Heat Exchangers
1. INTRODUCTION

KASTT in partnership with Reznor manufactures two basic versions of heat exchangers:
- rotary regenerative heat exchangers (RHE) - both thermal (for heat transfer) and hygroscopic (for heat and humidity transfer),
- cross-flow plate recuperative heat exchangers (PHE) - for heat transfer only.

2. THE PRINCIPLES OF ROTARY AND PLATE HEAT EXCHANGERS

Regenerative and recuperative air-air type heat exchangers are devices that return thermal energy from exhaust (outlet) air to clean supply (inlet) air in various air handling and air conditioning units. These two products transfer the energy in different ways.

Regenerative rotary heat exchanger (RHE)

The rotary regenerative heat exchanger works on the principle of accumulating the energy (heat, humidity) contained in the outlet air into a slowly rotating heat exchanger rotor (aluminium foil) and the subsequent transfer of this energy into the inlet air. While the rotor is rotating, each individual part of it moves into the stream of outlet and then the inlet air.

KASTT manufactures rotary heat exchangers in thermal and hygroscopic versions for various amounts of air with rotor diameters up to 5 meters.

The key advantage of rotary heat exchangers compared to plate heat exchangers is their small width in the air handling units and the higher efficiency of heat transfer (heat and cold). Moreover, rotary heat exchangers, unlike plate heat exchangers, are able to transfer heat and moisture altogether.

The disadvantage of rotary heat exchangers is their lower impermeability of the individual air handling channels (outlet - inlet) which is partially reduced by properly designed sealing, a purge chamber and by recommending an optimal fan layout in the unit. Another disadvantage are the rotary heat exchanger’s moving parts, which may become a source of breakdown (electric motor, gearbox, sealing) or require frequent servicing.
3. RHE TECHNICAL PARAMETERS

Exchanger housing

a) BASIC version

This economic version features a housing made of bearing sections, joining sections and segments from galvanized or stainless steel sheet metal. At first the bearing sections, together with the steel segments, are spot-welded into the front walls which are then attached to the exchanger housing using bolts. The BASIC version of the housing may be used for rotor diameters of up to 2,400 mm. Because of its specific design this version may be used as an inserted module for an air conditioning unit. The exchanger can be supplemented with peripheral panels and reinforcing elements. It can then be used as a stand-alone component of an air handling unit.

In its basic design the housing is undivided and is intended to be used in the vertical position (see figures A and B, page 5). Subject to prior consultation with the manufacturer, the design can be adapted so the housing can be used in the horizontal position too (see figure C). A suitable surface finish can be applied to the housing (e.g. a powder coat).

b) Assembled version

In this version the housing is made of closed galvanized sectional bars, joining corners and profile footers from certified manufacturers. The joining corners and footers used depend on the housing size and whether it is designed in steel, aluminium or plastic. This version is sufficiently rigid and suitable to be used as a stand-alone component of air handling units both for indoor and outdoor environments. The assembled version of the housing may be used for rotor diameters up to 3,800 mm.

These housings are manufactured undivided (one-piece) (see figures A, B) or divided into halves (see figure D) as standard. We can also divide the housing into quarters (see figure E, page 5) if required by the customer. The housing may be further fitted with by-passes (figure F). The standard design of the housing is intended for vertical positioning, however it may be adapted for horizontal or sloped use as well (figure C). Based on customer-specific requirements, the housing can be supplied either completely disassembled or preassembled and then finally assembled in-situ.

An optional surface finish (e.g. powder coat) can be provided. The housing can be fitted with 25 and 50 mm thick insulating panels. The panels are made of galvanized sheet metal filled with mineral wool. As an option we make stainless steel or painted sheet metal panels.
c) Welded version

The housing is welded from closed sectional bars. This version is highly rigid for an outdoor environment. The welded version is adapted to the complete size range of rotors (up to 5,000 mm in diameter).

These housings are manufactured undivided (one-piece) (see figures A, B) or divided to halves (see figure D) as standard. We can also divide the housing into quarters (see figure E) if required by the customer. The housing can be further fitted with by-passes (figure F). Depending on the housing design, it can be positioned vertically (figure A), horizontally (figure C) or at an angle (inclined).

An optional surface finish (e.g. powder coat) can be provided.

The housing can be fitted with 25 and 50 mm thick insulating panels. The panels are made of galvanized sheet metal filled with mineral wool. As an option we make stainless steel or painted sheet metal panels suitable for use as a stand-alone component of air handling units both for indoor and outdoor environments.
Exchanger rotor

The rotor is alternately wound from straight and wavy layers of aluminium foil. The resulting matrix is able to guarantee an optimum air flow and transfer of heat or heat and humidity at the highest degree of efficiency.

a) Rotor construction

- Rotors of up to a diameter of 3,000 mm are supplied as a single piece (undivided) as standard.
- The rotor is reinforced by aluminium bars combined with bonded coils (for special applications the aluminium rods may be replaced by stainless steel tubes).

- Rotors with a diameter from 3,000 mm up to 5,000 mm are supplied divided into segments as standard.
- Rotors of smaller diameters can also be divided up for assembly, transport or positioning reasons.
- For the horizontal versions of heat exchangers (see figure C, page 5) the rotors are always divided up into segments starting from a diameter of 1,800 mm.
- The segmented rotor is braced by spokes interconnecting the individual segments of the divided rotor. Additionally aluminium rods are used in combination with bonded coils (for special applications the aluminium rods may be replaced by stainless steel tubes). If bonded coils are used, the number of rods can be reduced, compared to the non-bonded version.
- Rotors up to 1,800 mm in diameter are segmented at 90° and then at 60°.
- For rotors with a diameter of 3,200 mm and more the coil is further divided into double-surface to triple-surface so that the individual parts of the coil do not exceed the admissible weight for easy handling and assembly.

The individual parts of the divided rotor (segments) are inserted into centred spokes anchored in the central spider. Finally the rotor is braced around its perimeter by the main coating, then constricted and fixed using special anchoring.
b) Rotor types

The thermal rotor is wound from aluminium foil and is used for heat transfer with an efficiency of up to 85%.
The hygroscopic rotor is wound from aluminium foil with a special hygroscopic layer allowing the transfer of heat together with humidity with an efficiency of up to 90%.
The epoxy rotor is wound from aluminium foil treated with an epoxy layer for use in aggressive environments.


c) Coil composition and geometry

- Aluminium foil thickness and wave height affect the geometry of the coil grid.
- Wave height is selected so that heat recuperation is the most efficient depending on the amount and speed of air flow. The purpose and location of the recuperation unit is also taken into consideration.

Coil size combinations:

<table>
<thead>
<tr>
<th>coil width</th>
<th>200 mm</th>
<th>250 mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>wave height (mm)</td>
<td>1.4</td>
<td>1.6</td>
</tr>
<tr>
<td>foil thickness (mm)</td>
<td>0.06</td>
<td>0.07</td>
</tr>
</tbody>
</table>

Wave 1.4 and 1.6  
Low wave design - high heat transfer efficiency thanks to bigger volume of aluminium. Better heat transfer at higher speeds of air flow through recuperation unit.

Wave 1.9  
Standard wave size - for air handling systems with medium level of exhaust air contamination.

Wave 2.3  
Special wave design - for more contaminated environments (paint shops). Better maintenance due to more rigid design of rotor coil.

Remark: With a coil width of 200 mm we are able to produce any wave height from 1.4 to 2.0 mm based on the customer’s requirements.
Purge chamber and fan arrangements

The purpose of the purge chamber is to allow some of the supply air to get through the rotor into the exhaust air stream. In this way the rotor channels are purged, which considerably reduces the risk of contaminating the supply air.

Table 1

<table>
<thead>
<tr>
<th>Pressure gradient</th>
<th>Purge chamber</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 - 200 Pa</td>
<td>Chamber effect is not guaranteed. Chamber is not in use.</td>
</tr>
<tr>
<td>200 - 500 Pa</td>
<td>Standard angle of chamber edges 2 x 5°</td>
</tr>
<tr>
<td>500 - 800 Pa</td>
<td>Angle of chamber edges 2 x 2.5°</td>
</tr>
<tr>
<td>more than 800 Pa</td>
<td>It is not recommended to use a chamber</td>
</tr>
</tbody>
</table>
**Fan arrangements**

- supply and exhaust air fans are sucking.
- pressure gradient between supply and exhaust air is optimal in this case.
- optimum air stream distribution on rotor.
- recommended purge chamber angling is 2 x 5°.

This layout is recommended for optimum parameters (pressure loss, distribution of air stream on rotor).

- supply air fan is blowing, exhaust air fan is sucking.
- high pressure gradient between supply and exhaust air.
- higher demands on amount of air conveyed through purge chamber resulting in more air going through fans.
- should this layout of fans be required, reducing the purge chamber to 2 x 2.5° is recommended.

- supply and exhaust air fans are blowing.
- it may be difficult to achieve the correct pressure gradient in the purge chamber.
- recommended purge chamber angling is 2 x 5°.

- supply air is sucking, exhaust air fan is blowing.
- this layout is only used if air circulation is permissible (exhaust air is mixed with supply air).
- in this case the purge chamber cannot be used.

Remark: Blowing fans should be fitted with an air diffusion device in order to achieve optimum distribution of the air stream on the rotor.
Sealing

Rotor sealing is an efficient way to avoid air escaping from the exchanger or unwanted mixing of supply and exhaust air. The degree of leakage of the rotary heat exchanger depends on the sealing elements used, the pressure difference between individual channels and the arrangement of the supply and exhaust fans. It also depends on the adjustment of the sealing prior to putting the system into operation. The average value of leakage with the use of contact and contactless sealing is about 5% of volume flow.

a) Sealing types

All sealing types are secured by a special-purpose holder that allows for a sealing arrangement “from” or “to” the rotor, as needed.

- contact sealing - brushes
- contactless sealing - felt

b) Sealing location

Rotor perimeter sealing
Attachment on the rotor perimeter the most suitable for this position is contact sealing - brushes
Attachment on the outer side of the housing the most commonly used for this variant is contactless sealing - felt

Rotor dividing plane sealing
this is fitted on the outer side of the housing. In this case both contact and the contactless sealing may be used.
Exchanger drive and regulation

a) Motor and drive elements

The rotary exchanger drive comprises of an electric motor with a worm-gear unit, a belt pulley and a belt. The electric motor is supplied with a power supply voltage of 3x400V, exceptionally 1x230V and an output of 60W up to 750W. The driving force transmission between the motor and the exchanger rotor is assured by a welded or mechanically connected belt (depending on the model). Based on customer requirements, the exchanger can be fitted with an EC or a stepping motor to achieve a higher range of revolutions for regulating recuperation unit performance or as a part of an anti-frost measure. Motors designed for use in explosive atmospheres can be fitted upon request.

b) Operation, regulation and speed sensing

To achieve higher efficiency of heat transfer, the rotors are run at speeds from 10 to 13 revolutions/min. (RPM). The rotary exchanger may also be run at constant speed - without regulation or with a frequency converter for external control within the overall air handling unit, where the rotor speed is controlled by a signal linked with the required output of the recuperation unit. Upon request by the customer, the drive is supplied adjusted so that the speed of the rotor can be controlled by means of the frequency converter within the range from 1.8 to 10 RPM.

Another option for controlling the rotor speed is the use of an EC drive. The EC drive is controlled externally by a control voltage from 0 to 10V. A speed sensing unit (revolution sensor) can be fitted as an option.
Rotary heat exchanger (RHE) operation

Operating temperatures:

The standard version of the rotary heat exchanger is designed for operation in a Central European climate at ambient temperatures from -20 °C to +55 °C. Optionally, exchangers can be supplied in versions suitable for use in other temperature ranges.

In summer time the supply air is usually warmer and more humid than the exhaust air. In this case the thermal rotor adjusts the temperature of the supply air to the temperature of the exhaust air - this means a cooling effect can be achieved.

The hygroscopic rotor, unlike the thermal rotor, is also able to adjust air humidity. The situation is, however, completely different in operations with optional humidifiers installed. The exhaust air is more humid and therefore it is desirable to transfer the humidity from the exhaust air back to the supply air. Under Central European climatic conditions, at temperatures below zero, the thermal rotor does not usually freeze despite the occurrence of partial water condensation, which is absorbed by the supply air. Under such conditions the thermal rotor is partially able to transfer a small amount of humidity too. Freezing occurs when excess water from the exhaust air, not absorbed by the supply air, is present in the rotor and the temperature decreases below approx. -10°C.

If both volumetric flows are equal, the following general rule applies:

\[ ft = \frac{(tO2+tP1)}{2} > 0°C \rightarrow \text{no risk of freezing} \]

\( ft = \) freezing temperature
\( tO2 = \) exhaust air temperature prior to entry into rotor
\( tP1 = \) supply air temperature prior to entry into rotor

Freezing results in reduced rotor throughput rate, lower efficiency and sometimes even permanent damage to the rotor. Therefore suitable anti-freeze measures are recommended to avoid rotor freezing.

- Pre-heating supply air.
- Temperature sensing or pressure loss metering in the rotor to adjust the rotor speed accordingly.
- Disabling the exchanger for a necessary period of time (when extremely low temperatures persist).
- Exchanger rotation.

Operating speed and pressure loss:

For standard conditions the recommended speed of air flow is 2 to 4 m/s. The local speed at the motor intersection may be exceeded subject to a tolerance of 30% due to uneven air current. Speeds above the tolerance range may result in permanent damage of the rotor.

If higher air flow speed is required, consult the manufacturer with your requirements.

Pressure loss depends on air flow speed, wave height, rotor width and rotor fill factor.

Scheme - Efficiency dependence on air flow speed (W) and pressure loss (dP)
**Rotor speed:**

For the highest thermal transfer efficiency the rotor speed should be from 10 to 13 RPM. If a combination of a motor with a frequency converter is used, the frequency of the motor power supply can be controlled within the range of 18 Hz to 100 Hz. If a stepping motor is used, rotor revolutions (speed) can be controlled in the range of 0 to 13 RPM.

**Scheme - Dependence of relative thermal efficiency on rotor speed**

![Diagram showing the dependence of relative thermal efficiency on rotor speed]

**Air intake to the rotor**

If it is not possible to secure a direct flow of air to the rotor (e.g. due to lack of space), a device must be fitted to provide for forced air dissipation resulting in an even air flow distribution to the rotor.

**Filtration, inspection and cleaning:**

To a large extent the rotary exchanger has a self-cleaning capacity. This is due to the counter-directional arrangement of air streams. Incoming contaminants in the supply air stream stick to the front side of the rotor and when the rotor turns into the exhaust air stream, the contaminants are released and blown away from the unit.

This self-cleaning capacity, however, is not 100%, so filtration must be used in both air stream directions.

During operation rotor contamination must be checked for on a regular basis.

**Rotors can be cleaned by:**
- compressed air
- compressed water (beware of improper application which may result in damage to the coil fins)
- a soft brush
- a vacuum cleaner
- a suitable solvent (depending on the nature of the contamination)

In case of other types of rotor contamination (e.g. greasy or sticky particles), the appropriateness and suitability of the filter used should be reconsidered.

In operations where other types of contamination occur (such as paint shops), the segmented rotor construction is required to allow for dismantling and subsequently cleaning outside of the air handling unit.

*N.B.: The operation of rotary exchangers is governed by the latest version of KASTT s.r.o. Technical Conditions available at www.kastt.cz.*
Code for RHE ordering

ROV ST XX/XX - X - X - XX - X - XX

- type
- coil width
- rotor diameter
- rotor type
- wave height
- drive
- according to purge chamber location: 1 - 8, 0 - no chamber
- housing position: V - vertical, H - horizontal, S - special
- rotor: divided - D, undivided - C
- environment: 1 - normal indoor, 2 - outdoors, 3 - with drive for explosive atmospheres

V1 - V8

- motor side
- direction of motor rotation
- exhaust air
- supply air
- purge chamber on front side
- purge chamber on back side

H1 - H8