Eurovent Industry Recommendation / Code of Good Practice

Eurovent 6/15 - 2021

Air Leakages in Air Handling Units: Guidelines for Improving Indoor Air Quality and Correcting Performance

First Edition

Published on 17 February 2021 by
Eurovent, 80 Bd A. Reyers Ln, 1030 Brussels, Belgium
secretariat@eurovent.eu

Document history

This Eurovent Industry Recommendation / Code of Good Practice supersedes all of its previous editions, which automatically become obsolete with the publication of this document.

Modifications

This Eurovent publication was modified as against previous editions in the following manner:

Modifications as against	Key changes
1st edition	Current document

Preface

In a nutshell

This Recommendation sets out the principles of good practice to limit the internal air leakage in bidirectional air handling units, notably those fitted with a rotary heat exchanger. It outlines the most important measures to be considered in the design and setting of a unit to minimise the leakage. The recommendation also presents guidelines on how to correct the declared performance due to leakages. Eurovent holds that these guidelines should become a common industry standard. The potential magnitude of internal leakage rates resulting from incorrect unit design and the corresponding consequences are also discussed.

Authors

This document was published by the Eurovent Association and was prepared in a joint effort by participants of the Product Group 'Air Handling Units' (PG-AHU) and the Product Group 'Energy Recovery Components' (PG-ERC), which represents a vast majority of all manufacturers of these products active on the EMEA market. Particularly important contributions have been provided by Gunnar Berg (editorial team leader), Hashim Alsadah, Bohumil Cimbal, Viktor Levickij, Igor Sikonczyk, Timo Schreck and Ernst-Peter Wachsmann.

Copyright

Suggested citation

Eurovent AISBL / IVZW / INPA. (2021). Eurovent 6/15 - 2021 - Air Leakages in Air Handling Units: Guidelines for Improving Indoor Air Quality and Correcting Performance. Brussels: Eurovent.

Important remarks

The Eurovent Association does not grant any certification based on this document. All certification-related issues are managed by the association's independent subunit Eurovent Certita Certification in Paris. For more information, visit www.eurovent-certification.com.

Contents

List of abbreviations and symbols

AHU	Air Handling Unit
EATR	Exhaust Air Transfer Ratio expressed in % (ratio between the exhaust air amount in supply air and supply air mass flow)
EHA	Exhaust Air (airflow leaving the extract air treatment system and discharged to the atmosphere)
ERC	Energy Recovery Component
ETA	Extract Air (airflow leaving the treated room and entering the air treatment system)
IAQ	Indoor Air Quality
OACF	Outdoor Air Correction Factor (ration between ODA and SUP mass flows)
ODA	Outdoor Air (airflow entering the system from outdoors before heat recovery)
PG-AHU	Eurovent Product Group 'Air Handling Units'
SUP	Supply Air (airflow entering the treated room after heat recovery)

Additional clarification of terms used in the text

'Supply air stream' means outdoor and supply airflow.

'Exhaust air stream' means extract and exhaust airflow.

Referred standards and regulations

[1] EN 13053 - Ventilation for buildings - Air handling units - Rating and performance for units, components and sections

[2] EN 16798-3 - Energy performance of buildings - Ventilation for buildings - Part 3: For non-residential buildings - Performance requirements for ventilation and room-conditioning systems

[3] EN 1886 - Ventilation for buildings - Air handling units - Mechanical performance

[4] prEN 308 - Heat exchangers - Test procedures for establishing performance of air to air and flue gases heat recovery devices

[5] Commission Regulation (EU) No 1253/2014 of 7 July 2014 implementing Directive 2009/125/EC of the European Parliament and of the Council with regard to ecodesign requirements for ventilation units

Foreword

In the vast majority of systems, ventilation is associated with the transport of air. During transport, the problem of air loss or uncontrolled air mixing due to leakages may occur. Leakages occur in different parts of the ventilation system. A significant share of them can be found in the ductwork. Another part of leakages is attributable to the air handling unit (AHU) and in particular to its energy recovery component (ERC).

Air leakages lead to a considerable waste of energy consumed for moving the redundant air that does not serve for ventilation purposes. The fan must generate pressure that includes the increased pressure drops due to the leakages. Besides energy waste, air leakages cause a deterioration of Indoor Air Quality (IAQ), which has a negative impact on the health and well-being of building occupants.

This Recommendation covers the AHU-related leakages and primarily focuses on the internal leakage (between supply and exhaust sides of bidirectional units) in heat recovery sections. The external leakages (through the casing) and filter by-pass leakage are only briefly outlined. Leakages in the ductwork are not covered.

Of the different types of heat recovery components, rotary heat exchangers offer several advantageous features including a truly counterflow heat transfer arrangement, high efficiency of heat and moisture recovery, low pressure drop and low sensitivity to freezing. But rotary exchangers are most prone to internal leakage. According to Eurovent Market Intelligence statistics, 44% of AHUs in the European market are fitted with a rotary heat exchanger. Proper care must be taken to eliminate the leakage, in order to save energy and preserve IAQ.

This Recommendation provides comprehensive guidance on measures to minimise and adequately compensate for leakages.

1 The 'air leakages' problem

Most HVAC planners and contractors are aware of air leakages associated with AHUs. Not all of them consider these leakages when designing the system. Even fewer realise how large these leaks can be if the AHU is not designed properly and what are the related consequences. This chapter provides a consistent overview of the types of leakage and their effects. It also discusses the status of current formal requirements for internal leakages.

1.1 Kinds of leakages

There are different types of air leakages associated with AHUs. Whereas this Recommendation focuses on the internal leakages, the other kinds of leakages must be considered in the product assessment as well.

1.1.1 Internal leakages across heat exchanger and AHU casing

Internal leakages are unwanted air transfers from the exhaust air stream into the supply air stream and vice-versa. This type of leakage can occur only in bidirectional ventilation units. They typically occur inside the AHU but also can occur outside the unit in case of wrong ductwork installation (e.g. the exhaust and outdoor air intakes are too close to each other).

1.1.2 External leakages

External leakages are unwanted air transfers from inside the AHU to outside (positive leakages) and vice-versa (negative leakages). Both bidirectional and unidirectional ventilation units are affected by this type of leakages. External leakages mostly depend on the quality of the AHU casing.

In both cases (positive or negative leakages), depending on the location of the AHU and the ambient air quality, such leakages can lead to a problem with IAQ. External leakages also cause a problem with energy lost on air volume, heat or cold.

1.1.3 Filter by-pass leakage

Filter by-pass leakage is unwanted untreated air transfer into the treated air bypassing filter media. Depending on the filter location inside the AHU, high filter by-pass leakage has two negative consequences: lower IAQ and unprotected internal AHU components. Filter by-pass leakage depends on the construction quality of the filter frame.

1.1.4 Leakage between ODA inlet and EHA outlet

Exhaust air can contaminate the supply air also outside the building. This can happen when the ODA inlet and the EHA outlet are too close to each other, when exhaust air flows are directed wrongly, or when wind directs the exhaust air to the supply air intake. This shortcut of airflows is not directly a leakage but will contaminate supply air in similar ways as internal leakages. Therefore, it needs to be considered and excluded when looking into problems of supply air contamination in ventilation systems.

1.2 Negative consequence of external and internal leakages

Incorrect design of the pressure distribution in a unit (notably due to the arrangement of the fans), low leak tightness of the casing, or poor quality of workmanship lead to negative consequences in terms of energy consumption, hygiene, and IAQ. In the worst case, leakages might hinder meeting the designed performance.

1.2.1 Impact of leakages on energy consumption

Positive external AHU leakages through the casing lead to a waste of energy. For example, heated or cooled air inside the AHU can leak out rather than serving the designated area. Negative external AHU leakages through the casing also lead to waste of energy. For example, warm air surrounding the AHU enters the unit, negatively affecting cooling efficiency in summer.

To maintain the required IAQ (see below), both internal and external leakages need to be compensated for by increased outdoor air flow. There are higher pressure losses in AHU components and the ductwork, which in turns means higher energy consumption. Air flow increases change the fan working point and fan efficiency, and, in most cases, also leads to higher energy consumption. So even if the ventilation unit might still be able to deliver the required rate of fresh air into the building, airflow must be generated that includes not only the effectively supplied fresh air but also the air wasted on leakages.

1.2.2 Deterioration of IAQ

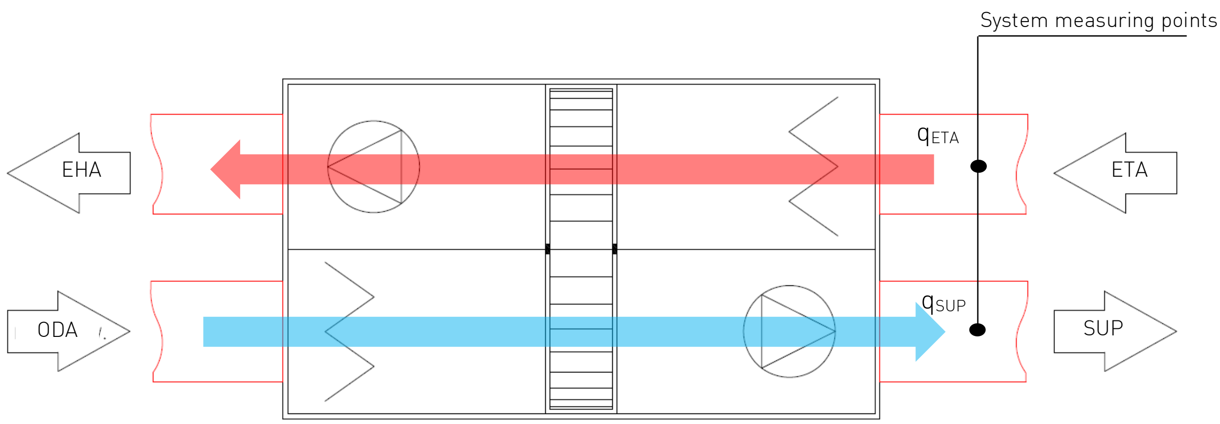
Positive external leakages can cause air that is being extracted from a polluted room (e.g. sceptic operating room or a morgue in a hospital) to leak into, and thereby pollute, the room in which the AHU is located. In the case of negative external leakages, pollutants can be sucked into the AHU from its surroundings and contaminate the air that is distributed to the building.

Depending on the quality of the extract air and the filter location inside the AHU, internal leakages and filter by-pass leakages can lead to contaminated air being supplied to the building as well.

2 References to leakages in regulations and standards

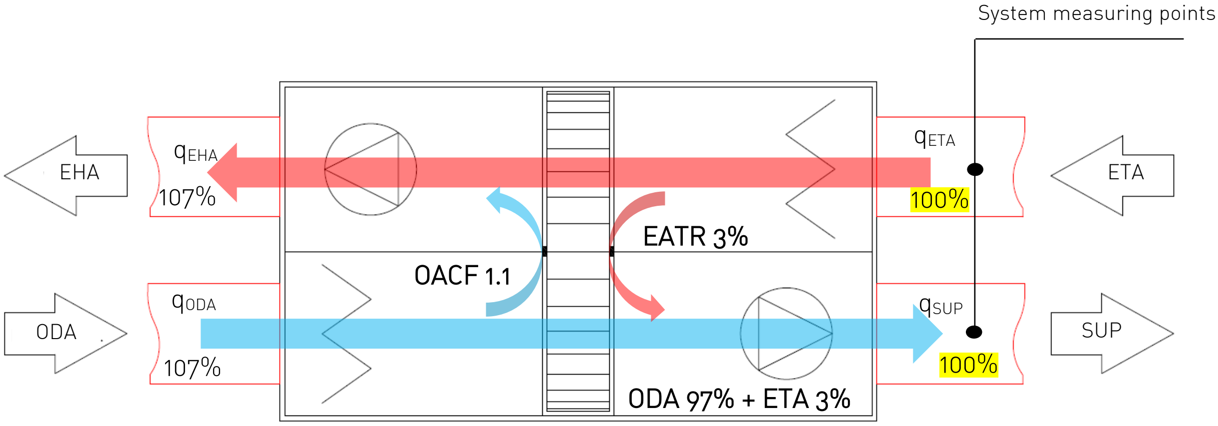
As stated above, leakages lead to a waste of energy and can cause a deterioration of IAQ. Although the problem is significant in case of incorrect design, it is not always well recognised by HVAC system planners and manufacturers of AHUs.

Usually, it is assumed that the nominal flow rate of the AHU is equal to the required design outdoor flow rate, specified by the system planner. As long as the internal leakage is negligible, this premise is correct. Yet, if the internal leakage is relatively high (typical for units with regenerative heat exchangers), the discrepancies cannot be ignored. The following two figures illustrate the problem:



premise: $q_{SUP} = q_{ODA}$ and $q_{ETA} = q_{EHA}$

Figure 1. Typical current approach. No consideration of internal leakages and their impact on energy consumption and IAQ



Due to internal leakages: $q_{ODA} \neq q_{SUP}$ and $q_{ETA} \neq q_{EHA}$

Figure 2. Real unit. Internal leakages affect energy consumption and IAQ

As Figure 2 shows, in a real unit, due to leakages, the outdoor air flow rate might be considerably lower than the air flow effectively supplied into the building. Moreover, the leakages cause increased flow in some parts of the unit, which in turn leads to higher energy consumption.

2.1 EN standards

The subject matter of internal leakages within the AHU is superficially addressed in a few EN standards.

The issue of leakages in heat recovery sections is raised in EN 16798-3, which deals with the design of ventilation and air condition systems. The standard provides general definitions of Exhaust Air Transfer ratio (EATR) and Outdoor Air Correction Factor (OACF), as well as the classification of OACF in heat recovery systems.

EN 13053, which specifies requirements and testing for rating and performance of air handling units, imposes on the manufacturer responsibility for avoiding leakages from the extract air stream to the supply air stream during the test of a unit with heat recovery. The EATR and OACF factors are expected to be addressed profoundly only in the upcoming revised EN 308.

However, the abovementioned standards are not harmonised in EU legislation and compliance with them is not mandatory. Moreover, they do not provide any requirements regarding internal leakages nor any testing method that might be applied by market surveillance authorities.

2.2 Building codes

Binding requirements for maximum leakage rates can be found in building codes of some EU member states. For instance, the Polish regulation concerning building technical requirements and building localisation (Journal of Laws 2002 No. 75 pos. 690 as amended) requires a max. leakage of extract air to supply air at 400 Pa for rotary heat exchanger of 5%, and a max. leakage of extract air to supply for plate heat exchanger of 0.25%. The Finnish regulation of the Ministry of the Environment on the indoor climate and ventilation of new buildings imposes an obligation on the designer to plan the heat recovery so as to avoid impurities or odours which are detrimental to health or well-being from being spread via the heat recovery.

Nevertheless, requirements of individual member states are not always consistent, apply locally and do not conduce to tackling the problem at the EU level.

2.3 Ecodesign Regulation

The Ecodesign Regulation for Ventilation Units (1253/2014) in force at the time of writing does not address requirements for air leakages either. However, it does define the purpose of a ventilation unit in Article 2, Definitions (1); 'to replace utilised air by outdoor air'. This purpose is undermined by leakages, as is the objective of the regulation to save energy.

3 Available indicators and test methods for internal leakage

3.1 Exhaust Air Transfer Ratio (EATR) and Outdoor Air Correction Factor (OACF)

At present, the most established factors for characterising internal leakages are EATR and OACF. Both factors are defined in EN 16798-3 and are under revision in prEN 308. Moreover, they have been adopted in the Eurovent Certita Certification performance tests for a long time.

For the time being, EATR and OACF are basically applicable to rotary heat exchangers and cover leakages within the component. However, ongoing works on the revision of EN 308 in CEN/TC 110 aim to extend their scope of application.

3.1.1 OACF

Outdoor Air Correction Factor (OACF) is a ratio between (i) outdoor air (ODA) and (ii) supply air (SUP) mass flows. It defines the sum of all leakages between supply and exhaust air. If the OACF is bigger than 1, the sum of these leakages is from supply air to exhaust air. If the OACF is smaller than 1, the sum of leakages is from exhaust to supply air. OACF is expressed as a function of pressure difference ($p_{22} - p_{11}$).

OACF gives a general value of the internal leakages, with indication of the main flow direction, but it is not explicit of the character of the leakage.

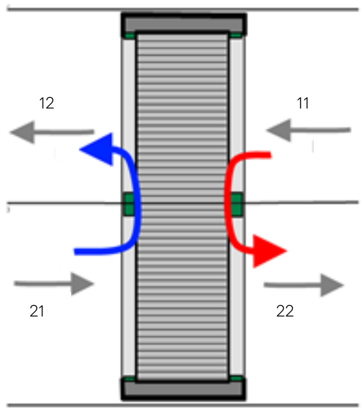


Figure 3. Leakages across the rotor may occur in both directions

3.1.2 EATR

Exhaust Air Transfer Ratio (EATR) is a ratio between (i) the exhaust air amount in supply air, and (ii) the supply air mass flow. It describes the level of contamination of supply air by extract air. EATR is expressed as a function of pressure difference ($p_{22} - p_{11}$),

3.1.3 Correlation of OACF and EATR

OACF and EATR are correlated so that when OACF is below 1.0-1.05, the EATR increases rapidly. When the OACF is high, the EATR decreases asymptotically to 0%. When OACF values are under 0.95, the EATR is also bigger than 5%. Figure 4 shows a typical OACF and EATR relation in function of pressure difference between supply and exhaust air ($p_{22} - p_{11}$).

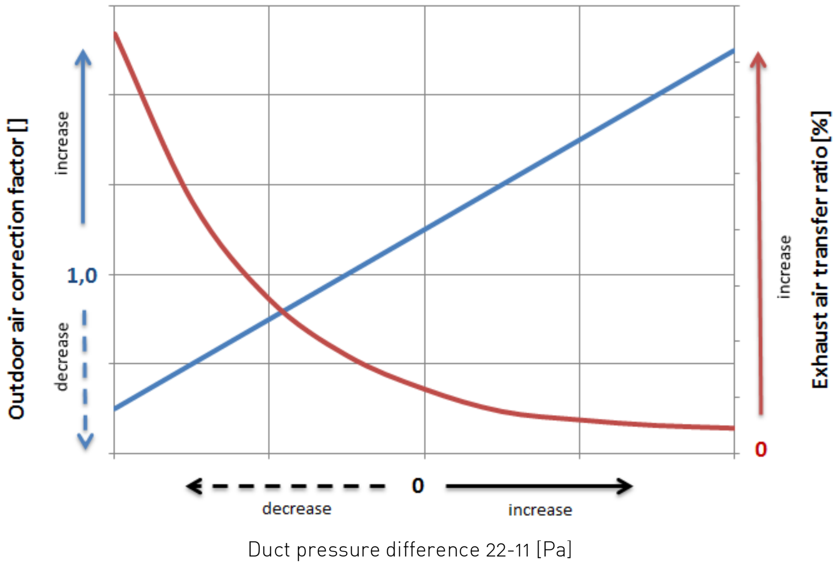
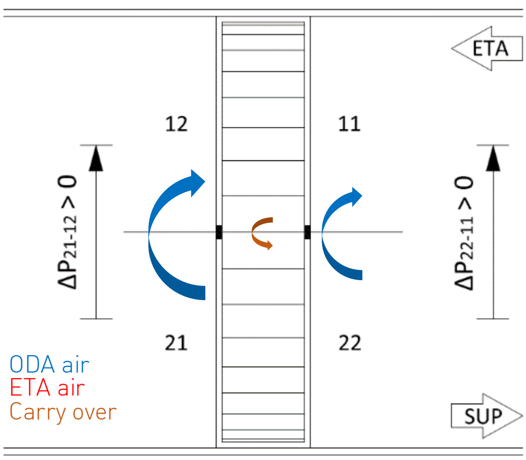


Figure 4. OACF and EATR relation in function of pressure difference

General behaviour of leakages depending on EATR and OACF as a function of $\Delta P_{22\text{-}11}$ at equal SUP/ETA airflows and without consideration of purge sector is illustrated in Figure 5 to Figure 7.

3.1.3.1 Behaviour at positive $\Delta P_{22\text{-}11}$

At both sides of the rotor, pressure relations are positive. Leakage direction is always from the supply air side to the exhaust air side. A small amount of exhaust air carryover is possible.



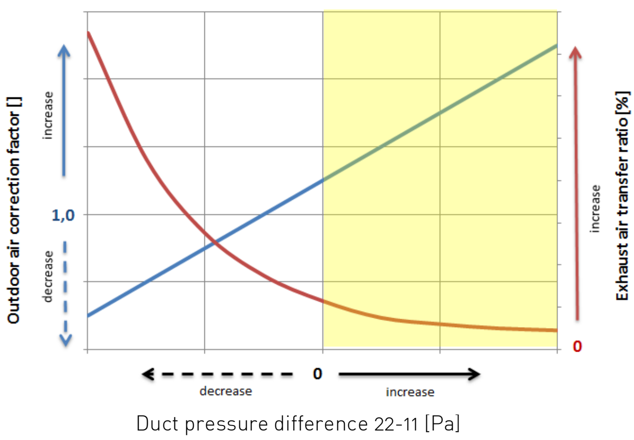


Figure 5. Behaviour of internal leakages at positive $\Delta P_{22\text{-}11}$

3.1.3.2 Behaviour at ΔP_{22-11} equal or close to zero

Pressure difference p_{22} - p_{11} is equal or close to zero. There is no leakage on the building side of the exchanger. The pressure difference p_{21} - p_{12} is positive. A leakage from supply to exhaust occurs on the outdoor side of the rotor. A small amount of exhaust air carryover is possible.

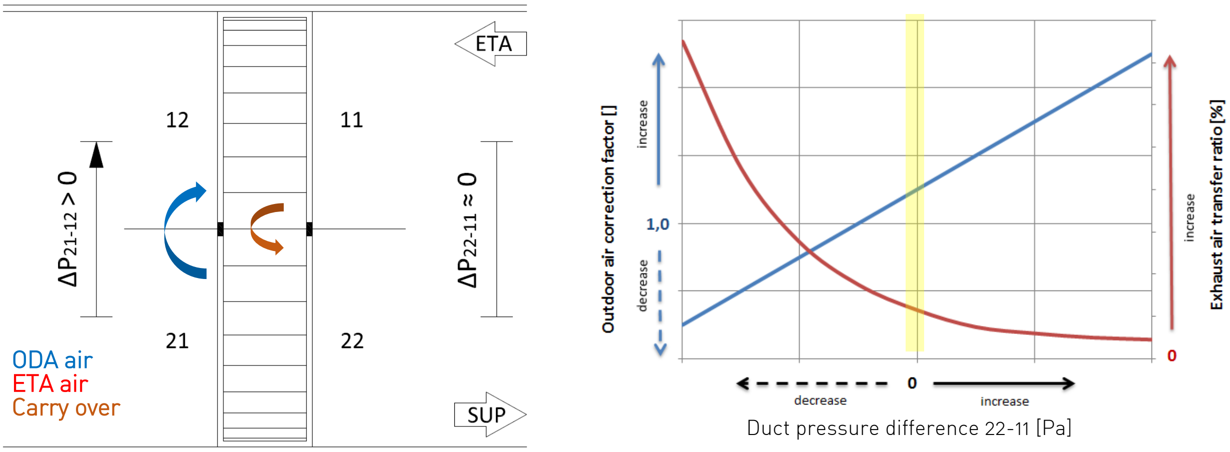


Figure 6. Behaviour of internal leakages at ΔP_{22-11} close to zero.

3.1.3.3 Behaviour at negative ΔP_{22-11}

The pressure difference on both sides of the wheel is negative. Exhaust air leaks on both sides to the supply air side. Additional small amounts of exhaust air carryover take place.

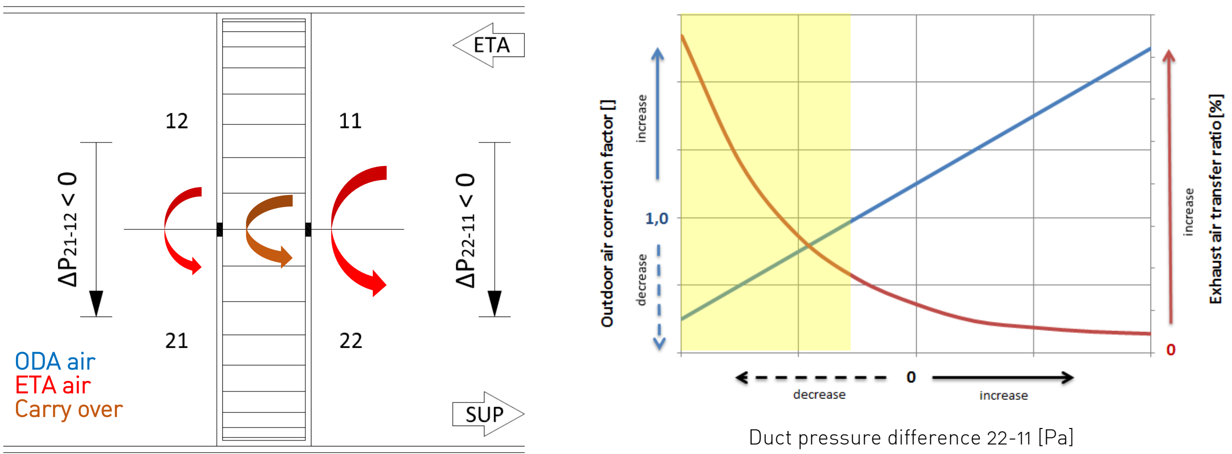


Figure 7. Behaviour of internal leakages at negative ΔP_{22-11}

3.1.3.4 Typical OACF values and influencing factors

Internal leakage is a function of pressure differences between supply and exhaust air, rotor diameter, sealing design and condition, purge sector, rotation speed, and some other less important parameters. With small rotors, internal leakages are relatively higher than bigger rotors. With 250 Pa pressure difference Δp_{22-11}, the OACF values vary mostly between 1.12 and 1.2 (extreme values down to 1.05 and up to 1.3) with 1000 mm rotors, settling to 1.08-1.16 (one supplier 1.03) with 2000 mm rotors.

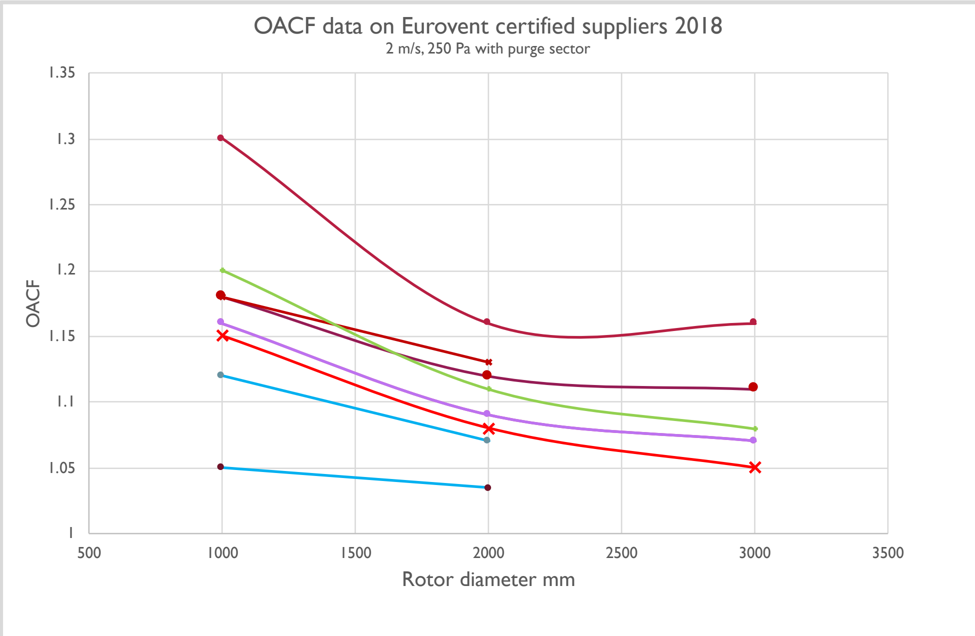


Figure 8. Typical OACF values from Eurovent certified suppliers

OACF drops below 1 when the pressure difference Δp_{22-11} goes below -100 Pa. Figure 9 shows OACF values of 1000 mm and 2000 mm rotors with standard brush sealing with pressure difference range of -750 to +750 Pa.

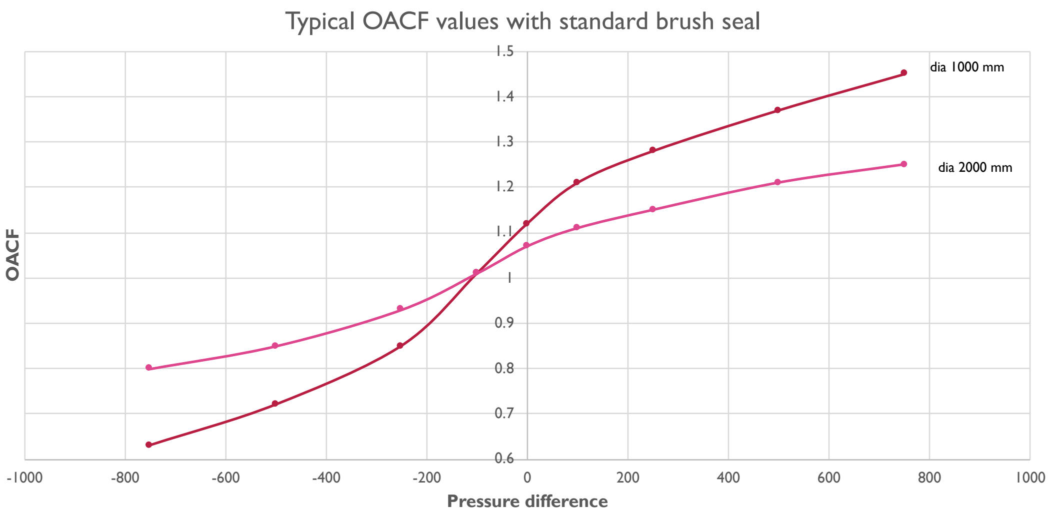


Figure 9. Typical values of OACF with rotary heat exchangers

The AHU configuration and especially fan positioning in relation to the rotor has the biggest individual impact on the pressure difference between supply and exhaust air around rotor. The placement of the AHU in the building will influence the ductwork length and pressure losses and therewith impact the pressure difference between supply and exhaust air. Therefore, Δp_{22-11} needs to be calculated for each installation separately. In analyses presented in paragraph 0, the AHU is assumed to be close to outdoors in both air flows.

3.2 Anticipated amendments to the revised EN 308

In the revision of EN 308, one of the main tasks was to set up an accurate measurement standard for internal leakages OACF and EATR. One option for recuperators and systems using intermediate medium can be to tests with a static method.

There will be 3 test types defined:

- Type A: ERC in laboratory
- Type B: ERC build in AHU and tested in laboratory
- Type C: ERC build in AHU and tested on site, most probably later upgrade

3.2.1 Type A: Internal leakage test of component in laboratory

The test type A is now quite well documented and has following key components of interest:

1. The C1 (recuperative systems) and C2 (systems with intermediary heat transfer medium) type ERC component will be tested with duct connections closed with 250 Pa over pressure on the exhaust air side (or 100 Pa for units for use lower than 250 Pa). Supply air side is set to 0 Pa.
2. If the static internal leakage is higher than 3% or category C3 (regenerative systems), the unit needs to be tested with dynamic test method to define OACF and EATR values.
3. The dynamic test procedure (for OACF and EATR) will be done with several differential pressure testing points. The points cover the maximum allowed pressure difference declared by the supplier. Both positive and negative pressure differences will be tested.
4. There is so far no test procedure described for alternating accumulative heat exchangers.
5. EATR will be tested with tracer gas method.

3.2.2 Type B: Internal leakage test of the component build-in an AHU in Laboratory

One of the main principles of testing is to provide leakage data to describe the AHU's performance regarding internal leakages.

The test type B will serve needs independent AHU certification tests and market surveillance. The definition of test type B is still under work at the time of writing. In the foreseen test procedure, the fans of the AHU will generate the design air flow and pressure conditions as defined in EN 13053. The OACF and EATR are defined with measurements in the outlets of the AHU. It is intended that the test will consider leakages across the exchangers and the AHU casing.

3.2.3 Type C: Internal leakage test of AHU installed on site

The work for this section has not yet started at the time of writing. The main obstacle is the measurement accuracy on site. It is possible be that this method will be documented in a later phase.

4 Available indicators and test methods for external leakage

External casing leakages on the AHU casing are measured and classified according to EN 1886 (Chapter 6). External leakages can be tested at overpressure (positive pressure in AHU in comparison with ambient) or underpressure (negative pressure in AHU in comparison with ambient).

AHUs with sections operating under positive pressure (where the operating pressure immediately downstream of the fan exceeds 250 Pa positive pressure) has the positive pressure sections tested separately from the rest of the unit. If the positive pressure does not exceed 250 Pa, a negative pressure test is sufficient. The remainder of the unit is tested under negative pressure. It is also allowed to test the entire unit under positive and negative pressure. Air leakage tests are also performed on a model box at both negative pressure and positive pressure. In this case, the leakage class shall be followed by; (M), according to EN 1886.

4.1 Negative pressure test

The air leakage of the assembled AHU is tested at 400 Pa negative pressure and it must not exceed the applicable rate given in Table 1.

Maximum leakage rate (f400) [l / s . m²]	Leakage class of casing
0,15	L1
0,44	L2
1,32	L3

Table 1. Casing air leakage classis of AHU under 400 Pa negative pressure

4.2 Positive pressure test

The test pressure applied to the positive pressure sections is 700 Pa positive pressure or the AHU's maximum positive operating pressure, whichever is the greater. The air leakage from the sections subjected to 700 Pa positive pressure is in accordance with Table 2.

Maximum leakage rate (f700) [l / s . m²]	Leakage class of casing
0,22	L1
0,63	L2
1,90	L3

Table 2. Casing air leakage classis of AHU under 700 Pa positive pressure

Eurovent recommends using AHUs with casing air leakage class at least L2(R). Class L1 is suitable for units for special application like cleanrooms.

5 Potential magnitude of internal leakage rate due to incorrect unit design

As stated in the previous chapters, internal leakage has significant impact both on IAQ and energy consumption. While internal leakage in plate exchangers and run-around systems is not a major concern, it cannot be ignored in rotary heat exchangers.

Rotary heat exchangers have among many good features one possible weakness that needs to be taken care of in order to avoid jeopardising supply air quality and loss of energy efficiency. The leakage rate across rotary heat exchangers may be higher compared to other types of exchangers. With good product design, correct AHU configuration (fan positions), good workmanship in installation, correct inspection and service of sealing system and other pressure difference minimising actions, the leakages between supply and exhaust air flows can be minimised. The internal leakages with interval energy recovery system should be considered similarly as rotors.

Normally, the rate of the internal leakage in rotary heat exchanger is affected most by the configuration of the fans. Typical leakage rates are outlined below in paragraph 0. As the presented figures show, some of the fan configurations lead to very high internal leakage rates and should be avoided.

5.1 Typical internal leakages rates for rotary heat exchangers

5.1.1 Case 1. Both fans after the rotor in the air flow (both suction fans)

This configuration is the most recommended to minimise internal leakages. The pressure differences between air flow around rotor are minimised.

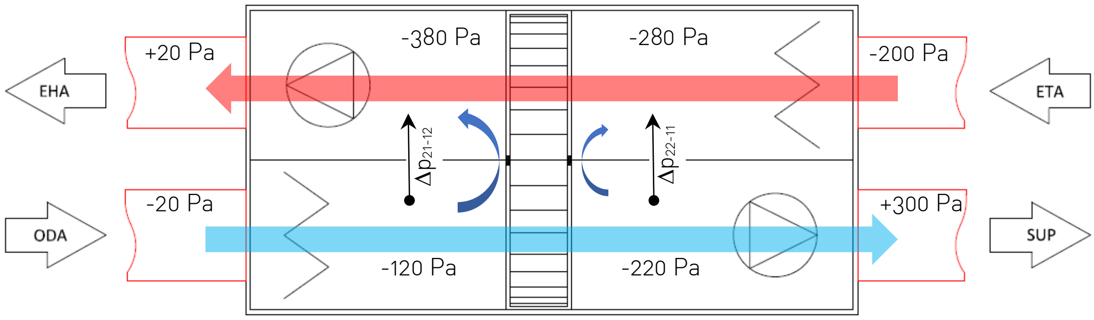


Figure 10. Ideal fan positions, the fans are placed after the rotor in the respective air streams

Typically, the static pressure difference between air flows is slightly over pressured in the exhaust or supply airside. Practice has shown that quite often the pressure difference Δp_{22-11} in installations is still negative and additional measures are needed to balance the pressure differences and to minimise EATR.

Pressure difference	Typical OACF value	Typical EATR value
$\Delta p_{22-11}>0$ $\Delta p_{21-12}>0$	OACF > 1	EATR < 3% without purge EATR < 1% with purge
$\Delta p_{22-11}<0$ $\Delta p_{21-12}>0$	1 < OACF < 1.15	EATR < 7% without purge EATR < 3-5% with purge
$\Delta p_{22-11}<0$ $\Delta p_{21-12}<0$	0.8 < OACF < 0.95	5% < EATR < 20%

Table 3. Typical OACF and EATR values for Suction Supply and Suction Exhaust Fan configuration. Estimation based on Eurovent Certified data.

5.1.2 Case 2: Both fans on building side (pressure exhaust fan – suction supply fan)

In ventilation systems with recirculation, or when customer requirements and market tradition tend to price driven solutions, this configuration is common.

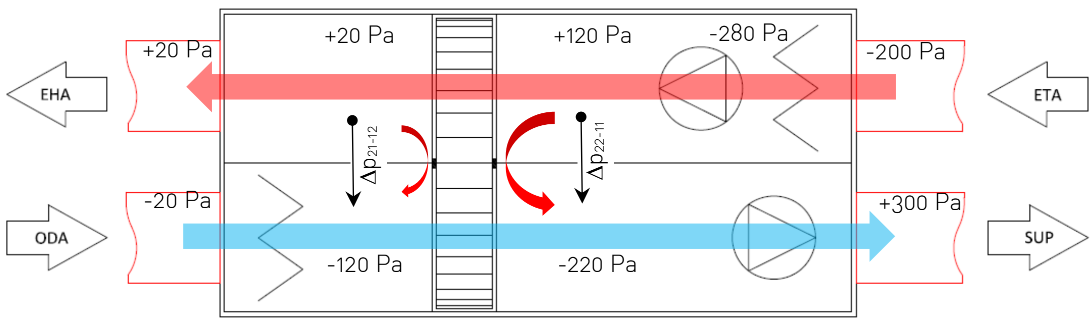


Figure 11. Both fans on the building side

The pressurising extract fan causes clear over pressure in exhaust air side (Δp_{22-11} is negative) in most installation cases. EATR will be high and OACF will be under 1.0. A purge sector should be avoided as it will not function and will cause only additional exhaust air leakage to supply air.

Pressure differences	Typical OACF value	Typical EATR value
$\Delta p_{22-11} < -300$ Pa $\Delta p_{21-12} < -100$ Pa	0.7 < OACF < 0.9	10% < EATR < 20% without purge 15% < EATR < 25% with purge

Table 4. Typical OACF and EATR values for Pressure Exhaust Fan and Suction Supply Fan configuration. Estimation based on Eurovent Certified data.

5.1.3 Case 3. Both fans on the outdoor side (pressure supply fan – suction exhaust fan)

It is assumed that when placing the supply air fan before the rotor, one could avoid exhaust air leakages to supply air. This is surely correct, but with a cost of very high supply air leakage to exhaust air, i.e. very high OACF values.

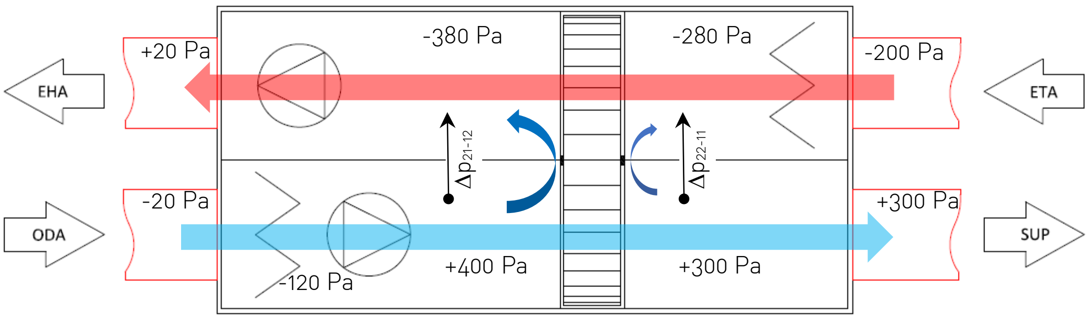


Figure 12. Both fans on the outdoor side

Pressure differences	Typical OACF value	Typical EATR value
$\Delta p_{22-11} > 300 - 600$ Pa $\Delta p_{21-12} > 500 - 800$ Pa	1.15 < OACF < 1.5	EATR < 1% without purge EATR = 0% with Purge

Table 5. Typical OACF and EATR values for Pressure Exhaust and Pressure Supply Fan configuration. Estimation based on Eurovent Certified data.

5.1.4 Case 4. Both fans before the rotor in air streams (both pressure fans)

In some cases, it is proposed that both fans would be before the rotor in the airstream. There will be much higher static pressure on the supply air side, and pressure differences will be highly positive causing rather high internal leakages.

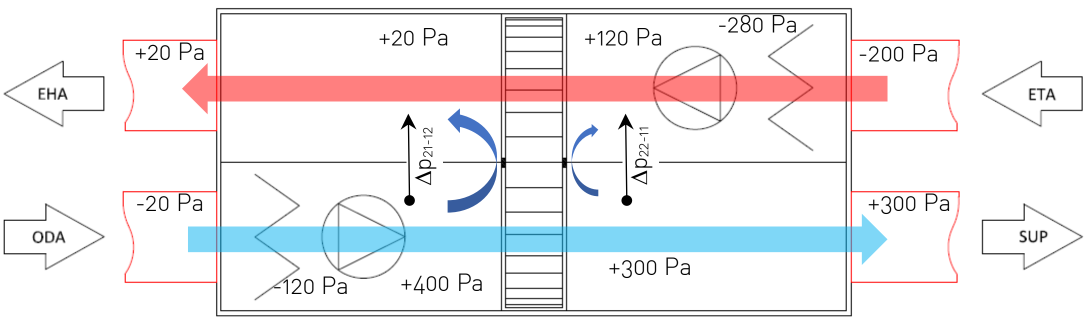


Figure 13. Both fans upstream the exchanger

Pressure differences	Typical OACF value	Typical EATR value
Δp_{22-11} < 200-400 Pa Δp_{21-12} < 400 Pa	1.1 < OACF < 1.3	EATR < 3% without purge EATR < 1% with purge

Table 6. Typical OACF and EATR values for Pressure Supply and Pressure Exhaust Fan configuration. Estimation based on Eurovent Certified data.

5.2 Problem of incorrect fans configuration

The previous paragraph shows that a configuration with both fans on the building side (case 2) results in high leakage of exhaust air to the supply side. This is at odds with correct IAQ and the protection of people's health and well-being in the supplied space. Maintaining internal leakages low always results in a more efficient unit both its terms of energy efficiency and IAQ.

However, placing the exhaust air fan before the rotor is favoured in many markets. Some standards recommend generally to place the exhaust air fan before the energy recovery component in order to save the fan heat. This is in general correct, but specifically for rotors there is such high disadvantage due to internal leakages that this should be avoided.

AHUs are becoming more compact, which allows production costs to be optimised by placing the exhaust air fan before the rotor. Although placing the exhaust fan upstream the ERC usually makes an AHU shorter and cheaper, it sacrifices IAQ and in most cases energy efficiency. When not taking into consideration leakages, designers might find this configuration an attractive option but in reality, it is a disadvantageous design.

It must be also noted that in case one would do field measurements of heat recovery, the exhaust air leakage to supply air would improve the measurement data and can be used to confuse the customer.

In most of the advanced ventilation markets where energy recovery wheels are commonly used, the practice is to use only the fan configuration with both fans after the rotor in the air stream.

A set of measures and limitations outlined in chapter 6 allow to eliminate from the market incorrectly designed products, significantly reduce internal leakages, and improve IAQ.

6 Problem solving

6.1 Setting the limits for EATR and OACF

All internal leakages, described by EATR and OACF values, deteriorate the quality of supply air and/or reduce the energy efficiency of the ventilation system. Both facts show the need to introduce reasonable limits for internal leaks. The recommended limits are based on the experience of producers and designers in the ventilation industry.

6.1.1 Eurovent recommendation on EATR

The contamination of supply air with the exhaust air (represented by EATR) can be a concern if the exhaust air quality is unsatisfactory. If the quality is acceptable, then outdoor air volume compensation can solve the problem.

For **EATR < 1%** at design conditions, no additional compensation action is required

For **1% ≤ EATR ≤ 5%** at design conditions, nominal supply flow rate shall be increased with the EATR percentage ($SUP_{corr} = SUP \cdot (1 + EATR)$) to compensate for the exhaust air leakage at design conditions and ensure the required supply flow rate (required design outdoor flow rate) to be delivered. Nominal extract air flow rate shall be increased with the EATR percentage ($ETA_{corr} = ETA \cdot (1 + EATR)$) to maintain the pressure balance in the building. This compensation is possible only if the extract air fulfils the category ETA1. In case of worse quality of extract air, EATR < 1% is mandatory.

EATR > 5% is not acceptable at all. Even if the extract air quality were good, the compensation would be so high that it would affect the designed ductwork and all elements.

6.1.2 Eurovent recommendation on OACF

The mixing of the outdoor air to the exhaust air (represented by OACF) mainly affects the energy consumption. So the recommendation is guided by efforts to mitigate the inefficiency of the ventilation system.

At design conditions OACF must be within the range of **0.95 to 1.1** (OACF class 4 of EN 16798-3:2017)

For AHUs including recirculation air and with outdoor air flow rate between 10% and 100% of nominal flow rate, EATR and OACF of the reference configuration are considered for maximum declared outdoor air flow rate under winter heating conditions.

6.2 Compensation of air flow

For rotary heat exchangers and periodic energy recovery systems, it may not be possible to eliminate internal leakages completely. In such cases, it is necessary to compensate air flow in order to maintain correct IAQ and to balance the supply and the extract air in the building.

A guideline on how to calculate the performance of an air handling unit with consideration of leakages can be found in Appendix I – Correction of AHU performance due to internal leakages. The guideline specifies how to calculate and treat leakages in an AHU with a rotary heat exchanger and two suction fans. The guideline can be used as a template for other AHU configurations.

The guideline will also specify how to correct the temperature efficiency and the moisture efficiency due to leakages.

6.3 Appropriate cooperation of all parties concerned

The outlined measures for limiting the 'internal leakages' problem cannot be tackled only by manufactures of AHUs. To take efficient actions and get the expected result, appropriate cooperation with ventilation system planners and commissioning engineers is necessary. First, the planners must provide correct values of pressure drop in all parts of the ductwork. Next, AHU manufacturers must carry out relevant calculations and take necessary design measures to minimise the leakage. Finally, commissioning engineers must correctly adjust devices (throttling, purge sector) on site, following manufacturer guidelines. Negligence at any of these stages might spoil the efforts.

7 Code of good practice to keep EATR and OACF low

7.1 Correct configuration of fans

A prerequisite for low internal leakages, notably for units fitted with a rotary heat exchanger, is the correct positioning of the fans. The most recommended configuration includes both fans located downstream the exchanger (see Figure 10 in par. 5.1.1, Case 1). It offers the best balance to limit EATR and to get a low OACF. If the EATR is below 1%, only the OACF for the supply air flow must be accounted for. To limit EATR, the extract air can be throttled by adding a damper or by correctly sizing the ductwork upstream the ERC.

Another acceptable positioning is the configuration with both fans located upstream the exchanger (see Figure 13 in par. 0.4, Case 4). It facilitates maintaining the correct direction of OACF and EATR. In this configuration, only the supply air can be throttled but normally there is no need to do it.

7.2 Throttling to keep the correct pressure balance

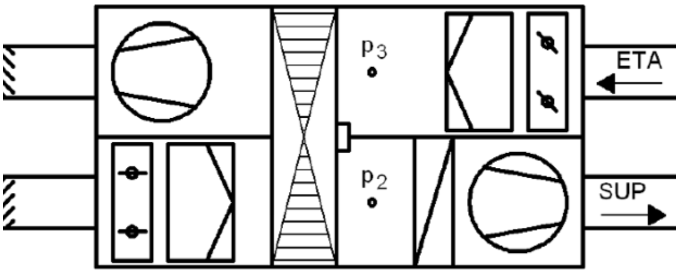


Figure 14. Throttling

Throttling depends on the configuration of fans as explained below.

7.2.1 Both suction fans (Figure 10)

Extract air throttling, constricting the extract air duct or adding a damper upstream of the ERC, this is done to ensure that p_3 is lower (negative pressures) or equal to p_2. OACF needs to be considered when sizing the exhaust fan. It can be considered negligible if under 1%.

7.2.2 Pressure exhaust fan – suction supply fan (Figure 11)

Throttling is not an option. In this configuration, EATR compensation will probably be impossible as increased supply and extract air flow will increase pressure drops and increase EATR.

7.2.3 Both pressure fans (Figure 13)

In this case the supply air might needs to be throttled in order to achieve the correct pressure difference between the supply and exhaust air stream. The OACF needs to be considered when sizing the supply air fan, and the EATR if below 1% does not need to be considered.

7.2.4 Suction exhaust fan – pressure supply fan (Figure 12)

Throttling again is not an option here, it will only result in more fresh air being 'lost' to the exhaust air stream. With this configuration, OACF must be considered when sizing both fans. This configuration results in no leakages from the exhaust air stream to the supply air stream but results in inefficient unit due to exaggerated flows (high OACF).

7.3 Application of the purge sector

The purge sector is used in rotors to decrease leakage. Due to the rotation of the wheel, some air passes from exhaust to supply side via rotation of the wheel. This leakage is called carry over and depends on rotation speed, rotor dimensions and pressure loss. Separation of outdoor air and exhaust air for regenerative rotary heat exchangers shall be ensured with a functioning purge sector.

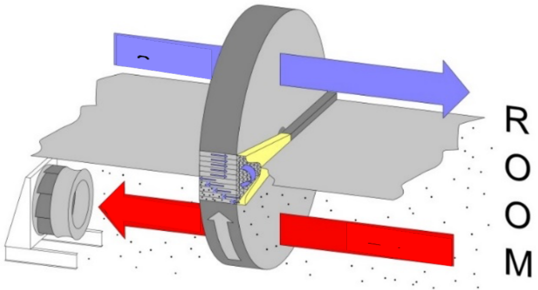


Figure 15. Purge sector

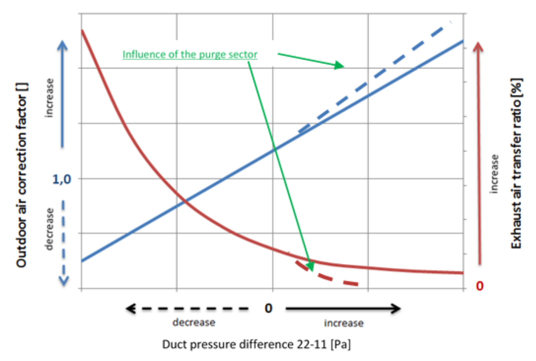


Figure 16. Influence of the purge sector on EATR and OACF

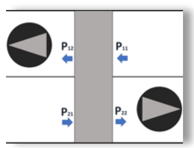
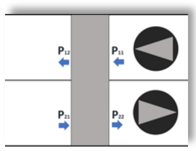
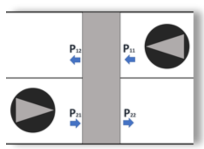
As Figure 16 illustrates, a functioning purge sector sets EATR technically to 0% (which means lower than 1% - the experimental tolerance), provided there is sufficient positive differential pressure, supply to extract air side. Actual measured values are far below 0.5%. Of note is that a functioning purge zone increases OACF approximately by the amount of purge flow.

A purge sector is the part of the rotary heat exchanger that ensures its proper operation. It only works correctly at positive pressure difference between supply and extract air flow. Thus, it should be always used if $\Delta p_{22-11} > 0$. In case of negative pressure difference, the purge zone is not recommended.

7.3.1 Setting and location of the purge sector

The advantage of having a variable purge angle is an option for setting the most effective angle for the given conditions, in order to optimise pressure drop and efficiency while maintaining the required purge flow.

The general guidance for the angle setting depending on the configuration of fans and actual pressure difference is outlined in Table 7 below.

Configuration	$p_{22}-p_{11} < 0$ Pa	$p_{22}-p_{11} = 0 – 250$ Pa	$p_{22}-p_{11} = 250 – 500$ Pa	$p_{22}-p_{11} > 500$ Pa
	No purge sector is recommended.	Large purge angle*	Small purge angle*	No purge sector required. Rotor is purged with the high-pressure differential.
	Purge will not work; it will only cause more contamination. In this case no purge sector is recommended			
	No purge sector is recommended.	Large purge angle*	Small purge angle*	No purge sector required. Rotor is purged with the high-pressure differential.

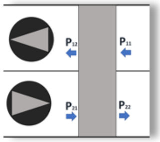
	No purge sector is recommended	Large purge angle*	Small purge angle*	No purge sector required. Rotor is purged with the high-pressure differential.
*Refer to the manufacturer recommendation				

Table 7. Recommended setting of the purge angle

The purge sector can be placed in different locations as Figure 17 shows.

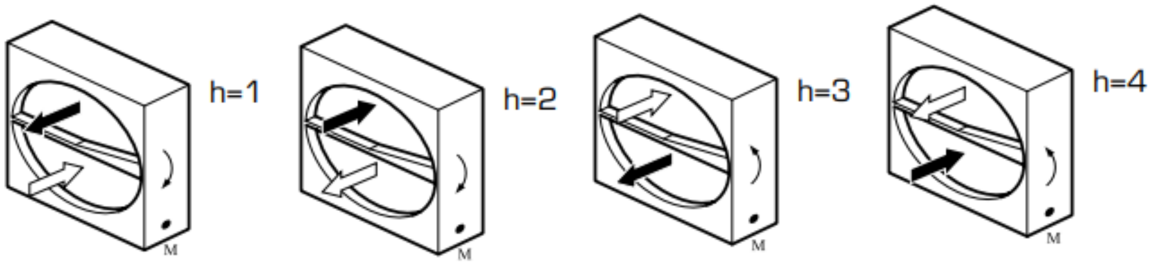


Figure 17. Location of purge sector

For the purge sector to work correctly, the rotor must rotate from the exhaust air stream into the purge sector where the supply air stream pushes out the trapped exhaust air. Maintaining this and the appropriate pressure differential as shown in the Table 7 above, should result in an effective purge sector. The location of the purge then will result in only a small change when it is located in any of the four positions listed in Figure 17. An effective purge sector means no carry over from the exhaust air stream to the supply air stream, the exhaust air stream that is trapped in the rotor while it rotates from one air stream to the other.

7.4 Effective seal of the rotor

Perimeter and middle beam sealing prevent air leakage from supply side to exhaust side. The sealing should be designed in a way that they are always in correct position. The best case would be a self-adjusting design or lack of any mechanical contact. Tolerances in rotor mass and casing have to be limited to support the function of the sealing system under all circumstances.

An efficient rotor sealing can never prevent carry over. For an efficient rotor sealing system, a proper purge zone must be used in case of positive differential pressure. The purge zone - if present - is a part of the sealing system.

Special care must be taken that the middle beam sealing must continuously separate supply and exhaust airflow in all areas despite the design of the purge zone. From the point of sealing, the purge zone area belongs to exhaust airstream.

The lowest OACF value without disturbing the function of the purge zone can be assumed at zero differential pressure. Typical values are between 1.02-1.21 for a rotor with 1 m diameter. The values get better with bigger diameters. Therefore, sealing is more important on small wheels. A good sealing has OACF values lower than 1.1 and as close as possible to 1.0.

If the permissible EATR is 5%, then the lowest acceptable OACF value is 0.95. Due to the mass balance EATR is equal or larger than (1 – OACF) in percent, provided OACF < 1.

In general is should be concluded that OACF should be in a range between 0.95 – 1.1 depending on the rotor diameter using a functional purge zone (EATR is technically zero). OACF values below 0.95 must be avoided.

All Eurovent certified manufacturers of rotary heat exchangers provide proven EATR and OACF values for different conditions.

7.5 Elimination of leakages between AHU sides – design and workmanship quality

Intersectoral leakages mostly arise in energy recovery components. This leakage can be solved and measured separately on this equipment as described in the previous chapters. But still there is a big task for AHU manufacturers and servicemen to minimise the internal leakages.

The riskiest part is the space for ERC installation. The border between the AHU and its embedded ERC should be carefully designed and checked in the factory. Rotary heat exchanger features considerable leaks itself, but also a plate heat exchanger can cause an intersection leakage if installed incorrectly. The block of the plate heat exchanger is regularly removed for cleaning. During reinsertion, the sealing can be damaged, or a gap left by incorrect installation, which can cause intersectoral leakage. It should be checked carefully at every service.

Another risky point is the intersectoral partition. This wall separating supply and exhaust air streams is often perforated by openings for cables or pipes. It is strictly recommended to use suitable cable glands in this case. The size of gland must correspond to the wall thickness and cable diameter. Pipes must be sealed around. The partition can be also perforated because of the installation of other internal parts. A bigger number of openings for screws or rivets can cause an appreciable leakage. The intersectoral partition should be sufficiently sealed on all sides in contact with the peripheral casing walls. In some arrangements, this partition is adjacent to the service door, and correct sealing depends on correct door position. The quality and correct position of the sealing should be checked each time the door is closed.

The last danger is directly in the casing. A side wall adjacent to the supply sector as well as the exhaust sector may cause an 'air bypass'. The openings in the inner surface of the panel can cause air short circuit though a hollow space inside the sandwich panel (filled only by an insulation). In this respect, units delivered in separate sections (complete tight casings for supply and exhaust side components other than ERC) may be advantageous to limit the internal leakage over the intermediate wall).

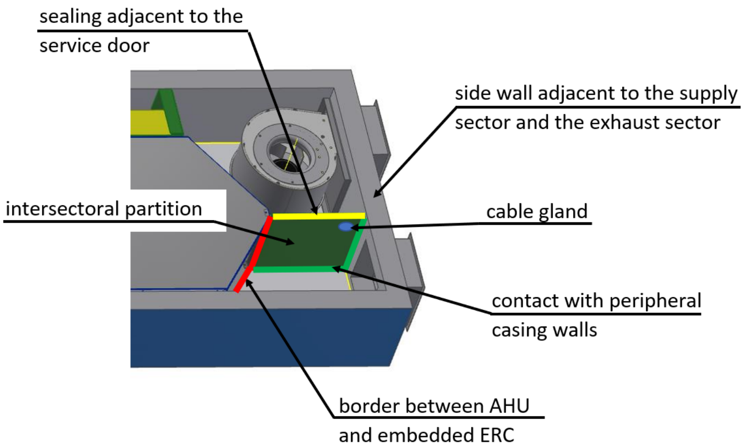


Figure 18. Example of AHU internal parts having impact on the leakage

A leak in a mixing chamber is a separate issue. Some leakage level is always expected in this part even when the mixing flap is closed.

Appendix I - Correction of AHU performance due to internal leakages

The main reason for leakage is normally the Energy Recovery Component (ERC), especially if it is a regenerator (normally a rotary heat exchanger). Leakages due to build in of an ERC or the intermediary planes in the AHU are not treated here but shall be evaluated and be taken care of, so also any external leakages.

A. How to calculate corrected air flow rates (compensation)

The first step in the calculation of leakages is to calculate all AHU pressure drops with respective air flow through each of them. Then, to be able to calculate the leakages, one has to calculate the pressure around the ERC at the two inlets sides; ODA = outdoor (p_{21}) and ETA = extract (p_{11}), and the two outlet sides; SUP = supply (p_{22}) and EHA = exhaust (p_{12}). This is done by summing up all pressures affecting parts, with signs (negative for a pressure drop and positive for a fan) from outdoor air intake to air upstream of the ERC (p_{21}) and from indoor air intake to air upstream of the ERC (p_{11}). Design pressure drops shall be used for filters. The calculation assumes that the pressures inside the building and outdoors are equal. The pressures downstream of the ERC, p_{22} and p_{12}, are found by adding the ERC pressure drop on respective air side to p_{21} respective p_{11}.

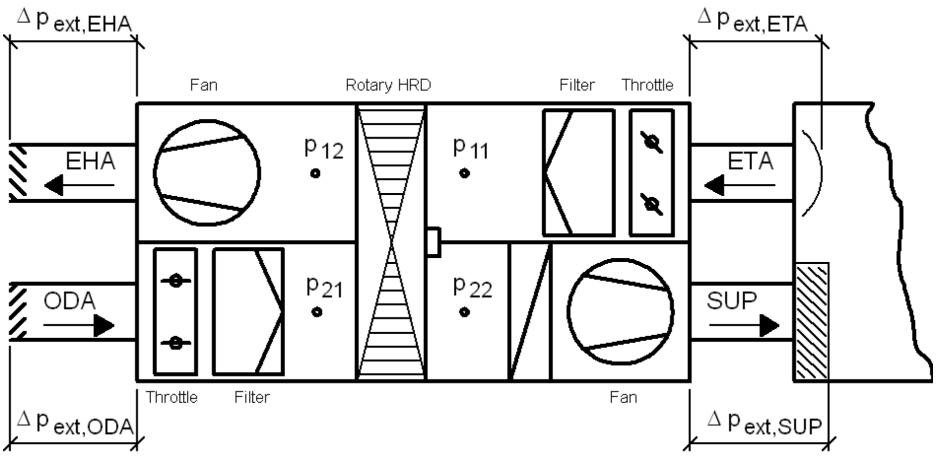


Figure 19. Pressure calculations in an air handling unit.

B. How to calculate any throttling

Throttling should be considered in case there is a risk for exhaust air leaking to supply air (EATR > 0%) due to adverse pressure difference between supply and extract air. Below follows possible handling of throttling.

The pressure difference on outdoor air side and exhaust air side is set to 50 Pa unless otherwise stated. The remainder of the external static pressures shall be set on the supply and extract air openings in accordance with EN 13053 paragraph 'Testing of unit with heat recovery'. However, it is useful to set the pressure difference on outdoor air side and exhaust air side to 1/3 of the external pressures if they are below 150 Pa (the remainder as before).

Both fans downstream the exchanger (suction exhaust air fan – suction supply air fan)

If throttling is considered and p_{11} is higher than p_{22} – adjust the throttle in the extract air so p_{11} will become equal with p_{22}, the throttle pressure drop will become $p_{22} - p_{11}$. It is recommended that the pressure p_{11} (the higher negative pressure) in an installed AHU is 0 to 20 Pa less than p_{22}.

Throttling at outdoor air side shall normally be avoided but if the OACF is too high and the pressure difference $p_{22} - p_{11}$ is more than 20 Pa then OACF could be decreased by adjusting the throttle in the outdoor air side. It is recommended to only make necessary adjustment to fulfil OACF requirement, the pressure p_{11} shall be at least 20 Pa less than the pressure p_{22}.

Both fans on building side (pressure exhaust air fan – suction supply air fan)

There is no possibility to use throttling in this case.

Both fans upstream the exchanger (pressure exhaust air fan – pressure supply air fan)

If throttling is considered and p_{11} is higher than p_{22} – adjust the throttle in the supply air so p_{11} will become equal with p_{22}, the throttle pressure drop will become $p_{22} - p_{11}$. It is recommended that the pressure p_{11} (the lower positive pressure) in an installed AHU is 0 to 20 Pa less than p_{22}.

Throttling at exhaust air side shall normally be avoided but if the OACF is too high and the pressure difference $p_{22} - p_{11}$ is more than 20 Pa, then OACF could be decreased by adjusting the throttle in the exhaust air side. It is recommended to only make necessary adjustment to fulfil OACF requirement, the pressure p_{11} shall be at least 20 Pa less than the pressure p_{22}.

Both fans on the outdoor side (suction exhaust air fan – pressure supply air fan)

There is no possibility to use throttling in this case.

C. Calculation of leakages around a rotary heat exchanger

Option 1. Calculation based on full knowledge about the rotary heat exchanger

The purge sector angle should be design so that the carry-over flow from extract air to supply air is zero when the rotor rotates at full speed (if it is made with a closed loop on extract air side, both sides shall have the same purge sector angle). The purge flow, q_{purge}, can be calculated out of the purge area (open face area in the purge sector) and the air velocity in that area. The velocity can be calculated out of the pressure difference over the purge sector by reverse calculation against pressure drop.

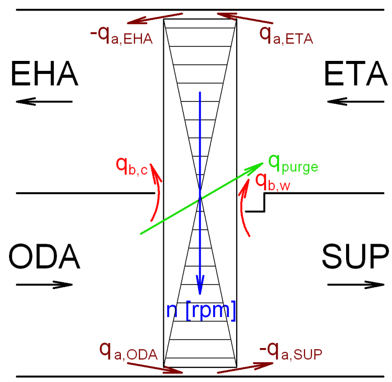


Figure 20. Leakages through the rotary exchanger

The leakages through the seals at the intermediary planes can be calculated out of the pressure differences $p_{22} - p_{11}$ (indoor side) respective $p_{21} - p_{12}$ (outdoor side), the leakage factor (could be found by measurement) and the length for respective seals (normally the rotor diameter). One has to keep track on the leakage direction which is given by the signs of respective pressure difference, the leakage goes from outdoor/supply air side to extract/exhaust air side if the pressure difference is positive. There will be a leakage of extract air to supply air if the pressure difference is negative, which will result in an EATR greater than zero. This must be taken care of by either throttling or possibly by compensation by increasing of the supply and the extract air flow.

To handle the rotor perimeter leakages, it is assumed that the void outside of the perimeter seals is airtight to the surrounding to avoid external leakages. If so, one can assume that the pressure in the void will be the mean pressure of the four different pressures p_{11} to p_{22} with consideration of respective sign. The leakages through the seals to the void from the four sides around the rotor can be calculated one by one with the pressure difference between respective side and the void, the leakage factor (could be found by measurement) and the length for respective seals (normally the half the rotor diameter multiplied by pi). One has to keep track on the leakage direction which is given by the sign of respective pressure difference, the leakage goes from a side to the void, positive flow direction, if the pressure difference is positive. The sum of the leakages to the void shall be zero (leakages to and from the void shall be in balance).

Assumption, for calculation of the impact of the leakages, is an AHU according to Figure 20 and that the supply and the extract air are checked and adjusted to be correct when the AHU is put into operation. The impact of the leakages on each of the air stream in and out from the rotor shall be handled (**Note: all additions and subtractions shall be done with respect of leakage direction**):

1. In case of purge sector: the purge flow, q_{purge} flow shall be added to both the outdoor air flow and the exhaust air flow and, if it is an open outlet in the extract air side, added to the air flowing through the rotor on the exhaust air side. In case of no purge sector: the carry-over effect will transfer the same amount of entrapped air between the air sides; supply and exhaust, the impact will be an increase of EATR according to carry-over flow divided by supply air flow.
2. Leakage flow from outdoor air to exhaust air through seals at the intermediary plane - the leakage flow shall be added to both the outdoor air flow and the exhaust air flow.
3. Leakage flow from supply air to extract air through seals at the intermediary plane - the leakage shall be added to the outdoor air flow, the air flowing through the rotor on both the supply and the exhaust air side and the exhaust air flow.
4. Leakage flow between outdoor air and the void shall be added to the outdoor air flow.
5. The leakage flow between supply air and the void shall be added to the outdoor air flow and the air flowing through the rotor in the supply air stream.
6. The leakage flow between extract air and the void shall be subtracted from the extract air flow and the air flowing through the rotor in the exhaust air stream.
7. Leakage flow between exhaust air and the void shall be subtracted from the exhaust air flow.
8. Calculate OACF and EATR.

$$OACF = \frac{q_{m,21}}{q_{m,22}}$$

where

$OACF$	outdoor air correction factor
$q_{m,21}$	outdoor air mass flow rate (outdoor air volume flow multiplied by air density 1.2), in kg/s
$q_{m,22}$	supply air mass flow rate (supply air volume flow multiplied by air density 1.2), in kg/s

$$EATR = \frac{q_{m,22} - q_{m,22,net}}{q_{m,22}} = \frac{q_{m,11,transfer}}{q_{m,22}}$$

where

$EATR$	exhaust air transfer ratio (normally stated in %)
q_{m22}	supply air mass flow rate (supply air volume flow multiplied by air density 1.2), in kg/s
$q_{m,22,net}$	the portion of the supply air mass flow rate that originates as outdoor air, in kg/s

$q_{m,11,transfer}$ the sum of extract air mass flow rate leakages to the supply air (leakages air volume flow multiplied by air density 1.2), in kg/s

9. If EATR is greater than 1%, the EATR/100 is multiplied by the required supply flow rate (required design outdoor flow rate) and added to the supply air flow and to the extract air flow to get the right amount of outdoor air and balance in the building:

   $q_{SUPcorr} = q_{SUP} \cdot (1 + EATR/100)$, and;

   $q_{ETAcorr} = q_{ETA} \cdot (1 + EATR/100)$.

Option 2 - Calculation based on knowledge of OACF and EATR (declared by rotor supplier)

Once the static pressure difference $p_{22} - p_{11}$ is calculated the Internal leakage values OACF and EATR can be calculated by ERC component software. It is recommended to use purge sector as recommended by the supplier of the component. It is also recommended to check that the components supplier is providing correct data for all pressure differential conditions.

The impact of the internal leakages OACF and EATR on each of the air stream in and out from the rotor shall be handled.

1. If EATR is greater than 1%, the supply and extract air flows are increased by EATR (%) value:

   $q_{SUPcorr} = q_{SUP} \cdot (1 + EATR/100)$

   $q_{ETAcorr} = q_{ETA} \cdot (1 + EATR/100)$

2. The outdoor and exhaust air flows are corrected by OACF value:

   $q_{ODAcorr} = q_{SUPcorr} \cdot OACF$

   $q_{EHAcorr} = q_{ETAcorr} + q_{SUPcorr} \cdot (OACF - 1)$

D. Iteration process

One has to use an iteration process to get the correct result due to the fact that air flows affect pressure drops and the pressures around the rotor, pressure differences lead to leakages and the leakages affects the air flows. However, in this case it is a convergent process. Just loop the calculation of paragraphs A and C at least three times or check when it converges. The following conditions should be used to stop the iteration:

If the $OACF_{n+1} - OACF_n < 0.01$ and $EATR_{n+1} - EATR_n < 0.2\%$, stop iteration.

If EATR is less or equal to 5%

The AHU meets reasonable requirements if OACF is within the range of 0.95 to 1.1.

If EATR is more than 5%

The AHU does not meet reasonable requirements.

Remark: If the AHU does not meet requirements, try throttling or another fan configuration.

E. Further calculations out of results

Fan performance shall be calculated out of the results and also quality factors for the AHU, such s the internal Specific Fan Power (SFP_{int}).

F. Correction of temperature and moisture efficiency

The internal leakages will possibly transfer exhaust air to supply air (EATR). This will increase the measured temperature and humidity efficiencies. To neutralise the exhaust air amount in supply air (EATR) in efficiency calculation term net efficiency is needed. This calculation is needed only in calculation of efficiency on site measurements or in AHUs in laboratory testing conditions where EATR is higher than 3%.

The net efficiencies are calculated as follows:

Temperature net efficiency $\eta_{t,net}$

Net transfer of sensible heat from exhaust to supply air, regarding the EATR on and air mass flow rates.

$$\eta_{t,net} = \frac{\left(\frac{\theta_{22} - EATR \cdot \theta_{11}}{1 - EATR} - \theta_{21}\right)}{(\theta_{11} - \theta_{21})}$$

Where

$EATR$	exhaust air transfer ratio
θ_{11}	temperature exhaust air inlet, in °C
θ_{21}	temperature supply air inlet, in °C
θ_{22}	temperature supply air outlet, in °C

Humidity net efficiency $\eta_{x,net}$

Net transfer of latent heat exhaust to supply air, regarding the EATR and air mass flow rates.

$$\eta_{x,net} = \frac{\left(\frac{x_{22} - EATR \cdot x_{11}}{1 - EATR} - x_{21}\right)}{(x_{11} - x_{21})}$$

Where

$EATR$	exhaust air transfer ratio
x_{11}	absolute humidity exhaust air inlet, in g/kg
x_{21}	absolute humidity supply air inlet, in g/kg
x_{22}	absolute humidity supply air outlet, in g/kg

Appendix II – Calculation examples for the correction of performance

The examples illustrate the calculation procedure presented in Appendix 1. Calculations of leakages around a rotary heat exchanger are carried out in accordance with Option 1 based on full knowledge about the rotary heat exchanger (Appendix I paragraph C).

Example 1

AHU in accordance with Figure 19. Both fans after the rotor in the air flow (both suction fans) - all pressures are negative pressures. Purge sector between outdoor air and extract air.

Data:		
	Supply air flow: 1.0 m³/s	Extract air flow: 1.0 m³/s
	Outdoor air, ODA, duct pressure drop: 50 Pa	Extract air, ETA, duct pressure drop: 200 Pa

Row nb	Charateristic	Formula (refers to row nb)	Iteration				Unit
			Start	1	2	3	
1	**Supply air stream**						
2	Outdoor air flow, initial value	26, column - 1	1	1.078	1.08	1.08	m³/s
3	ODA duct Pressure Drop		-50	-50	-50	-50	Pa
4	Design filter PD		120	126	126	126	Pa
5	Rotary PD		166	166	167	167	Pa
6	**Exhaust air stream**						
7	ETA duct pressure drop		-200	-200	-200	-200	Pa
8	Throttling PD	7-9-16; 0 if > 0	59	65	67	67	Pa
9	Design filter PD		77	77	77	77	Pa
10	Rotary PD		166	176	176	176	Pa
11	Exhaust air flow, initial value	29, column - 1	1	1.078	1.078	1.078	m³/s
12	**Pressure differences**						
13	p11	7-8-9	-336	-342	-344	-344	Pa
14	p12	13-10	-502	-518	-520	-520	Pa
15	p21	3-4	-170	-176	-176	-176	Pa
16	p22	3-4-5	-336	-342	-343	-343	Pa
17	pvoid	(13+14+15+16)/4	-336	-344.5	-345.75	-345.75	Pa
18	**Rotary leakages**						
19	qPurge (due to p21 -p11)		0.039	0.039	0.039	0.039	m³/s
20	qa,ODA (due to p21 -pvoid)		0.019	0.019	0.019	0.019	m³/s
21	qa,SUP (due to p22 -pvoid)		0	0.001	0.001	0.001	m³/s
22	qa,ETA (due to p11 -pvoid)		0	0.001	0.001	0.001	m³/s
23	qa,EHA (due to p12 -pvoid)		-0.019	-0.02	-0.02	-0.02	m³/s
24	qb,w (warm side) (p21 -p12)		0	0	0	0	m³/s
25	qb,c (cold side) (p22 -p11)		0.02	0.02	0.02	0.02	m³/s
26	*Calc. outdoor air flow*	qSUP+19+20+21+24+25	1.078	1.08	1.08	1.08	m³/s
27	*Calc. SUP rotor air flow*	qSUP+21+24	1	1.001	1.001	1.001	m³/s
28	*Calc. EHA rotor air flow*	qETA+19-22+24	1.039	1.038	1.038	1.038	m³/s
29	*Calc. exhaust air flow*	qETA+19-22-23+24+25	1.078	1.078	1.078	1.078	m³/s
30	OACF		1.08	1.08	1.08	1.08	
31	EATR		< 1	< 1	< 1	< 1	%

Example 2

AHU in accordance with Figure 19. Both fans after the rotor in the air flow (both suction fans) - all pressures are negative pressures. Purge sector between outdoor air and extract air.

Data:		
	Supply air flow: 0.6 m³/s	Extract air flow: 0.8 m³/s
	Outdoor air, ODA, duct pressure drop: 50 Pa	Extract air, ETA, duct pressure drop: 200 Pa

Row nb	Charateristic	Formula (refers to row nb)	Iteration				Unit
			Start	1	2	3	
1	**Supply air stream**						
2	Outdoor air flow, initial value	26, column - 1	0.6	0.6772	0.6731	0.6734	m³/s
3	ODA duct Pressure Drop		-50	-50	-50	-50	Pa
4	Design filter PD		78	89	88	88	Pa
5	Rotary PD		82	85	84	84	Pa
6	**Exhaust air stream**						
7	ETA duct pressure drop		-200	-200	-200	-200	Pa
8	Throttling PD	7-9-16; 0 if > 0	0	0	0	0	Pa
9	Design filter PD		60	60	60	60	Pa
10	Rotary PD		121	131	130	130	Pa
11	Exhaust air flow, initial value	29, column - 1	0.8	0.8761	0.8714	0.8718	m³/s
12	**Pressure differences**						
13	p11	7-8-9	-260	-260	-260	-260	Pa
14	p12	13-10	-381	-391	-390	-390	Pa
15	p21	3-4	-128	-139	-138	-138	Pa
16	p22	3-4-5	-210	-224	-222	-222	Pa
17	pvoid	(13+14+15+16)/4	-245	-254	-253	-253	Pa
18	**Rotary leakages**						
19	qPurge (due to p21 -p11)		0.0336	0.0315	0.0317	0.0316	m³/s
20	qa,ODA (due to p21 -pvoid)		0.0151	0.0149	0.0148	0.0148	m³/s
21	qa,SUP (due to p22 -pvoid)		0.0068	0.0061	0.0062	0.0062	m³/s
22	qa,ETA (due to p11 -pvoid)		-0.0041	-0.0024	-0.0026	-0.0026	m³/s
23	qa,EHA (due to p12 -pvoid)		-0.0167	-0.0168	-0.0168	-0.0168	m³/s
24	qb,w (warm side) (p21 -p12)		0.0055	0.0044	0.0045	0.0045	m³/s
25	qb,c (cold side) (p22 -p11)		0.0163	0.0162	0.0162	0.0162	m³/s
26	*Calc. outdoor air flow*	qSUP+19+20+21+24+25	0.6772	0.6731	0.6734	0.6734	m³/s
27	*Calc. SUP rotor air flow*	qSUP+21+24	0.6123	0.6105	0.6107	0.6107	m³/s
28	*Calc. EHA rotor air flow*	qETA+19-22+24	0.8431	0.8384	0.8388	0.8388	m³/s
29	*Calc. exhaust air flow*	qETA+19-22-23+24+25	0.8761	0.8714	0.8718	0.8718	m³/s
30	OACF		1.13	1.12	1.12	1.12	
31	EATR		< 1	< 1	< 1	< 1	%

Note: Throttling is needed on outdoor air side in order to reduce the OACF

About Eurovent

Eurovent is Europe's Industry Association for Indoor Climate (HVAC), Process Cooling, and Food Cold Chain Technologies. Its members from throughout Europe represent more than 1.000 organisations, the majority small and medium-sized manufacturers. Based on objective and verifiable data, these account for a combined annual turnover of more than 30bn EUR, employing around 150.000 people within the association's geographic area. This makes Eurovent one of the largest cross-regional industry committees of its kind. The organisation's activities are based on highly valued democratic decision-making principles, ensuring a level playing field for the entire industry independent from organisation sizes or membership fees.

Our Member Associations

Our Member Associations are major national sector associations from Europe that represent manufacturers in the area of Indoor Climate (HVAC), Process Cooling, Food Cold Chain, and Industrial Ventilation technologies.

The more than 1.000 manufacturers within our network (Eurovent 'Affiliated Manufacturers' and 'Corresponding Members') are represented in Eurovent activities in a democratic and transparent manner.

→ For in-depth information and a list of all our members, visit www.eurovent.eu