Heat recovery efficiency and pressure drop according to EU 1253

The European Regulation EU 1253-2014 limits the energy consumption of ventilation systems with a capacity greater than 250 m³/h for non-residential premises (NRVS). The reference configuration of the bidirectional ventilation system BVS is a casing with two fans, a heat recovery system HRS and one supply air and one exhaust air filter[1)] each. For these components, a minimum heat recovery efficiency (minimum HRE) is specified for the thermal power and the maximum permissible internal specific fan power $SFP_{int\ limit}$ is specified for the electrical power consumption of the fans. This is consistent and physically correct, but no longer gives a direct indication of the permissible pressure loss of the heat recovery system. This must now be determined for a specific system with the aid of the heat recovery efficiency η_t, the fan efficiency η_{fan} and the nominal air flow q_{nom}.

[1)] Since other typical components of ventilation systems – such as heating and cooling coils – are missing, it can be assumed that the overall philosophy is based on domestic ventilation. This makes some of the specifications easier to understand.

A clear target: The minimum HRE

Since 1.1.2018, a minimum HRE of 73% ($m_1 = m_2$, without condensation) has applied to plate heat exchangers according to EU 1253. Lower performance heat recovery is not permissible; a deficiency cannot be compensated by lower pressure losses. The regulation applies to all EU member states, but also sends a signal to other countries.

The efficiency bonus rewards higher HREs

The maximum permissible internal specific fan power $SFP_{int\ limit}$ is increased by the efficiency bonus E if the actual HRE exceeds the minimum value.

$E = (\eta_t - 0.73) * 3000$ [W / m³/s] (01)

Attention: If the minimum HRE of 0.73 is not reached, there is no bonus → E = 0!

The reason for this bonus is the assumption[2)] that a higher HRE also causes or requires a higher pressure loss. Therefore, 30 W/m³/s additionally consumed electrical power is allowed for each percent HRE increase. With a normal fan efficiency, this amounts to $\Delta p / \eta_{fan}$ = approx. 20 Pa additional pressure loss for heat recovery, i.e. approx. 10 Pa per air flow.

[2)] This consideration is controversial, since the increase in HRE is also possible by lower admission, i.e. lower pressure loss.

With the efficiency bonus, heat recovery can be optimized with regard to HRE and pressure loss. However, this always requires a profitability calculation to validate the advantage of higher performance. It is important to note that a high HRE is usually more expensive than a low one. In addition, due to the risk of freezing, high HREs cannot be fully utilised when they are needed, i.e. at low outside temperatures. It can therefore be expected that, in the long term, heat recovery units will be used that just meet the minimum requirement of 73%.

The electrical power consumed is limited

Whereas previously the pressure loss was directly combined with the heat recovery efficiency – e.g. in EN 13053 – Regulation EU 1253 limits the specific fan power of the reference configuration, which can be calculated with the internal pressure loss and the overall efficiency of the fans.

$SVL_{int} = \Delta p_{int} / \eta_{fan}$ (02)

$SVL_{int\ limit} = 1100 - 150 * q_{nom} + E - F$ (03) for $q_{nom} < 2\ m^3/s$

$SVL_{int\ limit} = 800 + E - F$ (04) for $q_{nom} \geq 2\ m^3/s$

It is interesting to note that the specification for nominal volume flows is subdivided into greater than and less than 2 m³/s. Presumably, this is intended to take account of the lower fan efficiency at low air outputs. However, if the high efficiency of EC fans is taken into account, it is questionable whether this measure is justified.

By specifying the specific fan power $SFP_{int\ limit}$, the device manufacturer and the plant manufacturer now have to take on responsibility. Only they are able to determine the fan efficiency η_{fan} required for the calculation on the basis of the components used. The permissible pressure loss of the heat recovery system can only be indicated with this. Physically this makes sense, but in practice it results in additional work, since iterative planning steps are necessary. A simple algorithm for the permissible pressure loss of the heat recovery would therefore make sense.

What is the permissible pressure loss?

According to the specified formulas, the permissible pressure drop of the reference configuration Δp_{int} depends on specified values for

- Nominal air flow q_{nom}
- Efficiency bonus E
- Filter correction F

and the assumptions for

- the overall efficiency of the fans η_{fan}
- the initial resistance of the filters Δp_F

The internal pressure drop Δp_{int} is the sum of the pressure losses of the heat recovery unit and the supply and exhaust air filters Δp_F.

$$\Delta p_{int} = \Delta p_{HRS} + \Delta p_F \qquad (05)$$

The overall efficiency η_{fan} of both fans takes account of the fan, motor, drive (e.g. belt) and open/closed-loop control (e.g. frequency converter). Since these values vary relatively widely in practice, especially for small output values, it is advisable to adopt a value that is validated in a standard or regulation. For example, European Regulation EU 327 can be used for this; it specifies target values for the overall efficiency of fans η_{target}. For free-blowing radial fans with backward curving blades, the following applies:

$$\eta_{target} = 0.0456 * \ln(P) + 0.515 \qquad (06)$$

P is the electrical power consumption in kW, which unfortunately does not match the volume flow-oriented EU 1253 with q_{nom} in m^3/s. However, a conversion is possible; the total fan pressure (i.e. with heating coil, duct, etc.) is assumed to be 600 Pa – the average value of supply and return air.

This produces the following:
$\eta_{fan} = 0.042 * \ln(q_{nom}) + 0.522$ (07)

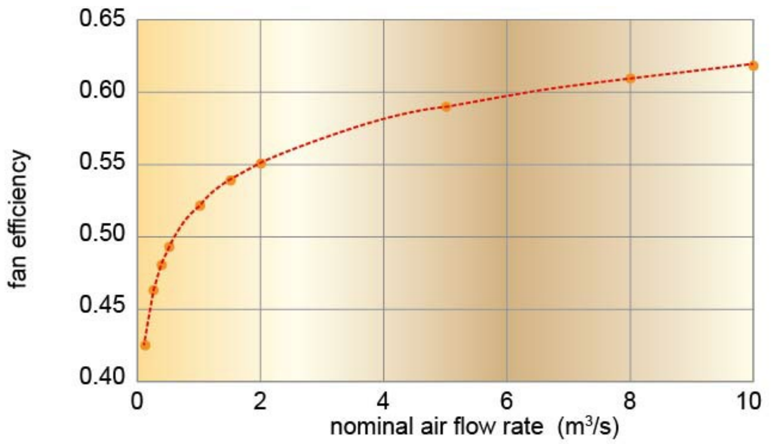

Image 1: Fan efficiency η_{fan} as a function of nominal air flow q_{nom}

The efficiency bonus E is already known from formula 01; it is only effective if the HRE is greater than 0.73. The filter correction F and the pressure drop of the filters depend on the configuration:

	Config. 1	Config. 2	Config. 3	Config. 4	
Fine filter	Yes	Yes	No	No	
Medium-fine filter	Yes	No	Yes	No	
Filter correction F	0	150	190	340	W/m³/s
Filter resistance	140	80	60	0	Pa

It is important to note that the filter correction F and the filter resistance are not identical and have different functions:

- The filter correction F is used for defining the $SFP_{int\ limit}$
- The filter resistance Δp_F requires a certain current consumption (and is measurable). The assumption was based on the approximate initial resistance according to Eurovent 4/21 for energy rating A.

With the assumptions and specifications, it is now relatively easy to obtain formulas that can be calculated/programmed.

For $q_{nom} < 2\ m^3/s$:

$$\Delta p_{HRS} = \eta_{fan} * [(1100 - 150*q_{nom}) + E - F] - \Delta p_F \qquad (08)$$

$$\Delta p_{HRS} = (0.042*\ln(q_{nom}) + 0.522)*[(1100 - 150*q_{nom}) + (\eta_t - 0.73)*3000 - F] - \Delta p_F \qquad (09)$$

For $q_{nom} \geq 2\ m^3/s$:

$$\Delta p_{HRS} = \eta_{fan}*[800 + E - F] - \Delta p_F \qquad (10)$$

$$\Delta p_{HRS} = (0.042*\ln(qnom) + 0.522)*[800 + (\eta_t - 0.73)*3000 - F] - \Delta p_F \qquad (11)$$

With the formulas 09 and 11, the permissible pressure drop $q\Delta p_{HRS}$ can be calculated for each nominal air flow q_{nom} and displayed in a diagram. Diagram 2 shows such a procedure, although the following should be pointed out:

- The pressure loss applies to the two extreme results:
  - Configuration 1 with both filters; this is the most common variant in practice.
  - Configuration 4 without filter generally has lower values.
- The curves for configurations 2 and 3 (one filter each) run approximately in the middle between configurations 1 and 4. They are not shown here to make the diagram clearer (and since they are of no practical significance).
- The pressure loss is valid for the minimum HRE of 0.73. For higher HRE the permissible pressure loss also increases Δp_{HRS} (by approx. 20 Pa/%).

- The permissible pressure loss Δp_{HRS} applies to the entire heat recovery system, i.e. supply and exhaust air together.
- The assumptions for fan efficiency η_{fan} and the filter pressure loss Δp_F can be corrected if the real values are known.
- The power limitation of 10 kW for the target efficiency (formula 06) does not have to be taken into account in this calculation.

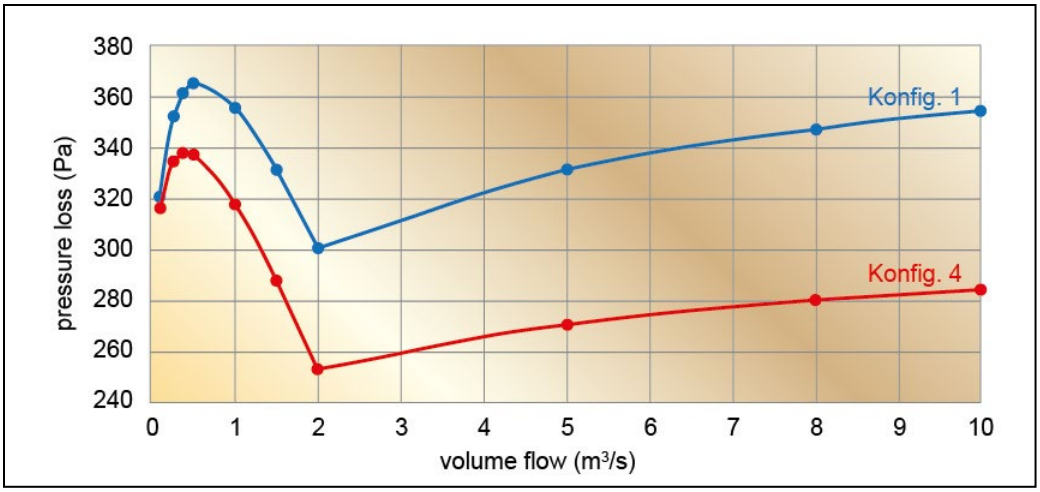

Image 2: Permissible pressure loss of the heat recovery system as a function of the nominal air flow rate

The curves of the two function branches for nominal air outputs greater than and less than 2 m^3/s are very different. At low air flow rates, the correction for fan efficiency has a very or excessively significant effect, which leads to this steep characteristic curve with a maximum of approx. 0.5 m^3/s. In contrast, the values for air outputs ≥ 2 m^3/s show the constant influence of increasing fan efficiency.

The results can also be approximated as a function of the nominal air flow q_{nom}. The following applies to configuration 1 with a HRE of 0.73, for example:

For $0.1 < q_{nom} < 2.0\ m^3/s$

$$\Delta p_{HRS} = - 48.849 \cdot q_{nom}^4 + 246.27 \cdot q_{nom}^3 - 453.53 \cdot q_{nom}^2 + 315.44 \cdot q_{nom} + 295.49 \qquad (12)$$

with a representation accuracy of 0.995

For $q_{nom} \geq 2.0\ m^3/s$

$\Delta p_{HRS} = 33.6*\ln(q_{nom}) + 277.6$ (13)

with representation accuracy 1.0

Similarly, such formulas can also be created for the other configurations with different boundary conditions.

If no information about the system concept or the boundary conditions is available, the permissible pressure loss of the heat recovery system can be estimated at 340 Pa, as a rule of thumb.

Summary

European Regulation EU 1253 limits the energy consumption of heat recovery systems by specifying a minimum heat recovery efficiency and the maximum specific current consumption of the fans. The permissible pressure loss required for the design of the heat recovery system is not directly apparent. This can, however, be calculated with the assumption of the fan efficiency η_{fan} and the filter pressure loss Δp_F. Appropriate formulas can be created for each filter configuration and boundary condition.

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