Heat recovery ventilation - what is it?
Heat recovery ventilation

Introduction

We have observed a growing trend in design to reduce the operating costs of residential buildings based on ensuring the best energy efficiency properties.

The growing investor awareness and an increase in the available materials allowing to improve energy efficiency mean that the gravity ventilation installations based on the natural air flow are no longer enough to ensure the proper level of air exchange. In such cases, gravity ventilation system is not very effective.

For this reason, designers are forced to employ mechanical installation in which the air flow is forced by the use of, for example, ventilator fans. However, as we see in practice, even with a proper modernization of the thermal parameters of the building, nearly 50% of the consumed energy is used up on heating or cooling the air supplied from the outside.

To sum up, it is perfectly legitimate to fit the ventilation system with a heat recovery device with forced air circulation. One of such devices, which meet all the requirements listed above, are the HRU-ECCO and HRU-ERGO recuperators by Alnor.

Basic terms

The concept of recuperation is related to recovering heat so that it can be further processed. Similarly, recuperators recover heat energy. This allows to limit heat loss by the ventilation system. To sum up, the main reason to use recuperators is to save energy and supply fresh and clean air.

The recovery parameter shows us the amount of savings, it is calculated using the following formula:

$$\Delta T = \frac{T_{RA} - T_{EA}}{T_{RA}} \cdot 100\%$$

$T_{RA}$ - temperature of foul air expelled from the room
$T_{EA}$ - temperature of foul air expelled outside
Operating principle

The main task of the recuperator is to expel foul air and supply fresh air with specific parameters - temperature, moisture, efficiency.

Warm air supplied from the outside by an intake ventilator passes through filters, where dirt, dust and pollen is removed, afterwards it is pumped into the heat exchanger. At the same time, foul air from the room is taken in by the exhaust ventilator and also lead to the heat exchanger. The two air masses are pumped through the heat exchanger.

Thermodynamic exchange takes place in the heat exchanger. In summertime, the cold from the outgoing air is transferred to the supplied air flowing from the outside. Next, the cooled air is pumped into the room, and foul air is expelled outside. It is a process of recovering heat from the expelled air. In wintertime, the process is as follows: cool air taken from the outside is cooled by the foul air expelled from the interior.

Thermal efficiency of the recovery process depends, among others, on the type of exchanger and the materials which it is made of. See illus. 2 below for an example of the installation which utilizes a recuperator unit.

SA - temperature of the air supplied to the room RA - temperature of the foul air expelled from the room
OA - temperature of outside air supplied to the room EA - expelled air temperature

Schematics of HRU-ECCO and HRU-ERGO recuperator units by Alnor:
- casing,
- pipe stub connections,
- heat exchanger,
- ventilators,
- filters,
- controller
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Casing

Casing of Alnor recuperators is made of galvanized steel. Casing size is optimized for efficiency of each unit type. The casing is compact and uniform. This means the unit does not require a lot of space for installation. Moreover, the unit can be mounted in a standard horizontal position, or upside down as required. The casing is partially thermal and acoustic insulated to limit energy loss.

Pipe stub connections

Stub diameters are 160, 200 or 250 mm depending on unit type. Connections are fitted with EPDM rubber washers. This means the system has the highest, Class D, insulation class.

Heat exchangers

The most important component of the recuperator unit is the heat exchanger. Presently, there are many different types of recuperator units with different structure, air flow direction, degree of recovery and application. HRU-ECCO and HRU-ERGO recuperator units by Alnor are fitted with, respectively, a cellulose cross-flow exchanger and a countercurrent exchanger.

See illus. 4 for schematics of the cross-flow exchanger. In the cross-flow exchanger, air flows converge at the 90 degrees angle (illus. 5) Cross-flow exchanger utilizes a system of perpendicular plate ducts. Heat exchange takes place at the contact point of these ducts. Supplied and expelled air flows mix.
According to the formula given above, the recovered amount is:

$$\Delta T_k = \frac{21 - 10}{21} \cdot 100\% \approx 52\%$$

The air distribution diagram is as follows (illus. 5):

- $T_{OA}$: l'air frais aspiré de l'extérieur
- $T_{RA}$: l'air usé est évacué des locaux
- $T_{EA}$: air usé jeté à l'extérieur
- $T_{SA}$: air frais aspiré aux locaux

*Illus. 4* HRE-ECCO cross-flow heat exchanger

*Illus. 5* Air distribution diagram for the cross-flow exchanger is as follows
Temperature recovery process in a cross-flow exchanger is shown on the diagram below:

Advantages of Alnor recuperators fitted with a cross-flow exchanger:

- simple construction,
- no moving parts,
- max heat recovery 75%.

In countercurrent exchangers, air flows laterally, in opposite directions (illus. 8) The air flow ducts have a triangular section. Such a solution means the contact surface is larger, which improves recovery efficiency. See illus. 7 below for an image of an counter-current exchanger.
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According to the formula given above, the recovered amount is:

\[
\Delta T_p = \frac{21 - 5}{21} \cdot 100\% \approx 76\%
\]

Temperature recovery process in a cross-flow exchanger is shown on the diagram below:

*Illus.8 Air distribution diagram for the countercurrent exchanger is as follows*

*Illus.9 Heat recovery diagram for the countercurrent exchanger is as follows*
Advantages of Alnor recuperators fitted with a countercurrent exchanger:

- simple construction,
- no moving parts,
- max heat recovery 80%,
- no frosting of the installation,
- no current obstruction.

An important factor is that both the countercurrent and cross-flow exchangers are made of a material with an antibacterial coating, which kills various types of bacteria and prevents the spread of various fungi in the exchanger.

The antibacterial coating is also resistant to abrasion. This means it’s not worn during cleaning. The coating is bactericidal, including the following strains: E coli 8099, Staphylococcus aureus ATCC6538, Klebsiella pneumoniae ATCC4352, Candida albicans ATCC10231.

Ventilators

Alnor recuperators are fitted with intake and offtake ventilators. Each ventilator unit is fitted with an AC motor. Construction of the ventilators ensures longevity, low noise even at high rotational speeds and relatively low energy consumption. Each ventilator unit guarantees optimal operation of the recuperator.

Intake and offtake ventilators are controlled laterally. Which means when we adjust recuperator efficiency from high to medium, this also alters the efficiency of the intake and offtake units on the same level. In practice, this guarantees that the same amount of air is supplied and removed through the installation.

Filters

Air filters used in Alnor recuperators improve the quality of the supplied air. The filtering system is fitted with EU3 class filters. Filter element consists of plastic casing and a filtering layer. Filter surface is carefully selected to limit pressure loss for nominal capacity as far as possible.

Controller

Alnor recuperators are fitted with an intelligent control system allowing to setup the working parameters for each unit for specific hours and days of the week. This means the operator only has to setup the temperatures for each day and hour once, and needn’t be bothered with setting up the unit any further. See illus. 10 and 11 for a view of the main display and control screen, respectively.

The controller, apart from the simple, standard functions such as setting up and viewing parameters for specific modes of operation also allows to program the weekly clock. This allows the operator to specify the exact time and date to turn on or turn off the recuperator unit.

For example, if a room will be vacant for an extended periods of time, there’s no need to keep the recuperator running. Which means, for example, that the recuperator can be set to turn off at 8 am from Monday to Friday, and turn on at 3 pm. This allows to ensure fresh air in a room when we get back home from work. More detailed information about the controller can be found in the instructions manual.
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**Illus.10 Controller display view**

- By-pass
- Power supply
- Clock
- Day
- Intake air
- Intake air speed
- Temperature of air supplied to the room
- Outside air
- Outside air speed
- Temperature of outside air at the intake

**Illus.11 Controller panel view**

- Decrease time
- Increase temperature
- Decrease temperatura
- Increase time
- Functions and saving data
- Cancel operation
- Air speed settings
- No function
- Clock setting
- Select day
- Turn on week clock
- Turn off week clock
HRU-ECCO and HRU-ERGO recuperators are fitted with a moisture recovery function. This means that Alnor recuperators can be used to recover both heat and moisture from the expelled air, and subsequently transfer the moisture to the air supplied to the room. This is especially useful when the air gets dry, especially when being heated in wintertime.

Moisture recovery process happens in the recuperator’s exchanger. The exchanger allows to directly transfer water molecules including the energy they contain. Condensation does not happen in this case, which means there is no energy lost as steam. This is one of the factors for the high efficiency factor of the countercurrent recuperators. The process described above is possible thanks to the special construction of the exchanger unit.

The exchange is made of a special 45µm paper, which is highly resistant to tear and aging. The entire secret lies in the thickness and structure of the paper used in the exchanger. The mesh size of the paper is 0,3nm. Dirt particles size is larger than 0,3nm, while water molecules are 0,288 nm in diameter. This means that only moisture is able to permeate through the mesh in the exchanger, and can be transferred to the air supplied into the room (illus. 12 and 13 as well as tab. 1). Despite such construction, the exchanger has very high tightness. Heat exchanger which also allows for moisture recovery is also known as an enthalpic exchanger.

In summer, the supplied air is cooled and its moisture is decreased. In winter, the supplied air is heated and its moisture increases. To sum up, Alnor recuperators are able to adjust the moisture of the air supplied to the room.

Table below shows the molecule diameters for different types of gases as well as the mesh size for the material used in the exchanger.

<table>
<thead>
<tr>
<th>Tape of gas</th>
<th>CO₂</th>
<th>NH₃</th>
<th>CH₄</th>
<th>H₂O</th>
<th>Mesh size [nm]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diameter [nm]</td>
<td>0,324</td>
<td>0,308</td>
<td>0,324</td>
<td>0,288</td>
<td>0,3</td>
</tr>
</tbody>
</table>

Table 1. Sizes of particles found in the air

*Illus. 12. Structure of the material which the exchanger is made of*
By-pass

Alnor recuperators are fitted with a by-pass function. The by-pass function lets the air pass through the by-pass circuit when certain conditions are met. The by-pass is a fully automated function. It is only required to specify the temperature ranges for the supplied air and the system automatically decides whether the intake air should pass through the exchanger or not.

If the fresh air temperature is equal to the temperature outside, the by-pass will engage automatically. This function is particularly useful in summer. If the outside air at nighttime is colder than the supplied air, there is no need to recover heat. Cold air from the outside is directly pumped indoors. The by-pass function allows to get past the exchanger if the difference between supplied and expelled air temperatures is small.

Which recuperator by Alnor to choose?

Choosing the right recuperator unit has a major influence on the correct operation of the entire ventilation system. Even the best class recuperator unit will not be up to your requirements if it’s not the right type for your installation. This leads to both the decrease in comfort in the ventilated room and higher running costs. The basic criterion for choosing the right type of the HRU-ECCO and HRU-ERGO recuperator units is to specify the amount of fresh air required. This amount will conform to the recuperator unit’s capacity.

Recuperator’s capacity should allow for an appropriate number of air exchanges in the room during one hour. Which means, the required number of full air exchanges in another important feature. It is assumed that the recuperator unit should ensure one full air exchange in a room per hour. In practice, this means that the recuperator working at full capacity should ensure full exchange of air in a facility within one hour.

To specify the amount of air which is to be supplied to the room, it is necessary to provide the size and intended function of the room. With these basic data, we can use the table below (tab. 2) to ascertain the two required parameters: amount of fresh air required for one person and the number of full air changes.

If there is a number of rooms with different amount of people using them, the air consumption should be calculated as a sum of products of the capacity required for each room and the amount of people present. When designing the ventilation system with heat recovery, please keep in mind to always supply the fresh air in the rooms and bedrooms, and expel foul air via the kitchen and bathroom. This means all the waste is disposed at the place where it is most likely generated. It also ensures that the supplied air is always fresh.

Let’s use an example to illustrate the considerations listed above. Assume a regular, non-smoking room used by 5 people, and a dining room used by 3 people at the same time. Room area is 30m², dining room area is 20m², room height is 3m.
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Table 2. Air required for one person and number of full air exchanges per hour

<table>
<thead>
<tr>
<th>Type</th>
<th>non-smoking</th>
<th>medium</th>
<th>heavy</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Typical</td>
<td>Theater</td>
<td>Office</td>
</tr>
<tr>
<td>Q [m³/h]</td>
<td>17 – 42</td>
<td>8,5 – 21</td>
<td>25 – 62</td>
</tr>
<tr>
<td>P</td>
<td>1.06 – 2.65</td>
<td>1.06 – 2.66</td>
<td>1.56 – 3.90</td>
</tr>
<tr>
<td>Typical Gymnasium</td>
<td>8 – 20</td>
<td>0.50 – 1.25</td>
<td>0.50 – 1.25</td>
</tr>
<tr>
<td>Theater</td>
<td>8,5 – 21</td>
<td>0.50 – 1.25</td>
<td>1.06 – 2.66</td>
</tr>
<tr>
<td>Dining room</td>
<td>20 – 50</td>
<td>2.50 – 6.25</td>
<td>1.25 – 3.13</td>
</tr>
<tr>
<td>VIP</td>
<td>30 – 75</td>
<td>1.25 – 3.13</td>
<td>1.88 – 4.69</td>
</tr>
<tr>
<td>Conference room</td>
<td>50 - 125</td>
<td>3.13 – 7.81</td>
<td></td>
</tr>
</tbody>
</table>

Data:

Q₁ from 17 do 42 m³/h - from 17 to 42 m³/h - based on the table, the used value for Q₁=30m³/h (room)

N₁ = 5 - number of people in the room

Q₂ from 20 to 50 - based on the table, the used value for Q = 40m³/h (dining room)

N₂ = 3 - number of people in the dining room

S₁ = 30m² - room area

S₂ = 20m² - dining room area

We make calculations for two cases:

1. Amount of fresh air

Which gives the amount of fresh air in each room:

\[ Q_{x1} = Q_1 \cdot N_1 = 30 \cdot 5 = 150 \text{m}^3/\text{h} \]

\[ Q_{x2} = Q_2 \cdot N_2 = 40 \cdot 3 = 120 \text{m}^3/\text{h} \]

Hence, total amount of required air is:

\[ Q_{xc} = Q_{x1} + Q_{x2} = 150 + 120 = 270 \text{m}^3/\text{h} \]

2. Number of changes

\[ Q_{y1} = P \cdot S_1 \cdot \bar{H} = 1,5 \cdot 30 \cdot 3 = 135 \text{m}^3/\text{h}, \text{from the table we assume } P = 1,5 \]

\[ Q_{y2} = P \cdot S_1 \cdot \bar{H} = 2,5 \cdot 20 \cdot 3 = 150 \text{m}^3/\text{h}, \text{from the table we assume } P = 2,5 \]

\[ Q_{yc} = Q_{y1} + Q_{y2} = 135 + 150 = 285 \text{m}^3/\text{h} \]

Finally, we use the higher calculated value, that is 285m³/h. Based on this, we choose the following recuperator models HRV-ECCO-300 or HRV-ERGO-250 or HRV-ERGO-350.
Icing and frost protection

HRU-ECCO and HRU-ERGO recuperator units are available with an optional feature to protect the exchanger from frost and freezing in low temperatures. It is a very important function, since ice in the exchanger very often leads to blocking the ducts preventing heat recovery. To better understand the concept of frosting, we have to see how it’s happening. We are going to use the saturation curve diagram to this end (illus. 14).

Saturation curve divides the areas of occurrence in one or two phase setups. This is a dividing line, when we cross it, as the temperature gets lower, dry air (also known as unsaturated air) turns into steam (oversaturated air), then water and finally ice. The saturation curve shows the relationship between temperature and absolute moisture of the air in a given state. There are two ways of cooling the air - with and without condensation of steam. Cooling with condensation process is shown with the red line on the diagram (illus. 14).

It is evident that condensation is something to avoid. Too much water may lead to flooding, or in this case to creating ice and blocking the exchanger. Consequently, the recovery rate shall drop considerably, or can even stop.

For this reason, it is important that the cooling process does not lead to the condensation of steam. This is possible if the process follows the green line on the diagram on illustration 14. As seen on the diagram, the line never leaves the area in which the air is unsaturated. It is possible to make use of such a cooling process in two ways.

First method is to use a heating system, e.g. a water heater, steam or electric. The heater is turned on to melt the ice as it appears. Recuperators by Alnor are not fitted with a heater.
The second method involves appropriately adjusting the operation of intake and offtake ventilator. When icing is detected, the offtake ventilator automatically increases its capacity, and the intake ventilator shuts down, when the supplied air temperature becomes greater than +15°C for one full minute. In short, the intake ventilator slows down.

The second method is much more advantageous, as the recuperator continues to supply fresh air to the room. Moreover, the heater increases energy consumption.

Operating temperature range for Alnor recuperators is -15°C to +40°C. In such a temperature range, it’s not possible for the recuperator to freeze. Using the recuperator in lower temperatures, that is below -15°C requires using an electric heater.

**Specification**

Each Alnor recuperator has a specification of parameters. See illus. 15 below for a sample specification for the HRU-ECCO-200 recuperator unit.

The above specification provides pressure loss for specific duct lengths. This may be useful when designing and choosing components for the installation to include the recovery unit. Moreover, diagrams show pressure loss for individual air runs and flows. With such data, we can establish the pressure loss value in a particular moment of the unit’s operation. Apart from that, the diagrams show thermal efficiency during heating and cooling.

*Illus. 15 Flow characteristics, pressure loss and recovery of the HRU-ECCO-200 recovery ventilator*
Maintenance

Recuperator unit longevity depends on a number of factors, e.g. its operating environment (office, production hall, etc.) operating time and its working capacity.

To ensure proper, long term and reliable operation, please follow the guidelines below:

- conduct periodic inspections of the ventilators and filters. In case of a noticeable decrease in recuperator efficiency, we recommend to change the filters;
- clean the exchanger periodically. We do not recommend cleaning the exchanger with high-pressure air, due to the high risk of damaging the unit. We recommend to clean the exchanger by gathering the dust by, for example a vacuum cleaner. Such cleaning should be done, for example, every 3 years. We recommend to change the exchanger for a new one after 10 years of operation.

Servicing

Alnor provides comprehensive technical service for its recuperators. During the warranty period, such services are provided free of charge. After the warranty period, technical service requires payment. Alnor provides a warranty of 1 year for its products.

Mechanical ventilation system components to utilize Alnor recuperator units.

Alnor offers a full product selection for mechanical ventilation systems with heat recovery. The comprehensive product offer entails that the customer may buy the recuperator unit along with the following additional products:

- round ducts and fittings

In order to distribute the air in the rooms, Alnor suggests to use the comprehensive SPIRAL® system which guarantees best possible Class D air-tightness attested by Sitac certificate. SPIRAL® system ensures that the fittings are easily installed with minimum risk of leaks. At the same time it ensures an aesthetic appearance, which is an important factor for visible parts of the installation.

System components include, among others, coil pipes, elbows, reducers, T-connections, dampers made fully of galvanized steel. The suggested diameter range of the installation required to support a recuperator unit is between ø100 and ø250, depending on recuperator type and size. It is also possible to use insulated ducts and fittings.
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- insulated and uninsulated flexible ducts

Uninsulated flexible ducts are recommended for the exhaust part of the installation, the section where foul air is expelled directly outside. In such case, energy losses are minimal.

Flexible ducts allow for easy distribution of air into inaccessible locations, with little space for installation. In many cases, it is required to use insulated ducts to limit the loss of heat and cold. Moreover, insulation prevents condensation due to temperature differences.

Insulated ducts should always be used in the part of the installation which directly supplies fresh air into the facility. Using such ducts ensures that the room temperature conforms to the set temperature for the recuperator unit.

- ventilation accessories - exhaust and intake valves, inlet vents

Ventilation accessories in the product group which is usually installed as the last part of the indoor installation, it is directly responsible for the distribution and outtake of air in and out of the facility.

Exhaust and intake valves are also very frequently used in the air supply and exhaust installations. These valves can be insulated or uninsulated, and can be supplied with or without a mounting frame. Valves are installed directly inside the duct or flexible duct, they serve as a highly aesthetic end section of the installation which complements the room interior.
- intakes, outtakes

Intakes and outtakes are mostly installed outdoors. Depending on place of installation, these components can be wall or roof mounted.

They are fitted with a special drip cap and a system which prevents condensate from entering the installation. Moreover, intakes are fitted with a mesh which prevents outside dirt from entering the installation. When installing these components, it is important to ensure proper spacing between the intake and outtake (min. 1m).

- installation accessories - clamps, profiles

All the ventilation system components: recuperator unit, ducts, fittings, accessories must be properly mounted. To this end, it is necessary to use appropriate installation accessories - pipe suspension bands, suspension bands, supports, suspensions, profiles, profile connectors, threaded bars and various types of sleeve anchors, steel nuts and bolts, etc.
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- insulation and sealing components

Insulation and sealing components include a comprehensive selection of sealing tapes, leak stoppers as well as stone wool and fiberglass insulation for ducts, which serves both as a thermal and acoustic seal. For duct insulation, we recommend wool covered with aluminum foil on one side.

To join sections of wool insulation, we recommend TALE reinforced tape. For installing the sealing components, we recommend to use nails: self-adhesive, welding nails, and nails weldable through insulation.

Summary

To sum up, HRU-ECCO and HRU-ERGO recuperators offer:
- high heat recovery efficiency, with 1 : 1 ratio of supply and exhaust air;
- resistance to recuperator frosting, which means the heat exchanger does not get blocked by ice in negative temperatures, it doesn’t use electric air heaters which would consume energy;
- air-tightness of the exchanger, which means there is no mixing of foul air and fresh supplied air to facility;
- large exchange surface in the recuperator, with long flow of both air streams, like in a countercurrent exchanger;
- countercurrent air flow through the exchanger (HRU-ERGO recuperator);
- automatic control system which automatically adjusts heat exchange efficiency to actual needs.

Advantages of Alnor recuperators:
- high energy recovery - countercurrent heat exchanger (more than 90%),
- moisture recovery - thanks to a special exchanger structure.
- exchanger - fresh and expelled air does not mix,
- exchanger is protected by antibacterial coating,
- high quality filters - ensure fresh and clean air,
- heavy duty ventilators intended for long, continuous operation,
- by-pass - allows operation in different climate conditions,
- simple construction - easy installation and maintenance,
- low energy consumption,
- three running speeds,
- small size.
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NOTES