in the front face, due to the thin alveolar structure. A counter flow system allows a « **self-cleaning** » effect. Dust brought by the airflow inside the wheel will be evacuated by the other airflow that is running in the opposite direction. Despite that, it is necessary to supply a filtration (F5 efficiency minimum) upstream of the wheel, on each side, in order to protect it from clogging.

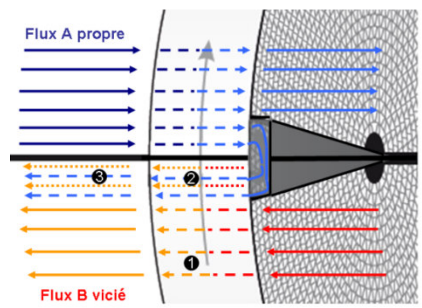
Purge sector

Due to its configuration and operation, the wheel can meet a risk of a mixing between both airflows. While the wheel is passing from flow B to flow A, a part of flow B will be trapped into the axial channels. It will be in contact with flow A and eventually contaminate it. A purge sector would minimize this contamination. It is composed of a fixed triangular plate, located on the junction of the flows A and B.

❶ The wheel is running, flow B is normally passing through the wheel.

❷ The wheel arrives at the purge sector level. Few particles of flow B are still in the channels. On the other side of the purge sector, flow A is passing through the wheel. A part of it is trapped into the purge sector and is evacuated in the opposite direction of flow B side.

❸ Particles of flow B are carried away with flow A. The channels are thus almost totally drained. A contamination is inevitable (up to 2 to 3% of the global airflow), advising against the use of this kind of exchanger for « **sensitive** » **application** such as hospital.



Efficiency

The wheel capability for heat and humidity transfer depends on several parameters linked to its geometrical structure (channels shape, material thickness, wheel depth), to its physical and mechanical characteristics (rotation speed, mass thermal capacity) but also to the air velocity.

The heat transfer capability can be defined according to the difference of temperature between both airflows :

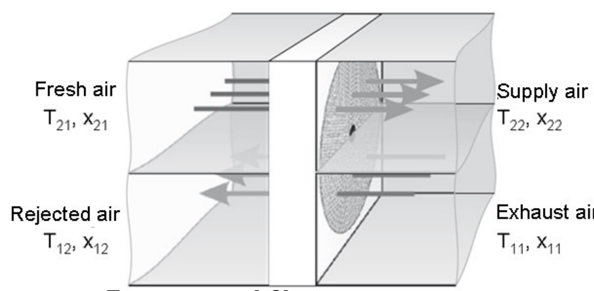
Heat recovery :

$$\varepsilon = \frac{T_{22} - T_{21}}{T_{11} - T_{21}}$$

The humidity transfer capability can be calculated on the water content (g. of water per kg of dry air) of the airflows :

Humidity recovery :

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



T: temperature [°C]
x: water content in the air [g water / kg of dry air]

Another parameter can help to determine the humidity transfer rate by condensation. This parameter is called **condensation potential** and can be defined as the water content difference between « warm » and « cold » air, at the saturation point.

- The higher the condensation potential is, the higher the generated condensation level is.
- If the condensation potential is null or negative, no condensation will occur.

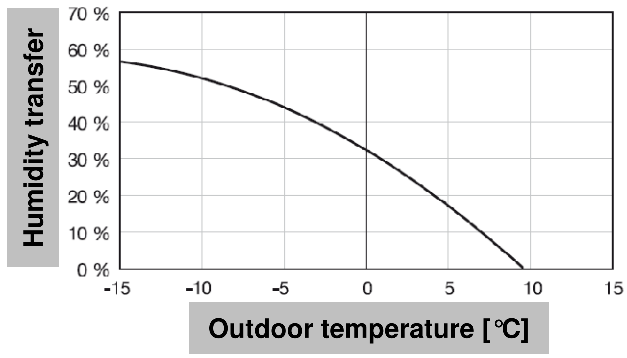
Different types of wheel

3 main types of wheel exist :
- the **condensation** or sensible heat wheel
- the **enthalpy** or hygroscopic wheel
- the **sorption** or dessicant wheel.

The condensation or sensible heat wheel

The condensation wheel is composed of axial channels with a smooth and non-treated storage mass (usually in aluminum). This wheel can transfer **heat** but also **humidity**, only by **condensation**. Depending on the operation conditions, a condensate pan will be supplied on the wheel bottom.
The more important the temperature difference of both airflows is, the higher the heat transfer is. This difference is mainly higher in winter than in summer.

The opposite diagram shows that humidity transfer can reach its maximum in **winter**. So the condensation wheel is a wise choice for heat and humidity transfer in ventilation applications in winter under occidental climates.



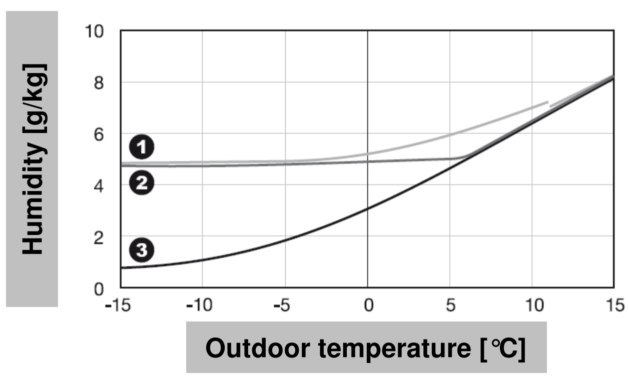
Humidity transfer of the condensation wheel according to the outdoor temperature (for an indoor exhaust air at 22°C/50%)

The enthalpy or hygroscopic wheel

The enthalpy or hygroscopic wheel can transfer humidity by **sorption** and by **condensation**. The storage mass is coating by a sorbent such as silicagel. The sorption is a physical phenomenon which consists to absorb air humidity by absorption (penetration of the water molecules in the mass porosity) or by adsorption (retained on the surface), without condensation of the water.
For the hygroscopic wheels, the contribution of the sorption in the humidity transfer depends on chemical treatment of the mass (different from a manufacturer to another). The sorption is not predominant regarding the condensation. That means hygroscopic wheels are not the best system for the summer air dehumidification. (we will understand why later in the paragraph on sorption wheel).

The opposite diagram shows the water content (g. of water /kg of dry air) in the supply air after the wheel according to the outdoor temperature in winter for the conditions of exhaust air (22°C/50%) according to VDI2067.

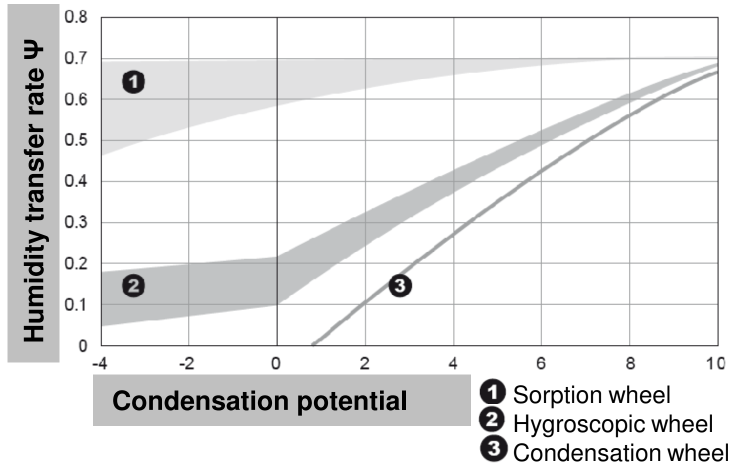
This diagram compares the hygroscopic wheel and the condensation wheel. With the enthalpy wheel, the water content of the supply air after the wheel is slightly higher between -5°C and 10°C after the wheel. This water content remains comparable for all others temperature ranges. In these conditions in winter, the enthalpy wheel can almost assure the same humidity and heat transfer as the condensation wheel.



❶ Supply air after the hygroscopic wheel
❷ Supply air after the condensation wheel
❸ Fresh air before the wheel

Water content of the supply air according to the outdoor temperature (for indoor temperature at 22°C/50%)

The dessicant or sorption wheel



The dessicant wheel can transfer humidity only **by sorption**; without water condensation contained in the air. The humidity recovery rate is almost independent of the condensation potential (see the opposite graph).

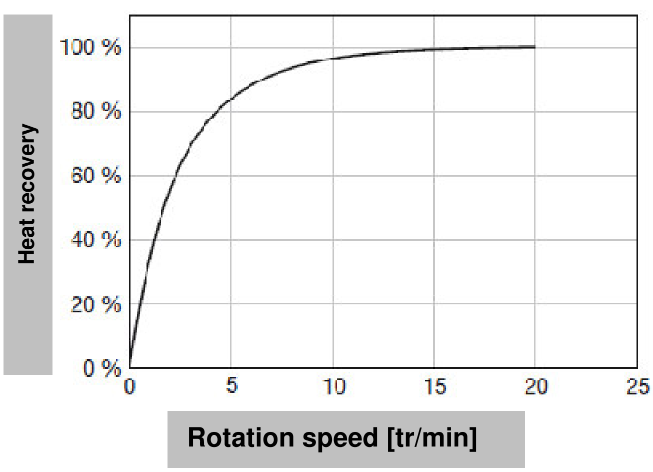
- For the condensation wheel, the humidity transfer rate is null when the potential of condensation is null or negative (condensation generation is impossible if the potential of condensation is under 0).

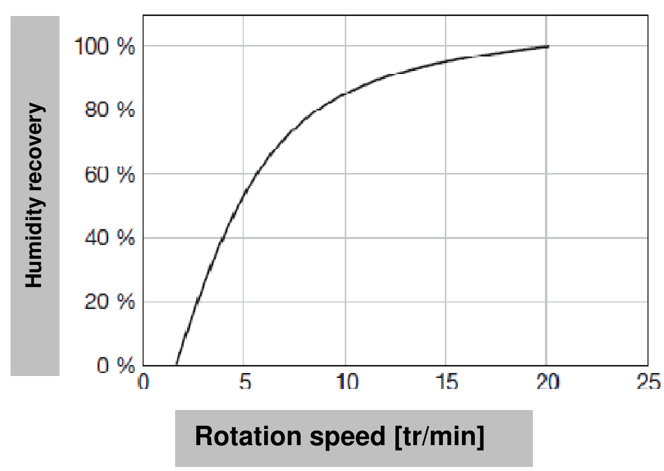
- The hygroscopic wheel works almost like a condensation wheel. The difference is in case of a null or negative potential of condensation, the humidity transfer is possible thanks to the hygroscopic mass.

- The dessicant wheel can also reach its maximum transfer rate even with a negative potential of condensation as it works only by sorption. This system is interesting during summer for applications of outdoor air dehumidification. During this season, the difference of temperature between outdoor and indoor air is not high enough to generate condensation and so a humidity transfer. The sorption phenomenon allows the outdoor air dehumidification without condensation, for all outdoor and indoor temperatures.

Regulation

The wheel performance control is possible by modifying the rotation speed. When it is necessary to reduce heat and/or humidity transfer, the rotation speed reduction leads to the wheel performance decrease. It is also possible to control the wheel efficiency with motorised damper, for the by-pass on one of the airflow (principle of the airflow variation).





Frost

In winter, exhaust warm air is cooled, so that the water steam contained in the air can condensate and freeze if the mass surface temperature is under 0. The cold fresh air temperature from which the frost is generated is called « the limit of the wheel frost ».

For the condensation wheel, the condensation generated by cooling can freeze when the outdoor temperature is lower than the « the limit of wheel frost » temperature.
For the same airflow on both sides, the risk of frost exists if the mean temperature Tm between the warm air inlet temperature (T21) and the cold one (T11) is lower than 5℃ :

$$T_m = \frac{T_{11} + T_{21}}{2} \leq 5°C$$

It is important to notice that for low outdoor temperatures, condensation and frost can be generated inside the outdoor ducts. Insulation is necessary.

For the sorption or hygroscopic wheels, water steam is transferred by sorption, which reduces the generation of condensation. The risk of frost is almost null.

The frost protection can be controlled by different methods :
- Fresh airflow reduction.
- Pre-heating of the fresh air by an electrical coil upstream the exchanger.
- Reduction of the rotation speed of the wheel.

Maintenance

The wheel does not need a major maintenance. It is necessary to regularly control it in order to maintain an optimum system work. A first inspection after 3 months is important. Then, yearly checks must be done, according to the manufacturer instructions. The inspection will especially check :
- The belt tension.
- The state of the motor bearings.
- The lateral and crossing airtight sealing (according to the wheel configuration).
- The general state of casing.
- The general state of the wheel mass.

The presence of the upstream-downstream filtration and the wheel self-cleaning principle reduce the dust storage. According to the applications, it can be necessary to clean the dust clogging the air channels and reducing the exchanger performances. Eliminate dust by sucking up and eliminate oils or others solutions with warm water and solvants (to use only in case of condensate pan presence). It is also possible to use compressed air for the cleaning but pay attention not to damage the channels fins (see the manufacturer instructions).