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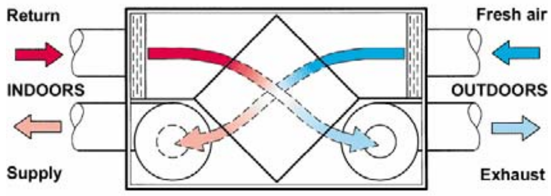
Operating Agent
and Management
Boulevard Poincaré 79
B-1060 Brussels – Belgium
inive@bbri.be - www.inive.org

International Energy Agency
Energy Conservation in Buildings
and Community Systems Programme

Air Infiltration and Ventilation Centre

Air-to-Air Heat Recovery in Ventilation Systems

Dr. Peter G. Schild
Norwegian Building Research Institute



1 Introduction

1.1 Basics

A heat recovery unit transfers heat (some units also moisture) from the exhaust air stream over to the supply air stream, thus reducing the heat loss due to ventilation, and reducing the need to condition the cold supply air. Conversely, in hot and humid outdoor conditions, a heat recovery unit can keep heat (some units also moisture) outside, thus reducing air conditioning costs.

1.2 General definitions

– **Air handling unit** (**AHU**): packaged unit with fans for ventilation, filters, maybe heating/ cooling batteries, de-/humidifier etc. AHUs are usually designed for balanced ventilation (i.e. both supply and exhaust), and can thus include a heat exchanger for air-to-air heat recovery.

– **Heat exchanger**: A component within the *heat recovery unit* that transfers heat between two fluid flow streams (i.e. air).

– **Heat recovery unit**: The part or module of *air handling unit* (*AHU*) that incorporates the heat exchanger and its auxiliary equipment (motor, controls, etc), but is often used to describe the whole packaged AHU incorporating its heat exchanger.

– **Bypass**: Alternative passage for air flow avoiding the heat exchanger, thus avoiding heat recovery (can be useful in summer)

– **Total enthalpy**: Specific heat content per kg of air, the sum of *sensible enthalpy* (temperature-dependent) and the *latent* heat of its moisture content.

1.3 Conditions of use

Heat recovery may be used in balanced ventilation systems (i.e. fan powered supply and exhaust air flows). The building should be satisfactorily airtight - air leakages constitute an extra heat loss since they do not pass though the heat recovery unit. For dwellings, the infiltration rate should not exceed 10–20 % of the flow rate through the heat recovery unit.

1.4 Use

Heat recovery is equally appropriate for buildings with any space heating system. Correctly dimensioned and maintained heat recovery units with high efficiency will pay for themselves in a few years, in terms of reduced ventilation & space heating costs. This profitability is higher if the exhaust fan is located before the heat exchanger. It should be possible to reduce the heat recovery efficiency outside the heating season, to prevent over-heating indoors. Some heat exchangers can also recover moisture. It can be desirable to recover moisture this way in buildings with central humidification in winter, to reduce humidification costs. For AHUs with cooling (air conditioning) moisture recovery can be desirable in summer (when the outdoor air is hot and humid) to reduce the cooling energy needed for dehumidification. If the exhaust air has water-soluble odours/pollutants, one should nevertheless use a heat exchanger that does not recover moisture, i.e. totally separate air streams. Heat recovery units require regular inspection and maintenance, though anyone with normal technical aptitude can do this, on the condition that a proper operation & maintenance manual is available.

2 Types and areas of use

2.1 Main types

There are two main types of heat recovery unit: *Regenerative* (cyclic) and *recuperative* (static).

2.2 Regenerative heat recovery

2.2.1 General

Regenerative heat exchangers transfer heat via heat-accumulating surfaces that are repeatedly exposed to either the exhaust air or supply air stream. The heat-accumulating surfaces are normally metal. These heat exchangers can also recover moisture. Undesirable leakage between the two air streams can occur, though this problem can be reduced by judiciously locating the fans to counteract the leakage.

2.2.2 Rotary heat exchangers

These consist of a rotor wheel (thermal wheel) with many small parallel channels through which air flows. While one half of the wheel is being heated up by the exhaust air, the other half is releasing stored heat to the supply air. There are two types:

– **Hygroscopic** rotors (enthalpy wheels), i.e. rotor of a material that adsorbs moisture (vapour and liquid), usually a surface of porous aluminium oxide. 'Sorption wheels' are the most effective type at moisture recovery.

– **Nonhygroscopic** rotors (condensation wheels). These can only transfer moisture if the moisture in the exhaust air condenses.

The recovery efficiency of rotary heat exchangers is controlled by regulating the rotor speed or intermittent operation. Bypass control may also be used. The alternating flow direction through the rotor tends to keep it clean for dust. However, to prevent recirculation of pollutants, a *purge sector* can be used. To prevent fouling of the rotor when it is static (e.g. during summer) it should be operated periodically. Normally freezing occurs only below approx. -20°C for hygroscopic types (depends on humidity of extract air, and heat recovery efficiency).

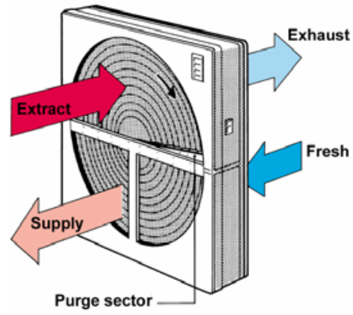


Figure 1: Rotary heat exchanger

The fans should be located such that the leakage is driven from supply to exhaust air stream (Figure 2). Without a purge sector, at least 2–4% of the extract air is recirculated. A purge sector can reduce this below 1%. The degree of transfer of odours and pollutants depends on each individual compound's diffusion coefficient and on the rotor surface's adsorptivity.

For hygroscopic rotors, the transfer efficiency of ammonia and butane exceeds 50%, and for CO_2, petroleum and cooking odours, it is approximately 10%. For such water-soluble compounds, a purge sector is of little help, so a hygroscopic rotor should not be used. Even non-hygroscopic rotors can become more hygroscopic with time, due to corrosion (and possibly dust deposition & accumulation) in their channels. This means that rotary heat exchangers should not be used when the exhaust air contains strong odours or unhealthy pollutants.

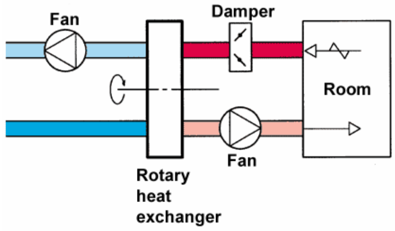


Figure 2: Location of fans and damper to reduce recirculation

2.2.3 Reciprocating heat exchangers

These consist of two separate heat-accumulating chambers and a motorized damper to alternate flow direction at regular intervals, normally each minute. Each chamber has many parallel plates or a material similar to rotary heat exchangers. Unwanted recirculation from the exhaust to supply air stream is similar to a rotary heat exchanger (1–6%, including external short-circuiting from exhaust to fresh air intake). Risk of frosting is very similar to that of rotary heat exchangers.

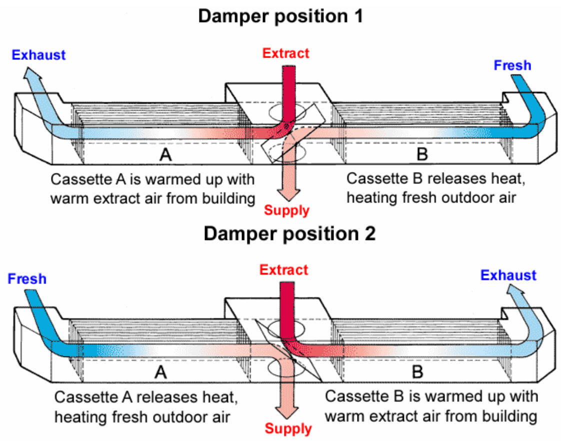


Figure 3: Example of reciprocating heat exchanger

2.3 Recuperative heat recovery

2.3.1 General

Recuperative heat exchangers transfer heat across a dividing plate by means of thermal conduction (plate or tube heat exchanger), or with an intermediate fluid (run-around heat exchanger, heat pipe or heat pump). Since the two air streams are kept separate, these exchangers can theoretically have zero transfer of odours, though in practice, plate heat exchangers, which are the most common type, typically have 1–3% recirculation due to internal leakage.

2.3.2 Plate heat exchangers

Plate heat exchangers consist of parallel plates (flat or corrugated) that separate the supply and exhaust air streams (Figure 4). If the plates' temperature drops below 0°C, ice can grow in the exhaust air paths in the exchanger, and it will eventually become blocked. When heat recovery is not desirable, in summer, a bypass damper may be used, or for small residential units, the exchanger may be replaced by one with only one plate ('summer cassette'). Due to condensation in the exchanger during winter, a condensate drain must be provided. The condensate must be protected from frost and have a gradient along its entire length, and must have a drain trap with sufficient height in relation to the maximal operating pressure within the AHU (Figure 6).

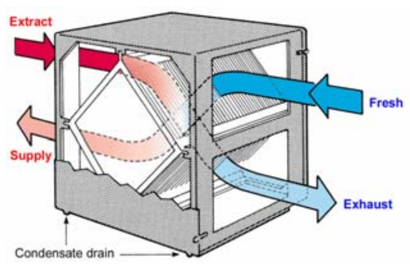


Figure 4: Cross-flow plate heat exchanger

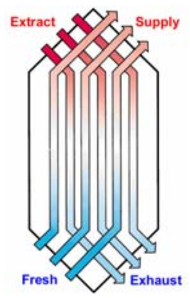


Figure 5: Principle of a contra-flow plate heat exchanger

Traditionally, cross-flow heat exchangers are the most common (Figure 4). Counter-flow heat exchangers (Figure 5) are a more recent development - they have higher recovery efficiency, but are more susceptible to frosting.

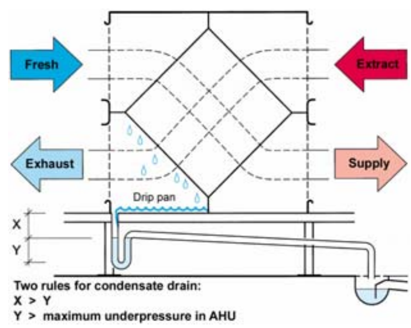


Figure 6: Correct condensation collection and drain trap

2.3.3 Tube heat exchangers

These function in much the same way as plate heat exchangers, where tubes replace plates. These are easier to clean than plate heat exchangers, and can be equipped with an automatic washing mechanism. The tubes can be made of glass, giving good corrosion resistance. The risk of becoming blocked due to frosting is less than plate heat exchangers, and the internal leakage is generally less.

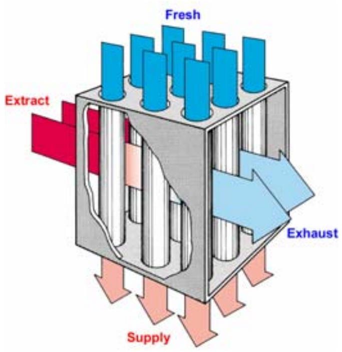


Figure 7: Tube heat exchanger

2.3.4 Run-around heat exchangers

These consist of two batteries (coils), one in each air stream, connected by a fluid circuit of water/glycol or water/alcohol (Figure 8). The concentration of glycol that is required [for frost protection] depends on the temperature operating range, but is usually 30–40%. The heat recovery efficiency is reduced with increasing glycol concentration. In large systems, brine is used instead of water/glycol.

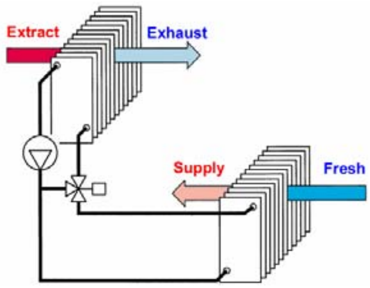


Figure 8: Run-around heat exchanger system

The advantage with this type of heat exchanger is that there can be a large distance between the supply and exhaust ducts, and heat can be reclaimed from multiple exhaust ducts by means of individual batteries. This system is appropriate in cases with heavily polluted extract air since there is no risk of air leakage from the exhaust to supply air streams (stainless steel, copper or plastic batteries give corrosion resistance). A 3-way valve is used to control the heat recovery efficiency - this is used for frost protection.

2.3.5 Heat-pipe

These function in much the same way as run-around heat exchangers. The working medium is a refrigerant that evaporates under heat and condenses when cooled. No pump is needed. The heat recovery efficiency is higher in colder weather. Heat recovery is controlled, if necessary, by a bypass. There are two types:

– **Vertical** heat pipes. See Figure 9.

– **Horizontal** (or slightly sloping) heat pipes are less common. Natural circulation is achieved by a wick inside the tube, along which the condensate is conducted.

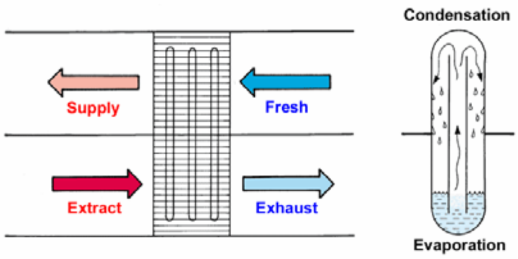


Figure 9: Vertical heat pipe

2.3.6 Heat-pump based heat-recovery

AHUs can have an in-built heat pump. The heat pump consists of two batteries (one in each air stream, just as a run-around) connected by a refrigerant circuit with a motorized compressor and a pressure reduction valve. The compressor's power consumption represents 20–30% of the heat extracted from the exhaust air stream, and is also released as heat in the supply air stream. Heat pumps do not transfer moisture. The heat recovery efficiency is normally controlled by regulating the compressor speed or by diverting gas from the compressor's pressure side to its suction side. Defrosting is done by periodical inverting or simply by changing the exhaust air set point to just over 0°C.

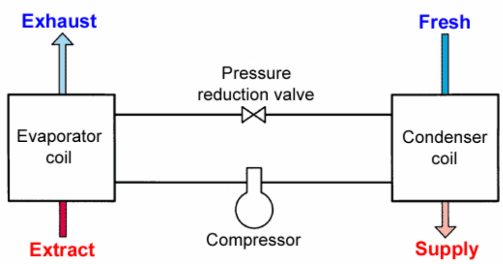


Figure 10: Heat pump based heat recovery. Cooling can be provided by changing pump direction, swapping the condenser and evaporator (requires two unidirectional pressure reduction valves)

Due to high installation cost, heat pumps are mostly used in buildings which need cooling, since the same system can be used for cooling in summer and heat reclaim in winter.

3 Moisture recovery and frost protection

3.1 Moisture recovery

Some heat recovery units recover water vapour (also known as 'enthalpy recovery'). These are mostly regenerative heat recovery units. Non-hygroscopic units recover moisture whenever condensation occurs, whilst hygroscopic units recover moisture under all conditions (with about the same efficiency for moisture & sensible heat).

Though normal recuperative heat exchangers do not recover moisture, some plate heat exchangers are constructed with materials that permit moisture diffusion through the plate walls (e.g. cellulose). Moisture recovery is normally used to reduce humidification costs in buildings where it is important to keep a high relative humidity in winter, such as paper and other industry, museums etc. For 'normal' buildings (dwellings, schools, offices etc.) moisture recovery is generally only appropriate in hot humid climates (where it can reduce dehumidification costs) or in very cold dry climates (where it reduces comfort problems related to dry indoor air below 25%RH). However, moisture recovery must be used with caution to avoid over-humidification indoors.

3.2 Frost protection

In cold weather, the water vapour in the extract air can fall below its dewpoint temperature and condense within the heat exchanger. Very dry exhaust air can have a dewpoint temperature below 0°C. Below 0°C the condensation freezes. The degree to which this ice causes operational problems depends on the type of heat exchanger and operating conditions. Ice poses less of a problem for regenerative heat exchangers, the due to the alternating air streams through the exchanger.

Frost protection is particularly important for [static] recuperative heat exchangers of high efficiency, especially when the extract air is moist (swimming pools) and in cold climates. Common frost protection methods are: bypass, preheat, periodic stopping of the supply fan.

Recuperative units need a condensate drain, whilst regenerative units generally do not. The heat recovery efficiency is reduced whenever frost protection is active (Figure 13), so it is used only when necessary. If a preheat battery is used, it should have sufficient capacity for expected coldest outdoor temperatures. Frost protection should be controlled automatically, e.g. with a humidity or temperature sensor to detect the conditions that cause ice growth.

4 Heat recovery performance

4.1 Definitions of heat recovery efficiency

The efficiency of a heat recovery system must be known in order to calculate its energy savings and profitability.

There are different definitions of efficiency for heat exchangers, depending on where you define the system boundary, i.e. either the heat exchanger itself, or the AHU, or the entire ventilation system (Figure 11).

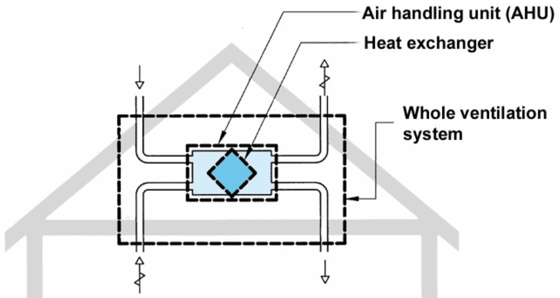


Figure 11: Illustration of nested system boundaries

Furthermore, efficiency can be measured for temperature (i.e. sensible enthalpy), moisture, or total enthalpy. It can also be measured under steady-state conditions or under varying conditions over a whole heating season (i.e. annual mean value). Some common definitions of efficiency are given below:

– **Heat exchanger sensible heat recovery efficiency**: the temperature ratio defined in Equation **1** [valid for balanced mass flows].

– **AHU net sensible heat recovery efficiency**: sensible heat recovery for the AHU as a whole, corrected for system losses (air leakages, recirculation, and the component of energy used by fans, defrost batteries etc. that is lost as heat in the exhaust). It is equal to the unit's exhaust temperature ratio (Equation 2) if the system is balanced and there is no condensation in the heat exchanger, and there is negligible recirculation from fresh to exhaust. For a more rigorous definition and equation, see ref.[2].

– **AHU supply temperature ratio** (Equation 3): This only gives an indication of the AHU's thermal comfort properties (i.e. supply temperature), and is not an accurate measure of heat recovery efficiency.

– **AHU net moisture recovery efficiency**: Same as Equation 2, but where humidity ratio [kg/kg] is measured instead of temperature. It accounts for recirculation. See also ref. [2].

– **AHU seasonal mean net heat recovery efficiency**: degree-day weighted mean value of AHU's net sensible heat recovery efficiency during heating season. It is based on measurements of heat recovery efficiency at different outdoor temperatures. It is valid for a specific combination of: (i) flow rate, (ii) local climate, and (iii) building's balance point temperature, which describes then the building's heating season starts/stops.

4.2 Measuring a heat exchanger's efficiency

The parameters in Equations **1**, 2 & 3 can be temperature [T °C], humidity ratio [w kg/kg], sensible enthalpy [T (1006+1805w) J/kg] or total enthalpy [T (1006+1805w) +2501000w J/kg].

$$\eta_{heatx} \approx \frac{T_2 - T_1}{T_3 - T_1} \qquad \text{(Equ.1)}$$

$$\eta_{\text{AHU-exhaust}} \approx \frac{T_r - T_e}{T_r - T_f} \qquad \text{(Equ.2)}$$

$$\eta_{\text{AHU-supply}} \approx \frac{T_s - T_f}{T_r - T_f} \qquad \text{(Equ.3)}$$

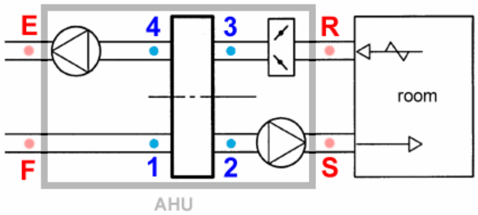


Figure 12: Measurement points for determining heat recovery efficiency

4.3 Seasonal mean net heat recovery efficiency

Figure 13 illustrates the influence of outdoor temperature on heat recovery efficiency of four different heat recovery units, all with ideal frost protection strategies.

In cold weather, condensation in the heat exchanger increases the sensible heat recovery efficiency. This effect is more pronounced for more efficient heat exchangers. However, at lower outdoor temperatures, and higher efficiencies, the condensation will freeze and block the unit. This is avoided by various frost protection strategies that reduce the heat recovery efficiency in cold weather (See also Section 3.2).

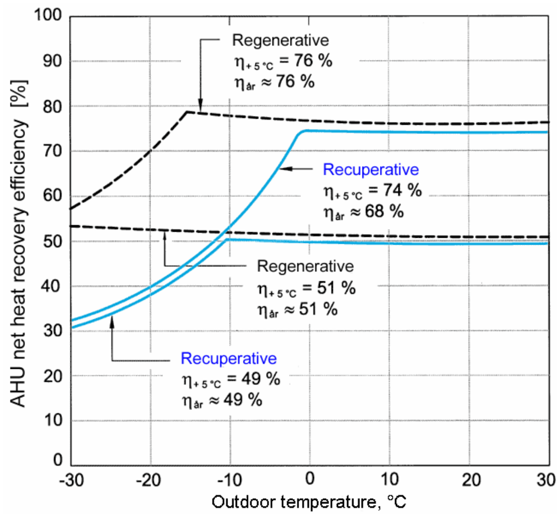


Figure 13: Illustration of the effect of outdoor temperature on heat recovery efficiency, for different types of heat exchanger, all with ideal frost protection.

The AHU's seasonal mean net heat recovery efficiency is used to calculate annual savings in heating costs. It can be calculated with the help of an annual distribution curve for outdoor temperature. The mean efficiency during the heating season is practically equal to the degree-day weighted mean value of the

AHU's net sensible heat recovery efficiency during the season [with extract air temperature as base]. The calculation method is described in [2].

Figure 14 and Figure 15 are examples of such distribution curves for a house and office building respectively. The blue curve (*supply air balance-point temperature*) is the supply air temperature above which space heating is not required, i.e. solar and internal gains (people, equipment) together with eventual heat recovery, are enough to keep the room temperature at the required level. The *supply air balance-point temperature* depends on the building's U-value, airtightness, and internal & solar gains. The four areas ① , ② , ❶ & ❷ represent four energy quantities:

– Area ① + ② + ❶ + ❷ represents the theoretical maximum energy loss due to ventilation without heat recovery.

– Area ① + ② is the part of the aforementioned ventilation heat loss that consists of internal & solar gains.

– Area ❶ + ❷ is the part of the aforementioned ventilation heat loss that is heat from bought energy if there is no heat recovery.

– Area ① + ❶ is heat that is recovered by the heat exchanger, of which ❶ represents savings in space heating costs, but ① does not lead cost savings, but merely overheating in summer.

– Area ❷ is bought energy to heat the supply air up to room temperature

– Area ❸ applies to buildings that have low internal gains relative to the heat losses, such that the supply air can be heated above room temperature in winter without causing overheating.

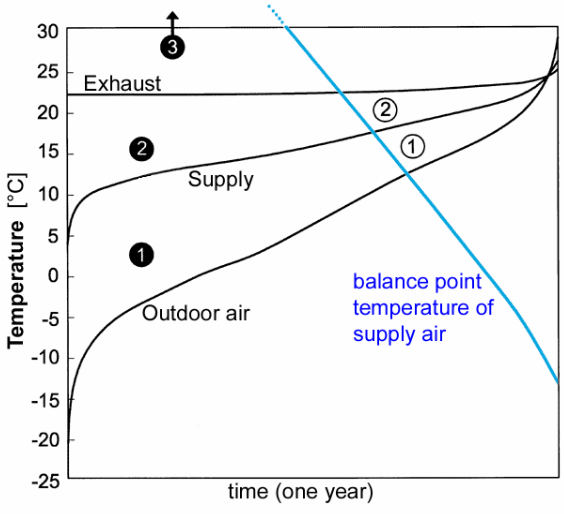


Figure 14: Annual temperature distribution curve, house

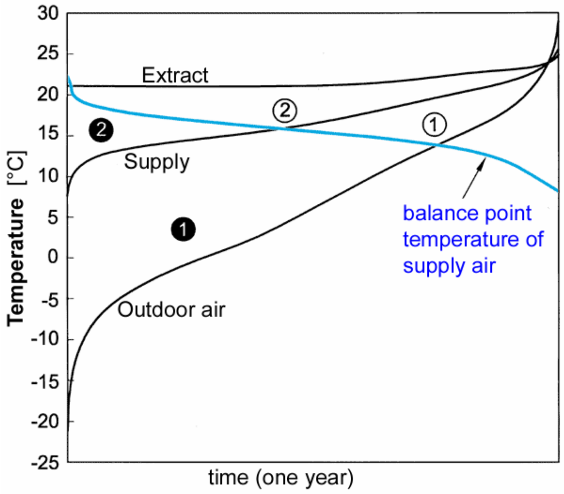
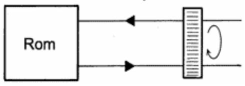
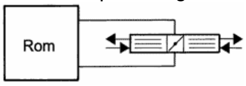
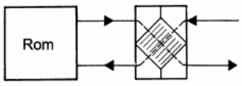
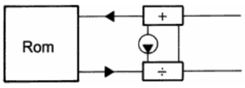
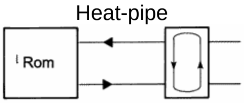
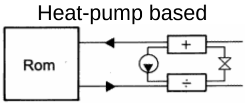


Figure 15: Annual temperature distribution curve, office

Table 1: Comparison of different types of heat recovery system for balanced ventilation

Type heat exchanger	* Relative installation cost	Supply temp. ratio (Equ.3)	Seasonal net efficiency	Controls (winter/ summer) & comments	Advantages	Disadvantages
Regenerative						
Rotary 	1.00	70~ 80%	50~ 70%	• Rotational speed control. • Bypass damper. • Moisture recovery efficiency with hygroscopic rotor: 70~85%.	• High heat recovery efficiency. • Can have equally high moisture recovery efficiency. • Efficiency easily controlled. • Frost protection not needed above approx –15°C (especially for dry indoor air).	• Risk of recirculation of odour & pollutants. • Risk of smoke spreading during fire. • Supply & exhaust ducts must be gathered to the same location. • Has moving components requiring maintenance. • Risk of fouling of rotor when static.
Reciprocating 	1.15	75~ 90%	70~ 85%	• Change alternating time interval. High efficiency at 1-minute intervals; longer intervals less efficiency.	• Highest heat recovery efficiency. • Can have reasonable moisture recovery efficiency. • Efficiency easily controlled. • Frost protection not needed above approx –15°C (especially for dry indoor air). • Damper is the only moving component.	• Risk of recirculation of odour & pollutants. • Risk of smoke spreading during fire. • Supply & exhaust ducts must be gathered to the same location. • Large space requirement. • Must be located adjacent to external wall.
Recuperative						
Plate or pipe heat exchanger Plate : crossflow or contraflow 	1.05	Cross: 50~ 70% Contra 80~ 90%	45~ 60% 60~ 75%	• Bypass damper. • Some small units have replacement summer cassette.	• Minimal recirculation of odour & pollutants. • Bypass damper is only moving component. • Mechanically reliable. • Contraflow plate heat exchanger has high heat recovery efficiency.	• Supply & exhaust ducts must be gathered to the same location. • Bypass requires extra space. • Requires frost protection. • Must have condensate drain. • Risk of fire spreading.
Run-around 	1.45	50~ 65%	45~ 55%	• Change fluid flow rate. • Shunt bypass control of fluid flow. • Periodic stop of pump.	• Zero recirculation of odour & pollutants. • Supply & exhaust ducts can have different locations; relatively easy to install in existing buildings. • Heat recovery efficiency is easily controlled.	• Has moving components requiring maintenance. • Requires frost protection, and fluid must have antifreeze. • Requires piping between batteries.
Heat-pipe 	1.25	55~ 65%	50~ 55%	• Partly self-regulating. • Bypass damper. • Changing slope of heat pipes (applies to 'horizontal' type).	• Zero recirculation of odour & pollutants. • No moving components. • No pipe connections. • Less risk of freezing than plate heat exchanger due to more uniform temperature distribution.	• Supply & exhaust ducts must be gathered to the same location. • Requires frost protection. • Control of heat recovery efficiency is complicated. • Bypass requires extra space.
Heat-pump based 	2.0~ 3.0	60~ 80%	35~ 60%	• Control compressor power.	• Zero recirculation of odour & pollutants. • Supply & exhaust ducts can have different locations, if heat-pump system is split; relatively easy to install in existing buildings. • Can provide cooling in summer.	• Requires a lot of space. • Has moving components; higher risk of failure. • Control of heat recovery efficiency is complicated. • Requires frost protection (or limit cooling of exhaust to +5°C). • Risk of noise problems. • High investment and running costs.

5 Calculating energy savings and profitability

5.1 Savings in energy consumption

5.1.1 Accurate method

The energy savings provided by a heat recovery unit can be accurately estimated by using building thermal simulation software (such as EnergyPlus, ESPr, TRNSYS, BSim etc.). Ideally the software should be able to account for the change in heat recovery efficiency as a function of outdoor temperature (Figure 13). It is also important that one specifies the heat recovery efficiency correctly: If it models the individual components of the AHU separately (e.g. heat exchanger, fans, etc), then the *heat exchanger's sensible efficiency* has to be specified. If the model does not calculate fan power separately (this includes simpler methods such as EN 832), then the *AHU's net sensible heat recovery efficiency* should be used.

5.1.2 Simplified method

As an alternative to using software, the following simple equation may be used to estimate energy savings compared to natural ventilation:

$$kWh_{saved} = 3 \cdot n \cdot V \cdot \overline{\eta} \cdot k \cdot \left(22 - \overline{T}_u\right) \qquad \text{(Equ.4)}$$

where:

3 constant (= 1.2 kg/m³ × 1050 J/kgK × 0.001 kW/W / 3600 s/h × 8760 h/år) [J/m³K]

n Mean air change rate during the heating season due to mechanical ventilation (infiltration not included). The mean value takes into account periods of reduced flow rate or no ventilation (e.g. nights, weekends) [h^{-1}]

V Ventilated building volume [m³]

η AHU's *seasonal mean net sensible heat recovery efficiency* at relevant air flow rate and local climate [fraction between 0.0 and 1.0]. For mechanical exhaust ventilation of dwellings (with no heat recovery) $\eta \approx 0.05$

T_u Annual mean outdoor temp. [°C]

k Fraction of recovered heat that constitutes a reduction in heating costs, i.e. not surplus heat [fraction 0 to 1]:

$$k \approx a\left(1 - b \cdot \overline{\eta}^3\right) \qquad \text{(Equ.5)}$$

Constants *a* and *b* depend on the building construction, use and internal/solar gains. See Table 2:

Table 2: Examples of values of constants 'a' and 'b' used in simplified estimation of energy savings, for Nordic climate with U-values: walls =0.22 W/m²K, windows =1.6 W/m²K, roof & ground =0.15 W/m²K

Building type	a	b
detached house	0.87	0.03
apartment	0.83	0.06
kindergarten	0.87	0.14
school	0.79	0.30
office building	0.77	0.27

5.1.3 Enthalpy or sensible heat recovery?

In buildings with central humidification, energy savings can be estimated by calculations based on total enthalpy recovery efficiency (See Section 4.2). However, simplified calculations using total enthalpy recovery efficiency can lead to overestimation of cost savings. It is preferable to conduct separate calculations of sensible heat savings (using *net sensible recovery efficiency*) and latent heat savings (using *net moisture recovery efficiency*) and to add the two. Latent heat calculations need only be done for buildings with central humidification (or equivalent) that has a lower running cost due to moisture recovery in the heat exchanger.

6 Choice of heat recovery for different building types

6.1 General

Choosing between different types of heat recovery system is a question of both profitability and functional qualities such as leakage (recirculation), moisture recovery, and frost protection (See *Table 1*). Fire safety can be a decisive factor in large buildings — to prevent risk of smoke & fire spreading via the ventilation system. Profitability increases with increasing flow rate and operational hours. Savings are greatest for swimming pools, industry and hospitals, less for offices, and least for dwellings.

6.2 Location & ductwork requirements

The best location for the AHU is in a dedicated plantroom or other technical room (washroom, store) or a warm loft with good access. The chosen location should also give a short duct system (especially the fresh air duct), and wide ducts. In cold climates, locating the AHU outdoors or in a cold loft (outside the building's insulation envelope) is not recommended. If the supply and exhaust ducts do not gather to the same location, then a run-around or split heat-pump system must be chosen. The fresh air and exhaust air ducts must always be insulated along their entire length, and the supply and extract ducts must be insulated where they pass through unheated or especially hot zones (e.g. attic). Duct insulation should be ≥ 50 mm, or 100~150 mm in especially cold climates.

6.3 Houses

Balanced ventilation with heat recovery provides the best combination of good air quality and energy efficiency in dwellings, especially multi-storey houses in cold climates. The house should be airtight (≤ 2 air changes at 50 Pa pressure blower door test). Special attention must be given to preventing noise (sound attenuator in the supply duct after the AHU, wide ducts ideally never less than 125mm∅, quiet supply diffusers) and draught problems (in cold climate a afterheat battery should be considered in cold climates to prevent the supply air temperature from falling significantly below approx. 17°C, and the set-point should not exceed 19°C).

6.4 Apartment buildings

In new apartment buildings, and existing buildings with balanced ventilation, heat recovery is almost standard today. For existing apartment buildings that were constructed with only an exhaust system, it is generally not profitable to install balanced ventilation with heat recovery due to lack of space for new supply ducts. In this case, it is more economic to install an exhaust air heat pump that can heat the domestic hot water or preheat water in the radiator heating system. Nevertheless, balanced ventilation ensures the best air quality and least draught problems.

6.5 Office buildings

Most office buildings now have balanced ventilation with heat recovery. If cooling is necessary, a heat pump heat recovery unit may be used, which can provide cooling in summer. Moisture recovery is generally recommended.

6.6 Hospitals

Continual operation combined with large flow rates, makes heat recovery very profitable. Both regenerative and recuperative types are pertinent, depending on the application. For ventilation of zones with a high risk of infection, regenerative heat exchangers must not be used, due to risk of recirculation — run-around or heat-pipe exchangers can rather be used.

6.7 Schools, Kindergartens, Halls

For buildings that are occupied for only a short part of the day, and have a high occupancy density (hence high internal gains), the profitability of heat recovery is less distinct. Moisture recovery could at times lead to too high humidity indoors so is not necessarily beneficial.

6.8 Industry

For industrial applications perhaps the greatest concern is the influence of pollutants, both on the reliability of the heat recovery system, and the risk of cross-contamination (recirculation). For rotary heat exchangers, the risk of cross-contamination can be reduced with a purge sector, and correct location of the fans (Figure 2). Dry particles pose less of a fouling risk than sticky particles. The rotary wheel is also protected by a filter on the extract air side. Measures against specific pollutants are described below:

– **Oil or fat vapours** can lead to significant dust accumulation at the front face of the heat exchanger as well as ducts. A filter must be placed in front of the heat exchanger. If the extract air contains oil aerosols with particles, the system must be designed for cleaning with solvents and pressure hose. Pipe heat exchangers are often the best choice.

– **Fibrous materials**, e.g. from textiles, mineral wool or glass fibre, can be removed with fine gauze in the extract duct. In addition, a normal filter should be located after the gauze.

– **Solvents**. Regenerative heat exchangers with hygroscopic or sorptive material must not be used if the extract air contains ammonia, formaldehyde or solvents. Even nonhygroscopic aluminium heat exchangers become increasingly hygroscopic over time due to fouling and oxidation of the aluminium.

– **Paint and lacquer**. The degree of fouling and blockage depends on the type of paint and how dry the particles are. Specialised filtration is required in the extract duct.

– **Salts** present a significant risk of corrosion. The AHU, together with the heat exchanger and condensate drain must be of a corrosion-resistant material.

– **Welding smoke**. Cleaning of the heat exchanger whenever necessary is the most economic strategy. Filtration of the extract air is of little practicability, due to rapid blocking. Cyclonic separators are an alternative. Rotary heat exchangers have good self-cleaning properties if they run continually.

7 Commissioning, operation and maintenance

7.1 Hand-over test

Heat exchangers should be checked as part of the hand-over procedure for the ventilation system. The choice of measurement method, and extent of the tests, depend on the size of the system, and should be specified in the. For larger AHUs the casing leakage should be documented and comply with limits set in EN 1886 [4]. Other tests for larger AHUs are described in EN 13053 [5]. Installation checks for residential units are described in EN 14134 [6]. The hand-over tests should also check if the controls and functioning. See for example [7].

7.2 Function testing

The heat exchanger's performance is normally checked by a simple measurement of the temperature ratio. This involves measuring the supply and exhaust flow rates, and measuring the air temperature in both air streams before and after the heat exchanger. Due to uneven temperature distribution in the heat exchanger, many temperature measurements must be made across the flow area. It is also possible to measure the temperature after a fan or other mixing device (subtracting the temperature rise through the fan). Measurements should be conducted under conditions that do not cause condensation in the heat exchanger.

For some types of heat exchanger, it is also appropriate to measure the moisture recovery efficiency. Other function tests include: measuring afterheat power, pressure drop, and ventilation noise level in some selected rooms and outside.

7.3 O&M instruction documentation

Reliable and economic functioning of the heat recovery system can only be achieved if there are good routines for operation, inspection and maintenance (O&M). This requires proper O&M documentation tailored for the individual ventilation system.

8 References

[1] *AIVC Technical Note 45: Air-to-Air Heat Recovery in Ventilation.* December 1994.

[2] *Nordtest method NT VVS 130: Air/air heat recovery units – Aerodynamic and thermal performance. www.nordtest.org*

[3] *EN 308. Heat exchangers – Test procedures for establishing performance of air to air and flue gases heat recovery devices*

[4] *EN 1886. Ventilation for buildings – Air handling units – Mechanical performance*

[5] *EN 13053. Ventilation for buildings – Air handling units – Ratings and performance for units, components and sections.*

[6] *EN 14134. Ventilation for buildings – Performance testing and installation checks for residential ventilation systems*

[7] *CIBSE Commissioning Code M: Commissioning Management* 2003. ISBN 1 903287 33 2 - *www.cibse.org*

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