We explain why the counterflow and crossflow plate heat exchanger complement each other according to eco-design.

Since the first energy crisis in 1973, heat recovery in HVAC systems has become the benchmark in the industry – even though there was previously no obligation to use it and no mention of minimum thermal efficiency. With the implementation of the Ecodesign Directive 2009/125/EC, minimum thermal efficiency values were then required for the first time. These had a direct impact on the choice and design of heat recovery systems. Plate heat exchangers using the crossflow principle in particular had difficulties delivering the required values at low air flow rates (approx. 1000 – 4000 m³/h). However, it was possible to resolve this with counterflows. The different flow types now have their own specific areas of application.

Increasing efficiency requirements

As a result of the various pieces of legislation and standards, there are also – unfortunately – different requirements relating to thermal efficiency and pressure drop. What's more, the scope (EU or CEN member states) and the status (mandatory requirement or state-of-the-art technology) are also different. However, the basic conditions are always the same mass flows for supply air and extract air (without condensation). In terms of effect, the European Commission Regulation EU 1253/2014 is the main piece of legislation.

- **European Commission Regulation EU 1253/2014**
  This is an EU Commission Regulation, which needs to implemented in all member states. It stipulates a minimum thermal efficiency of 0.73 (previously 0.67) for plate heat exchangers as of 01.01.2018. On top of this, the SFP value also indirectly limits the pressure drop; when converted, this is approx. 280 Pa in total (2 x 140 Pa). Finally, a bypass for the heat recovery system needs to be installed to regulate the output.
- **European standard EN 13053 (2017)**
  CEN member states must translate this European standard into a national standard; it basically describes what is considered to be the benchmark in terms of technology. It specifies thermal efficiency values for four quality classes – H1 to H4. The value for the class H2 is 0.73 and therefore corresponds to the specification in the EU Commission Regulation. There is also a kind of net thermal

efficiency value, which is corrected with the required output for pressure drops. Unfortunately, these permissible pressure drops – e.g. 480 Pa (2 x 240 Pa) for class H2 – are considerably higher than the specifications in EU 1253/2014.

- **European standard EN 16798-3 (2017)**
  This is also a European standard, which refers to EN 13053 with regard to heat recovery. Interestingly, 300 W/m³/h of additional electrical power is permitted for operating classes H1 and H2. This means an increase in the permitted pressure drop in EN 13053, which contradicts the objective of EU 1253/2014.
- **Other guidelines**
  In addition to the regulations and standards specified above, there are also national heat recovery guidelines in nearly every country (e.g. SIA, Switzerland). The focus is on high thermal efficiency and a low pressure drop. The impact of domestic ventilation (e.g. through the Passive House Institute) on the parameters for HVAC systems must also be emphasised.
- **Market response**
  In the markets, the thermal efficiency and pressure drops are being adjusted to the specifications. Higher thermal efficiency values and lower pressure drops only occur in exceptional cases – as a result of the high requirements, economic considerations are rare. Unlike before (when there were no minimum values), the ventilation unit or plant constructor now has overall responsibility for the dimensioning, rather than the heat recovery unit manufacturer. System technology which combines components efficiently is very much in demand.

Calculating plate heat exchangers using the NTU method

The NTU method is ideal for calculating the impact of the flow in the plate heat exchanger (crossflow or counterflow). The following basic conditions apply to heat recovery:

- Same medium for both flows (air)
- Same mass flow for both flows
- No change of state (condensation)

As a result, the thermal efficiency values will be the same for the two air flows (supply air and extract air). The dimensionless size N provides the general formula for different flows.

$$\text{Ø} = \frac{N \cdot F}{(1 + N \cdot F)} \qquad (1)$$

Ø = degree of change in temperature (thermal efficiency)
N = number of transfer units (NTU figure)
F = correction factor, which depends on the flow (counterflow, direct flow, etc.) and N; it is for counterflow.

By defining N, you can deduce the size of the heat exchanger (plate size, number of plates.)

$$N = \frac{k \cdot A}{c_p \cdot m} \qquad (2)$$

k = heat transfer coefficient
A = transfer surface
c_p = specific thermal capacity
m = mass flow

If you take a look at chart 1, which shows the thermal efficiency subject to N, you will see that

- The crossflow heat exchanger requires N to be 4.24 to achieve a thermal efficiency of 0.73 as specified by EU 1253/2014.
- The counterflow heat exchanger requires N to be 2.70 to achieve the same efficiency.

To put it simply, this means that a pure crossflow heat exchanger would need to be 1.57 times larger than a counterflow heat exchanger to achieve the same thermal efficiency. It is assumed that the k and thermal capacity cp are the same for both flow types.

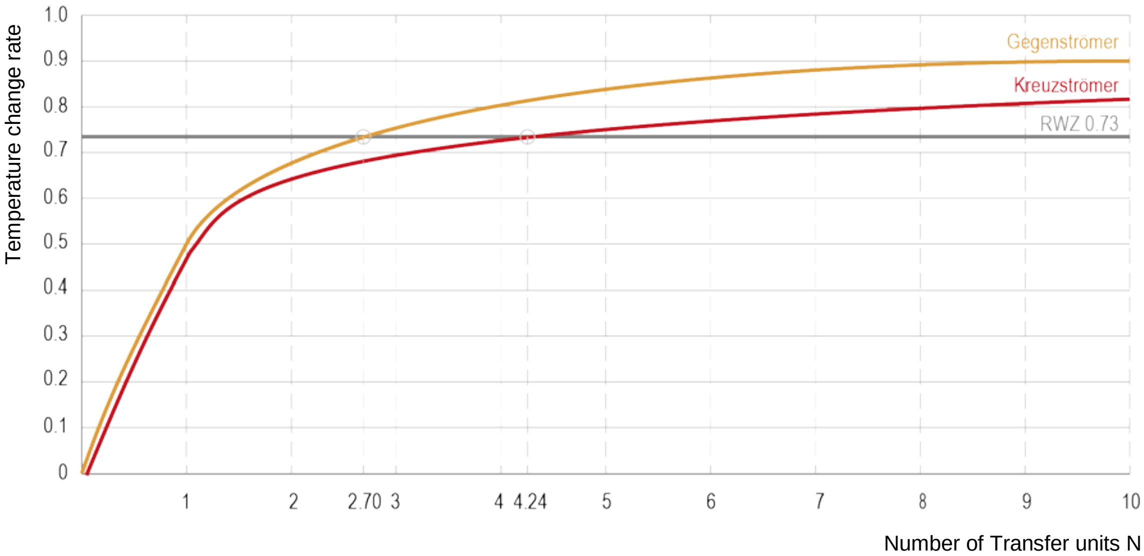

Chart 1: Thermal efficiency of a counterflow heat exchanger and a pure crossflow heat exchanger subject to the NTU figure N

Area of application of the crossflow heat exchanger

To achieve a thermal efficiency of 0.73, a pure crossflow heat exchanger must have an NTU figure N of at least 4.24. What options are available for achieving this value, which is higher than that of a counterflow heat exchanger?

Defining the NTU figure N provides the answer:

- **Heat transfer coefficient k**

  This value is generally optimised with regard to pressure drop and plate shape, meaning that no (considerable) improvements are possible.

- **Transfer surface A**

  This can be increased with larger plates, i.e. edge lengths. However, large plates (edge lengths of approx. 0.8 m and above) cannot currently be used with low air flow rates (up to approx. 4000 m³/h) due to the small ventilation unit dimensions (height).

- **Thermal capacity c_p**

  It is not possible to improve the cp value for air as this is a property of the substance.

- **Mass flow m**

  This refers to the mass flow per plate, which can be changed with the plate spacing. With the same exchanger width (dictated by the width of the ventilation unit), reduced plate spacing results in more plates and therefore a lower mass flow per plate. The NTU figure increases. Unfortunately, you cannot reduce the plate spacing to whatever you like as the exchanger:

  - can get dirty and clog up.
  - can barely absorb an elastic deformation in the event of a pressure difference. This can increase the pressure drop considerably.
  - is difficult to produce as a result (dimensional tolerance).

  The minimum plate spacing specified in EN 3803-1 is based on these observations. Another aspect of the plate spacing is the pressure drop, which is subject to this; it increases as the spacing gets smaller.

The minimum plate spacing specified in EN 3803-1 is based on these observations. Another aspect of the plate spacing is the pressure drop, which is subject to this; it increases as the spacing gets smaller. The old wisdom states that you require long edge lengths and minimal plate spacing to achieve a high thermal efficiency – this sums up these observations perfectly. In practice, this means that a crossflow heat exchanger with the minimum permissible plate spacing generally requires an edge length of at least 0.8 m to achieve the necessary thermal efficiency of 0.73. With the usual widths for ventilation units and permissible pressure drops, this results in an air flow rate of approx. 3500 m³/h. With anything less than this, it is not possible to create a solution with a plate heat exchanger using the crossflow principle alone. However, tried-and-tested crossflow heat exchangers do bring major advantages for greater air flow rates of up to 100,000 m³/h:

- They are easy to produce.
- They are easy to install in the ventilation unit.
- They have proven to be successful in practice for decades.
- The accessories, such as the bypass, have also been tested.
- They allow different geometric connection variants.
- They allow different freeze-protection options.
- Discharging any condensate is simple.

Area of application of the counterflow heat exchanger

When it comes to the best heat transmission (theoretically), we often ask ourselves why counterflow heat exchangers are not used in general. This is down to the difficult flow control at the inlet and outlet, which makes the units complicated to design and produce. As a result, the counterflow heat exchanger is made up of two mixing zones with the actual counterflow heat exchanger itself in-between..

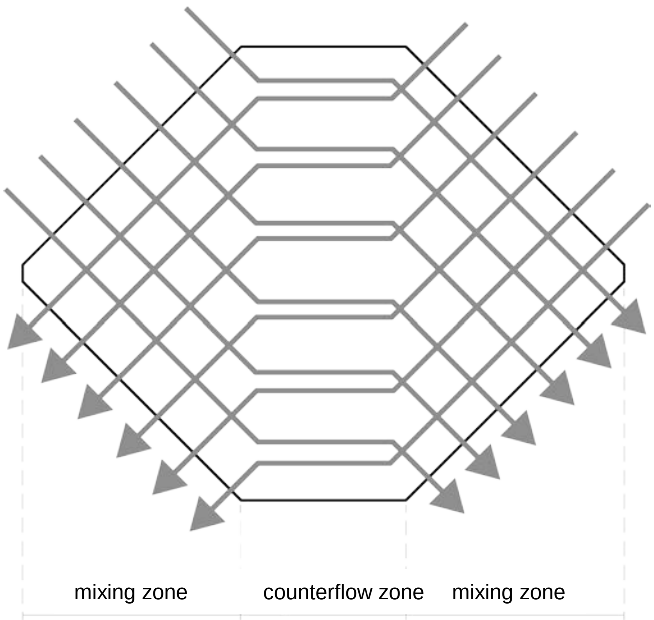

Figure 2: Mixing zone and counterflow zone

In the mixing zones, the flow corresponds more or less to the crossflow, whereas pure counterflow prevails in the middle part. The length of this middle part determines the output first and foremost. This means that it is always possible to achieve the required thermal efficiency of 0.73; higher values are not required/common. Calculating this arrangement is therefore complicated.

As the air flows must not mix with one another, the plates are made from one piece; this requires large tools and is consequently expensive. Using a counterflow heat exchanger is therefore only deemed to be economical when a crossflow heat exchanger with the same output cannot be used. In practice, this means that an air flow rate of approx. 1000 to 5000 m³/h can be covered, with a bit of a grey zone. Larger counterflow heat exchangers are currently not available on the market.

Counterflow heat exchangers are flatter (but longer) than crossflow heat exchangers, which is advantageous with small ventilation units.

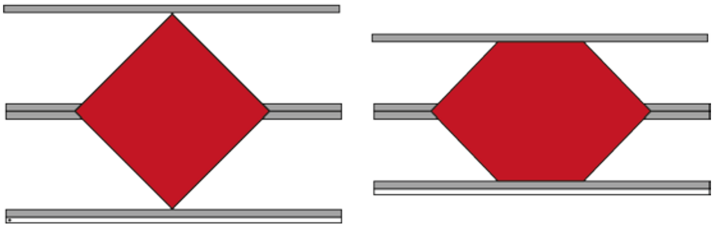

Figure 3: The counterflow heat exchanger is flat

The outlet temperature is almost consistent, which is beneficial as it reduces the risk of icing. As far as the air guide is concerned, the counterflow heat exchanger can be installed in a similar way to the crossflow heat exchanger. There are also similarities with regard to the bypass and condensate discharge.

Summary

The European Commission Regulation EU 1253 (2014) has meant that a thermal efficiency of at least 0.73 has been required for plate heat exchangers since 01.01.2018. This value cannot been achieved with crossflow heat exchangers in small ventilation units with a flow of up to approx. 3500 m³/h. One solution is to use counterflow heat exchangers, which can comply with the minimum thermal efficiency value in this air flow range. Apparently, it is currently not possible/advisable to use larger counterflow heat exchangers for air flow rates above 5000 m³/h for production reasons..

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