Leakage characteristics according to VDI 3803 Sheet 5

The transfer of partial mass flows from one air flow to the other is referred to as (internal) leakage. It is caused by leaks as a result of a pressure difference (seal leakage) or is function-related, such as the co-rotation of a rotor. While the leakage in plate heat exchangers, heat pipes and common circulation systems is so small as to be negligible, it can lead to significant changes in the nominal mass flows in rotary heat exchangers and changeover accumulators; this must be taken into account during planning and implementation. This is pointed out in the guideline VDI 3803 sheet 5. At the same time, key figures are defined to indicate the size and type of leakage.

Leakage has many effects

Due to the internal leakage, the mass flows of extract air/exhaust air and outside air/supply air are changed; the planned values (= without leakage) are no longer achieved. This has many effects:

- The extract air and outside air mass flows must be corrected in such a way that the necessary and therefore planned supply air and exhaust air volumes (= without leakage) are achieved. This seems to be a matter of course, but is hardly ever done – even today.
- Increased air output of the fans
  To achieve the nominal outputs of extract air and supply air, at least one fan, but often both depending on the fan arrangement, must additionally convey the leakage. This means more drive power and therefore higher power consumption. It therefore makes sense to select larger flow cross-sections in the ventilation unit and in the ducts in order to reduce pressure losses and thus operating costs.
- Reduced supply air quality
  If there is a transfer/leakage from the extract air to the supply air, the quality of the supply air can be impaired. This is pointed out in VDI 6022 sheet 1: "If such a transfer cannot be excluded, these heat recovery systems are only allowed to be used if the use of circulating air in the system is also hygienic".
- Modified heat recovery data
  Due to the leakage, the configuration conditions of the heat recovery unit and thus its technical data (temperature efficiency, pressure loss) are modified. In order to take this into account, however, not only the size but also the location of the leakage

currents must be known. This leads to problems in practice, so that a simplified model makes sense. **It is assumed that all leakages upstream of the heat exchanger – seen in the direction of flow of the emitting stream – are transmitted.** The resulting error is acceptable.

Because of these effects, the leakage must be kept as small as possible; the planner can make a decisive contribution to this through a low pressure loss (from the outside air to the exhaust air) and the heat recovery system manufacturer through high-quality sealing systems. Using the rotary heat exchanger as an example, an attempt will be made to explain the complex transmission mechanism of the leakage. This also applies as a corollary to the changeover accumulator, where the dampers correspond to the seals (seal leakage) and the air volume of the accumulator to the co-rotation (functional leakage).

Seal leakage

The rotor is sealed on both sides (air inlet and outlet) towards the housing. A transverse seal is installed on the separator web and a radial seal on the rotor circumference, but these cannot completely prevent seal leakage. This depends on the pressure difference, the rotor diameter, the type of seal, the rotor quality (runout = the rotor does not run exactly flat in axial and radial directions) and the adjustment of the seal (maintenance).

m_{D1-2} = Seal leakage from extract air to supply air (kg/h)

m_{D2-1} = Seal leakage from the outside air to the exhaust air (kg/h)

The direction of transmission is determined by the pressure loss; ideally it should go from the outside air to the exhaust air to prevent transmission from the extract air to the supply air (Figure 1).

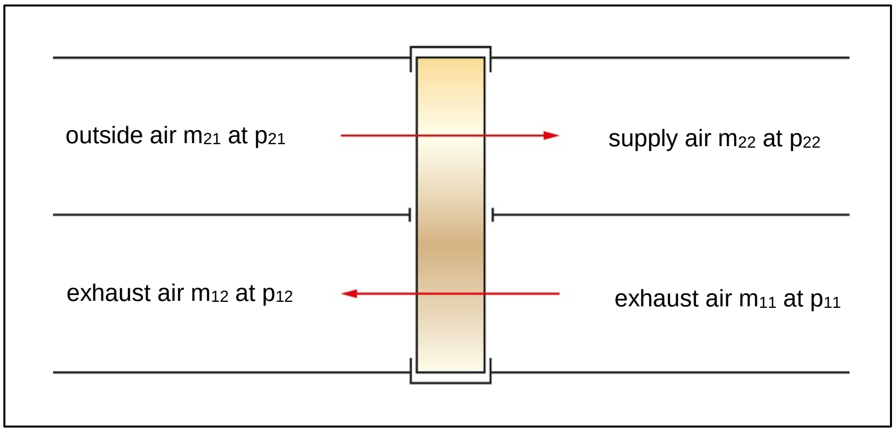

Figure 1: Mass flows and pressures at the rotor

1. Index
   - 1 = Extract air, exhaust air
   - 2 = Outside air, supply air
2. Index
   - 1= Inlet into the heat recovery unit
   - 2 = Outlet from the heat recovery unit

There are differences with regard to sealing quality:

- Sliding seal
  The radial seal, e.g. made of plastic, is movably mounted and thus continuously slides on the rotor; there is no gap despite the (unavoidable) runout of the rotor. The maintenance effort is therefore very low and the effect is constant.
- Fixed seal
  The seal made of a plastic or rubber section is installed as close as possible to the rotor, so it just touches the rotor at the greatest runout. Due to the design, this always results in a (small) gap, which increases the leakage compared to the sliding seal. The maintenance effort is low and the effect is constant.
- Brush seal
  This seal is usually set so that the flexible brush (usually with additional plastic band) absorbs the rotor runout. During operation, however, there is still a gap due to wear. Ongoing maintenance/adjustment is therefore necessary.

Normal values for seal leakage at medium diameter and well-adjusted seal are 2 – 8 % of mass flow. With low sealing quality and/or poor maintenance (setting), the values can increase 2 – 3 times. The pressures p11, p12, p21, p22 must be known to determine the seal leakage.

Functional leakage (e.g. co-rotation)

For functional reasons, air is rotated from one air stream to the other as it flows through the rotor; this is called co-rotation. It depends only on rotor speed, rotor diameter and rotor depth, and therefore not on pressure difference. With a rotor depth of 200 mm, an air density of 1.2 kg/m3 and neglecting the storage volume, the following applies:

$m_{F1\text{-}2} = 11.3 * n * d^2$

$m_{F2\text{-}1} = 11.3 * n * d^2$

$m_{F1\text{-}2}$ = Functional leakage from the extract air to the supply air (kg/h)
$m_{F2\text{-}1}$ = Functional leakage from the outside air to the exhaust air (kg/h)
n = Rotor speed in rpm
d = Rotor diameter in m

It can be seen that the co-rotation occurs twice in the rotor - in equal amounts:

- once from the extract air to the supply air
- once from the outside air to the exhaust air

Usual values for a speed of 10 rpm are 2 – 4% of the mass flow, for a speed of 20 rpm the values are 4 – 8%. Under suitable pressure conditions (pressure drop from p22 to p11), the transfer to the supply air can be prevented by a purge chamber; $m_{F1\text{-}2}$ then becomes zero. However, the rinsing chamber must be dimensioned exactly for the application. The co-rotation on the exhaust air $m_{F2\text{-}1}$ remains unchanged. (If pressure conditions are unsuitable, auxiliary fans can be used which ensure the function but require additional investment and operating costs.)

Total leakage

The seal leakage and the functional leakage together result in the total leakage from one airflow to another:

$m_{1\text{-}2} = m_{D1\text{-}2} + m_{F1\text{-}2}$	Recirculation air leakage from extract air 1 to supply air 2
$m_{2\text{-}1} = m_{D2\text{-}1} + m_{F2\text{-}1}$	Short-circuit leakage from outside air 2 to exhaust air 1

Both opposite leakages occur simultaneously, but not in the same place; they must therefore not be set off against each other. This is important in the case of co-rotation on both sides. In order to obtain a clear and comprehensible representation, it is assumed that the leaks are transmitted in front of the rotor (seen from the emitting air stream)

(Figure 2). This is not entirely correct, but avoids complex calculations and still provides sufficiently accurate results.

Leakage figures

Two leakage figures are defined which indicate the mass flows in relation to leakage-free operation:

$L_1 = m_{11} / (m_{11} - m_{1\text{-}2}) = m_{11} / m_1$ Leakage figure exhaust air

$L_2 = m_{21} / (m_{21} - m_{2\text{-}1}) = m_{21} / m_2$ Leakage figure outside air

m_1 = Leakage-free exhaust air flow

m_2 = Leakage-free outside air flow

In addition, the circulating air figure U describes the proportion of circulating air in the supply air:

$U = m_{1\text{-}2} / (m_{21} - m_{2\text{-}1}) = m_{1\text{-}2} / m_2$ Circulating air figure

With these three key figures, a heat recovery unit can be comprehensively defined in terms of leakage; the values should always be given as a specification.

Configuration corrections

With the known leakages, the outputs of the fans must be corrected in such a way that the planned values for exhaust air and outside air are achieved.

$m_{11} = m_1 + m_{1\text{-}2}$

$m_{12} = m_1 + m_{2\text{-}1}$

$m_{21} = m_2 + m_{2\text{-}1}$

$m_{22} = m_2 + m_{1\text{-}2}$

Here (as a rule) the leakage-free air flows are planner's data and the leakages are data from the heat recovery unit manufacturer. In order to ensure the necessary outputs, the effects of the leakages must be compensated:

- Assuming that the leakages are transferred before the heat recovery unit, the heat recovery unit (temperature efficiency, pressure loss) can be designed with the leakage-free air outputs m1 and m2. The resulting slight deviations from the real values are justifiable.

- For the fans, the actual air flows must be taken into account (pressure losses, power consumption).

Default values

If no project-specific data is available at the time of design, the leakage-free flows for exhaust air m1 and outside air m2 must be increased by 10% each. The examples show that these are values that are perfectly in line with actual practice. If extract air is transferred into the supply air through the leakage, it must be pointed out that rotary heat exchangers are only allowed to be used if the specifications according to VDI 6022 sheet 1 are observed.

Examples

The three fan arrangements common in practice in HVAC systems are assessed with regard to leakages.

a) Extract air fan pushes – supply air fan sucks in

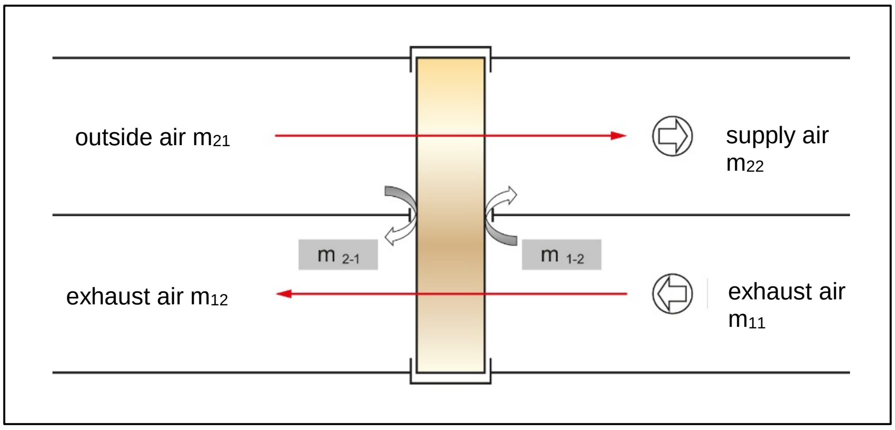

Figure 2: Extract air fan pushes – supply air fan sucks in

This arrangement is the dominant one in Germany; most systems are designed in this way.

With regard to the use of a rotor, the following should be noted for this arrangement:

- Compact design of the ventilation unit
- Low pressure differential → Low seal leakage
- Pressure drop to supply air → Seal leakage to supply air

- Contamination of the supply air
- No purge sector possible

Conclusion: Due to the unavoidable co-rotation as a result of the pressure constellation, the air circulation m_{1-2} is relatively large at 5 – 10% despite the small pressure differential. Both fans must deliver an air output that is higher by the amount of leakage.

b) Outside air fan pushes – exhaust air fan sucks in

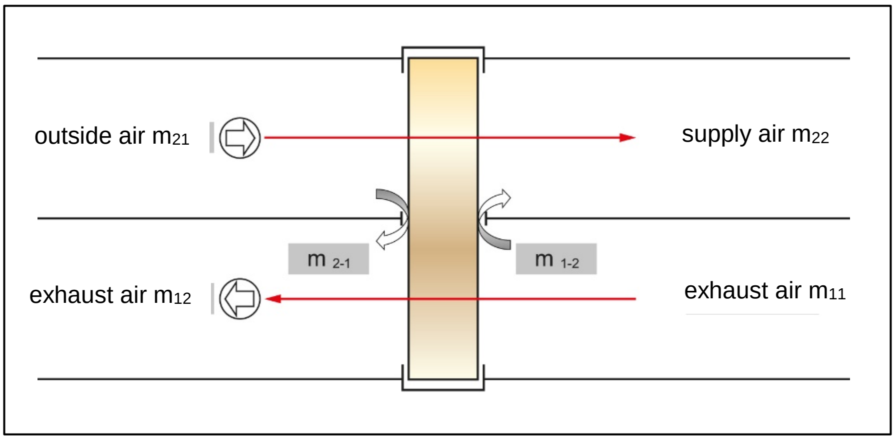

Figure 3: Outside air fan pushes – exhaust air fan sucks in

In this arrangement, no seal leakage into the supply air is possible; however, the pressure differential is high. With regard to the use of a rotor, the following should be noted for this arrangement:

- Compact design of the ventilation unit
- Pressure drop to exhaust air → Seal leakage to exhaust air
- Purge sector is possible → $m_{F1-2} = 0$
- No contamination of the supply air
- High pressure differential → High seal leakage
- High seal quality required

Conclusion: Due to the flushing zone there is no co-rotation m_{F1-2} and thus no recirculation air leakage m_{1-2}. However, the short-circuit leakage m_{2-1} is quite high at 7 - 17 % due to the large pressure differential. Both fans must deliver an air output that is higher by the amount of leakage.

c) Supply air fan sucks in – exhaust air fan sucks in

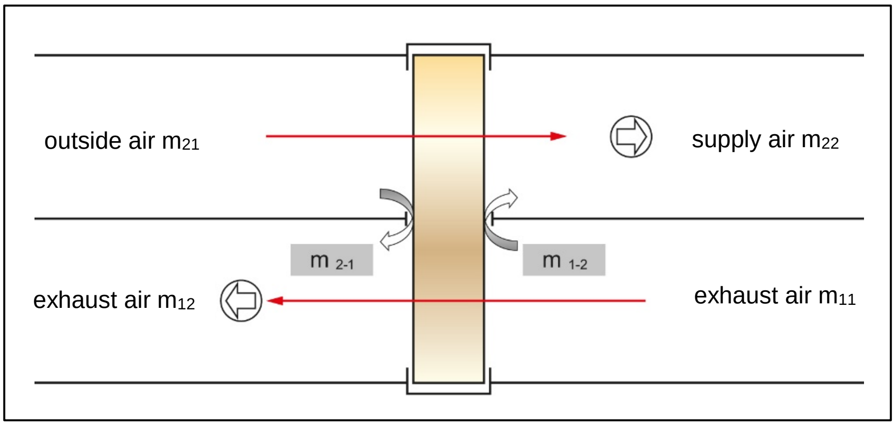

Figure 4: Outside air fan sucks in – exhaust air fan sucks in

Also with this arrangement, a pressure drop to the exhaust air usually occurs; in comparison to b), however, the pressure differential is relatively small.

With regard to the use of a rotor, the following should be noted for this arrangement:

- Pressure drop to exhaust air → Seal leakage to exhaust air
- No contamination of the supply air
- Low pressure differential → Low seal leakage
- Purge sector is possible → $m_{F1-2} = 0$
- Requires a lot of space

Conclusion: Due to the flushing zone there is no co-rotation m_{F1-2} and thus no recirculation air leakage m_{1-2}. The short-circuit leakage m_{2-1} is relatively low at 5 - 10% due to the small pressure differential. Only the exhaust air fan must deliver an air output that is higher by the amount of leakage.

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