Practical Guidance for Epidemic Operation of Energy Recovery Ventilation Systems
Authored by ASHRAE TC 5.5

June 9, 2020

Contents

Context for development of this Document

Statements of the ASHRAE Board of Directors, as found in the ASHRAE Position Document on Infectious Aerosols April 14, 2020:

> **Statement on airborne transmission of SARS-CoV-2:** Transmission of SARS-CoV-2 through the air is sufficiently likely that airborne exposure to the virus should be controlled. Changes to building operations, including the operation of heating, ventilating, and air-conditioning systems, can reduce airborne exposures.
>
> **Statement on operation of heating, ventilating, and air-conditioning systems to reduce SARS-CoV-2 transmission: Ventilation** and filtration provided by heating, ventilating, and air-conditioning systems can reduce the airborne concentration of SARS-CoV-2 and thus the risk of transmission through the air. Unconditioned spaces can cause thermal stress to people that may be directly life threatening and that may also lower resistance to infection. In general, disabling of heating, ventilating, and air-conditioning systems is not a recommended measure to reduce the transmission of the virus.

Given the need to control airborne exposure to SARS-CoV-2, what does a building operator need to know about Energy Recovery Ventilation (ERV) systems in their building?

The scope of ASHRAE TC05.05 is "…air-to-air heat exchangers, their application and cost benefit relationship. It includes consideration of the needs and procedures for standardization and testing, rating and terminology applicable to air-to-air energy recovery".

To prepare this guidance the TC made use of the expertise available within the committee membership, reached out to experts in other TCs, and worked to complement the efforts with ASHRAE and other organizations responding to the pandemic. In particular, the Building Readiness Team of the ASHRAE Epidemic Task Force was involved in the development of this document to be able to supplement their Building Readiness Guide that is providing practical guidance on building systems and how they need to be checked and or adjusted for operation. The Building Readiness guide has used excerpts from this document, but points to this guidance for additional level of detail and information.

Contributors from TC-5.5 to this document are listed in APPENDIX 3: Contributors.

The scope of this document is the operation of existing systems. (NOTE: **Bold** terms are defined in the Terminology Section.)

Many building HVAC systems include Energy Recovery **Ventilation** (ERV) systems, either stand-alone or integrated with Air-Handling Units (AHUs), Unitary Rooftop Units (RTU) or Direct Outside Air System (DOAS) units. Their purpose is (1) to facilitate or provide **Outdoor Air Ventilation** and (2) to reduce the energy use and system capacity required to condition that Outdoor air to comfort conditions.

There are many types of ERVs. Their descriptions can be found in HVAC Systems and Equipment ASHRAE Handbook Chapter 26 "Air-to-Air Energy Recovery Equipment". It is important to note that this document is focused on ERV units with exhaust and supply ducts co-located in the same cabinet. These include rotary wheel and fixed-plate heat or energy exchangers. (Heat pipe and thermosiphon heat exchangers sometimes are used in ventilators with co-located ducts in the same cabinet.) Any ERV ventilator with co-located ducts or compartments is potentially vulnerable to some degree of leakage between airstreams, whether at the exchanger or at leaks between the co-located ducts. The coil energy recovery (runaround) loops, heat pipes, and thermosiphon heat exchangers when built to provide distance, or a physical air gap between the two airstreams, are not.

Leakage from the exhaust airstream to the supply airstream, if it occurs within the energy exchanger portion of the **Ventilation** system, is referred to as **Exhaust Air Transfer (EAT)** (T-9). The rate of **EAT** into the **Supply Air** (T-1) is called the **Exhaust Air Transfer Rate (EATR)** (T-8). For manufacturers who participate in AHRI 1060, EAT/EATR is an independently certified performance rating.

Some ERV units or sections are designed to allow for as much as 5% or 10% **EATR**. This is within ASHRAE Standard 62.1 allowances and is the most energy-efficient for some spaces. ASHRAE Standard 62.1 is a minimum guideline meant to cover all systems. This technical documentation will provide additional best practice guidelines to exceed the minimum ASHRAE guidelines. ERV systems for other spaces such as healthcare facilities are designed to minimize EATR to negligible levels, see ASHRAE/ANSI/ASHE Standard 170-2017 Ventilation of Health Care Facilities [2]. When well-maintained and properly operated the **EAT** may be similar to or an order of magnitude less than the **Re-entrainment** (T-10) amount.

In many HVAC systems air from the space also is deliberately recirculated into the **Zone Supply Air** to the space so that the required heating and cooling can be provided. When HVAC systems include **Recirculated Air** (T-1), that typically is responsible for much more reintroduction of contaminated air from the space than is **EAT** in the ERV or **Re-entrainment**. Leakage also can exist between adjacent (co-located) ducts or compartments in air handling equipment. Finally, air exhausted from the building can be pulled back into the Outdoor air intakes through **Re-entrainment** (T-10).

Re-entrainment of contaminants from exhaust air occurs in all building design. ASHRAE 62.1 recommends that Class 1 exhaust be limited to 20% (dilution factor of 5) of the **Zone Supply Air**, and that class 2 exhaust be limited to 10% (dilution factor of 10) of the **Zone Supply Air**. ASHRAE RP 1635 and ASHRAE 62.1 Normative Appendix B provide guidance on how to calculate separation distances and modify dilution factors for specific job site or applications that could be applicable to various designs of HVAC systems which includes but are not limited to ERV and DOAS.

From RP 1635, dilution factor can be positively affected by some of the following basic principles:
1) an exhaust is pointed away from the Outdoor air intake.
2). The exhaust is not capped or redirected toward the Outdoor air inlet
3) Exhaust outlet is on a different wall relative to (i.e. hidden from) the outdoor inlet.
Each of these can be used in conjunction with one another to improve their impact on dilution. Using

the calculations in ASHRAE will allow you to calculate reasonable duct design extensions if the first 3 recommendations do not achieve the desired dilution affect.

General Recommendations

The TC5.5 ESTF position is that well-designed and well-maintained air-to-air energy recovery systems should remain operating in residences, commercial buildings and medical facilities during the COVID-19 pandemic. This is because maintaining at least normal **Outdoor Air Ventilation** rates, with proper temperature and humidity conditioning of the inside space, is important for maintaining health and combatting infectious bioaerosols.

Dilution of contaminants, including infectious aerosols, by outdoor air **Ventilation** is an integral IAQ strategy in ASHRAE Standard 62.1 Ventilation for Acceptable Indoor Air Quality [4][5]. A properly designed system also includes filtration in many forms, along with proper building pressurization controls.

However, when it is known or expected that an infectious outbreak has or will occur in a building, the ERV systems should be inspected for proper operation and condition and can be evaluated for any possible contribution of **Zone Return Air** with infectious bioaerosols to the building's **Zone Supply Air**. Practical advice is provided below (See APPENDIX 1: Estimating total return air recirculation in operational HVAC systems with ERVs).

The TC5.5 ESTF warns that changing the system operation settings without an effective understanding of the system likely will result in unintended consequences such as reduced **Outdoor Air Ventilation** rates or out-of-control indoor humidity conditions which may themselves favor the spread of viruses. When competent system operators are available, the most appropriate adjustment generally would be to continue operation of the ERV component appropriate to climate conditions, and to increase **Outdoor Air Ventilation** rates, which is consistent with both the April 3, 2020 REHVA COVID-19 guidance document [9] and the April 14,2020 ASHRAE Position Document – Infectious Aerosols [6].

The ASHRAE Position Document – Infectious Aerosols also recommends that increasing filter efficiency be considered. TC5.5 restricts its advice on this topic to the observation that increasing filter efficiency may lead to an initial reduction in airflow, or to earlier reduction in airflow due to filter fouling. Fan adjustments might be required, and static pressure regimes might change.Refer to the Building Readiness Guide for additional guidance in increased filtration.

The term "well-designed" in the context of this document means the supply and exhaust fan are located correctly for pressure control at the exchanger, that the ERV is sized for an appropriate velocity and pressure drop, and that appropriate seals or purges have been specified for the application. There is much more guidance in Chapter 26 Air-to-Air Energy Recovery Equipment of the ASHRAE Handbook [8] (online access to the Handbooks is free during the pandemic).

The term "well-maintained" assumes that the well-designed ERV device was installed and set-up correctly during the construction phase and has been properly maintained since then. (See practical advice for inspection in ERV exchanger on-site inspection)

In an epidemic environment, it must be recognized that even if the units and systems are designed properly, they must have been constructed and maintained properly to ensure they are not allowing excess transfer of exhaust air to supply air. It is also possible that the facility was not designed with epidemic conditions in mind. The facility maintenance team should do a check of their systems, in accordance to the manufacturer's guidance. That should include consulting the original engineer of record, a Commissioning Provider and a Test and Balance (TAB) agent if needed to determine the ERV device is functioning properly and as needed – which might not be the same as originally intended.

Notes on single-family residential systems

1. If no resident of the house is self-quarantining from other members of the household, continue to operate the ERV.
2. If a resident IS self-quarantining from other members of the household, the HVAC system needs to be modified such that no air from the quarantine space should be returning to the ERV or the air handler. This can be done by blocking off return registers in the quarantine space and improvising a system to exhaust air directly from the space to the Outdoor.
3. The remainder of this document does not necessarily apply to residential heat recovery units.

Notes on Medical Facilities

With respect to healthcare facilities, pressurization of spaces and ductwork and equipment is a significant tool in containment and is addressed by ANSI/ASHRAE/ASHE Standard 170-2017, Ventilation of Health Care Facilities[3] and, to some extent, ANSI/ASHRAE Standard 62.1-2019, Ventilation for Acceptable Indoor Air Quality[4]. Other critical spaces like labs have their own design guidelines, standards, regulations and recommendations. This pressurization of spaces is a significant and effective method used to reduce air movement from spaces with infectious aerosols into other spaces in order to reduce transmission. Similarly, differential pressurization the compartments adjacent to ERV exchangers are used when necessary to control **Exhaust Air Transfer** to negligible levels in HVAC systems. If in medical facilities it is thought that COVID-19 requires new infectious aerosol control strategies in non-critical-care areas, enhanced filtration of the **Zone Supply Air** will likely be the most effective adaptive strategy. When the **Ventilation** system design includes any air **Recirculation**, enhanced filtration of **Zone Supply Air** is critical with or without an ERV device.

Whether the ERV is being used in patient care area, converted space to patient care, or occupied non-patient areas, the unit should be inspected following the procedures below. An estimate of Exhaust Air Transfer for the ERV, **Re-entrainment** amount, and **Recirculation** with the HVAC system should be made, and the building operators should work in coordination with the hospital infection control team to determine whether to modify the operation of the ERV and/or the system.

Evaluation and on-site inspection of ERV systems in operational buildings

System Design Considerations

The energy-recovery wheel or plate exchanger is a sub-component of the overall system and any analysis should be made based upon the total system configuration.

HVAC Systems with Intentional Recirculation

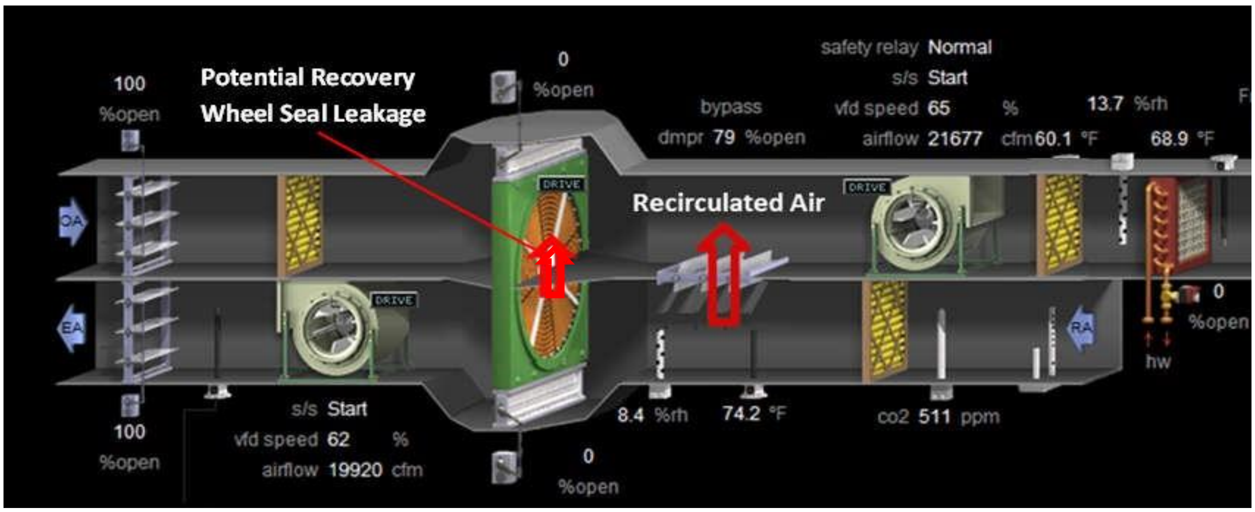


Figure 1 AHU Configuration with Recirculated Air and Energy Recovery Exchanger

If the ERV exchanger is installed in a system where the outdoor air portion of the total system airflow is being processed by the ERV, but a portion of the **Zone Return Air** is being **Recirculated** back to the space as shown in Figure 1 (as are most AHUs and Unitary RTUs) then turning off the wheel would do little to improve the **Zone Supply Air** quality since the **Exhaust Air Transfer** rate associated with the wheel would be small compared to the **Recirculation** rate.

However, if such a system can be operated as a 100% outdoor air unit, this mode of operation might be preferred when epidemic concerns exist. To accomplish this, the supply and return **Outdoor Air Ventilation** rates should be increased, the recirculation damper closed and temporarily sealed to minimize leakage, and the system balanced so that **Static Pressure Differential** is correct for the exchanger type. See the next section for a discussion of static pressures.

HVAC Systems with 100% Outdoor Air (No Recirculation)

If the recovery wheel is installed in a system that is processing 100% outdoor air (no intentional **Recirculation** of **Zone Return Air**) then the **system re-entrainment** and the **exchanger exhaust air transfer** following system operational parameters should be considered to establish and assess any relative source of cross-contamination associated with the energy recovery wheel in the system.

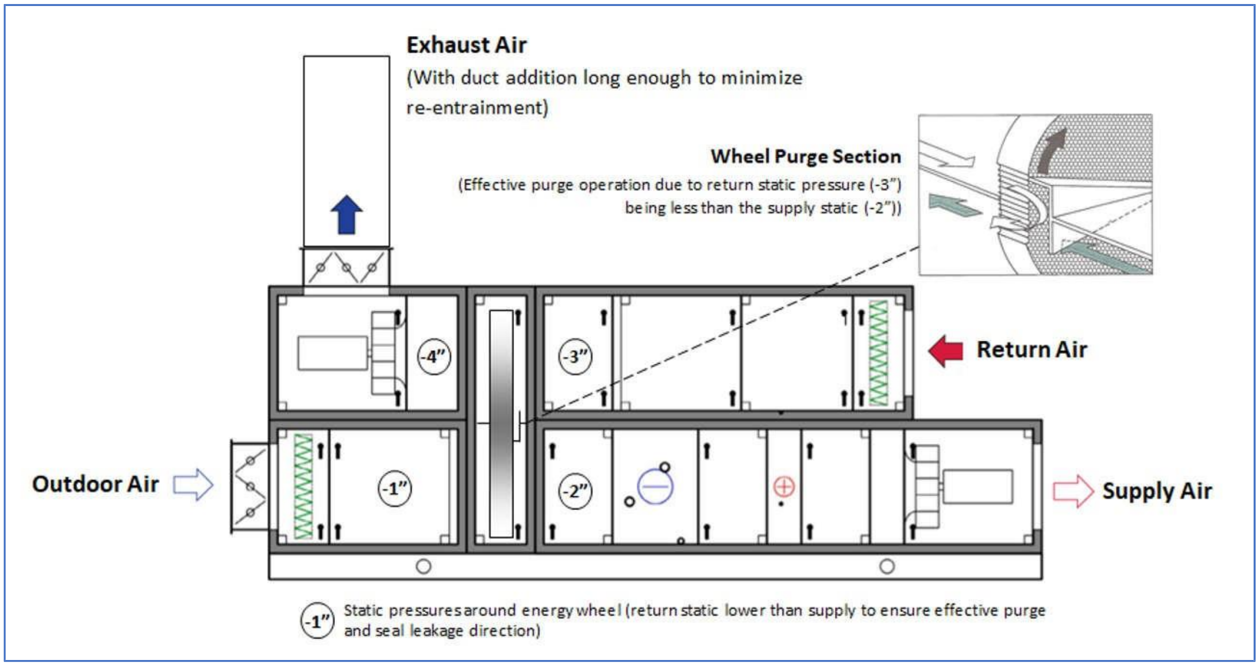


Figure 2 DOAS System designed for little or no EAT

1) Whether there is **exhaust air transfer** at an exchanger is strongly determined by the fan positioning in the energy recovery unit or HVAC system. In all fan arrangements, it is expected than the gross air flow of either the exhaust or supply fan will be greater than the air delivered or exhausted from the space to achieve a desired exhaust air transfer. Gross airflow and exhaust air transfer are also dependent on proper **Static Pressure Differential**. If the static pressure in the supply side of an exchanger is at least 0.5" greater than the static pressure in the return side air entering the energy recovery wheel, then any seal leakage will move from the clean to the dirty airstream and any carry-over will be insignificant. Under these pressures, energy wheels equipped with a properly installed purge section will have an EATR less than 1-3% and in some cases effectively approaching zero when laboratory or field measurement resolutions are taken into account. In some cases, this may be less than the **Re-entrainment** previously discussed.

   Exhaust Air Transfer can occur in ERV units or HVAC systems using plate exchangers, as well. In most cases the Exhaust Air Transfer rates are lower, and the driving forces are confined to the **Static Pressure Differentials** between the compartments adjacent to the exchanger.

   Figure 3 shows all the potential fan configurations used for energy recovery or DOAS systems. ERVs with fan Arrangement 4 should not be used since the seal leakage will always go from the dirty to the clean airstream and the purge section will not function; Exhaust Air Transfer ratio in excess of 10% will be typical. If such units are found, they should be shut down and alternate temporary means of ventilation should be provided until a properly configured ERV can be installed. Almost all energy recovery systems installed will employ either Arrangement 1 or Arrangement 2 shown in Figure 3, and both can be effective in limiting Exhaust Air Transfer provided that a proper minimum pressure differential exists between the return and supply airstreams. See also Figure 2 showing a DOAS system with fans in Arrangement 1.

2) If a system uses Arrangement 2, and if, for wheels, a purge section is in place and the wheel is rotating in the proper direction (discussed later) then it is almost certain that leakage will move in the desired direction and the purge section will function well with air carry-over being generally less than 1%, and therefore there is no need to measure to confirm system pressures except in the most critical applications. This arrangement works well for plate exchangers as well.

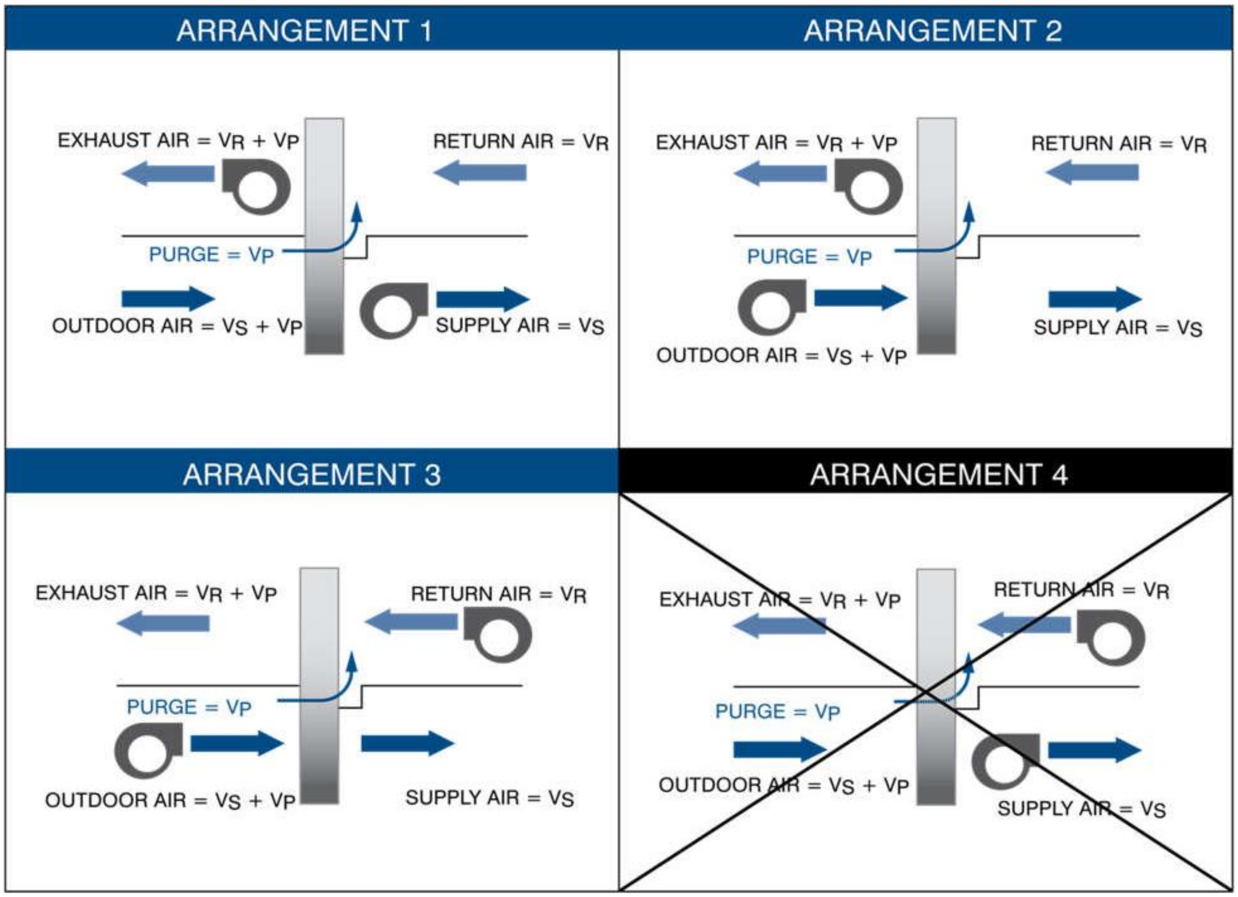


Figure 3 Fan arrangements for energy recovery exchangers

3) If a system uses Arrangement 1 or 3 shown in Figure 3, the static pressures at the inlets and outlets of the exchanger can be significantly impacted by pressure drops or rises caused by other components in the system including filters, ducts, and coils. The direction of leakage at the exchanger cannot be predicted without a determination of the **Static Pressure Differential** at the exchanger, but general trends, particularly with stand-alone ERV units, are as follows:
   a) With rooftop units which typically are ducted only at the exhaust air outlet and Supply Air inlet of the unit, static pressure at the exchanger **Entering Exhaust Airflow** is usually lower than at the **Entering Supply Airflow** rate, therefore leakage is from Outdoor air to exhaust air;
   b) For indoor units with ducts at both inlet and both outlets:
      i) When pressure drop between the unit and the building's inlet and outlet grilles are low compared to those on the other side of the unit, leakage at the exchanger again tends to be from supply to exhaust, resulting in no or low EATR;

ii) When pressure drop between the unit and the building's inlet and outlet grilles are high compared to those on the other side of the unit, leakage at the exchanger tends to be from exhaust to supply, and **Exhaust Air Transfer** occurs.

The above discussion is not intended as a substitute for inspection and validation that the ERV exchanger or unit is operating effectively, but as a guide to understanding the behavior of these systems an d the mechanisms by which air from the building can be reintroduced to its **Zone Supply Air**, intentionally or unintentionally.

ERV exchanger on-site inspection

Inspection process for all types and systems

This section provides the first steps in field inspection of ALL units or systems with ERV exchangers. With system documentation in-hand, if possible:

G-1. Clean the unit with a vacuum to facilitate inspection. It may be helpful to remove filters in order to inspect the exchanger(s).
WARNING: If it is thought that an ERV system might have been exposed to virus-laden aerosols, treat filters, exchangers and surfaces with the assumption they have active microbiological material on them. Use N95 respirators, gloves and other PPE; ventilate the space; and bag and dispose of the filters. Please see more here: (https://www.nafahq.org/covid-19-corona-virus-and-air-filtration-frequently-asked-questions-faqs).

G-2. Clean the exchanger surface as recommended by the manufacturer, or simply clean the exchanger with a vacuum and soft brush (use a HEPA vac if possible, and <u>always</u> if the unit is inside a building).
NOTE: Some exchangers can be washed, others cannot. Confirm with the heat exchanger manufacturer that the cleaning and disinfection solutions proposed to be used are compatible with the heat exchanger's frame and heat exchange media.

G-3. Check for gross leak paths between compartments that might result from age or deterioration. Check inside cabinet to see if light is coming in thru fastener holes or seams.

G-4. Check that the bypass and other damper are operating properly, not jammed, and that the damper seals are in good condition.

G-5. Determine the general layout of the system and identify the four compartments adjacent to the energy recovery exchanger, referring to Figure 8 for the standard designations. Also identify any bypasses between compartments.

G-6. Check filters: dirty filters affect airflows and pressure differentials.

G-7. Verify the outdoor air path is not obstructed (e.g. by clogged intake screen or louvers).

SP1	static pressure measured at **Entering Supply Airflow** Compartment 1
SP2	static pressure measured at **Leaving Supply Airflow** Compartment 2
SP3	static pressure measured at **Entering Exhaust Airflow** Compartment 3
SP4	static pressure measured at **Leaving Exhaust Air Airflow** Compartment 4

Table 1 Static Pressure Designations at Compartments adjacent to Exchanger

ERV exchanger on-site inspection: energy wheels

For a person not familiar with the energy recovery wheel devices, here are the first steps to take when inspecting a wheel for proper operation. Prepared, if possible, with the building systems documentation determine the following:

Inspection with System Turned Off (energy wheels)

W-1. Is the wheel clean?
A dirty wheel can affect both flow and leakage, which will change the operating characteristics of the fan system.

W-2. Is the wheel visibly damaged?
Look for areas of wear, loose or damaged media, or structural failure. These may affect the operation of the wheel and system.

W-3. Are the seals set properly?
Seals should be inspected for wear. Both contact seals and non-contact seals are common, consult the original manufacture to determine the proper setting. Older wheels that rely on seals that are in contact with the wheel surface may have seals that are worn or damaged.

W-4. Is the wheel equipped with a purge?
If so, determine or estimate the purge angle, and whether the purge is adjustable. This information will be needed later if asking the manufacturer for an EATR rating.

Inspection with System Operating (energy wheels)

With the system running and any wheel bypasses closed, confirm and record the following information:

W-5. Is the wheel turning?
Many projects rely on the building management system or some other indicator, but the only sure way is to visually inspect.

W-6. Is the wheel rotating at the correct speed (RPM)?
An incorrect factory speed can be attributed to a replacement motor/pulley combination being used or an improperly programmed VFD.
(Note: since Exhaust Air Transfer is lower at reduced wheel rotation speeds, it is most important that actual wheel rotation speed not be higher than the designed speed.)

W-7. Is the wheel turning in the correct direction?
When the wheel is equipped with a purge section, the wheel must rotate in a specific direction, see Figure 4.

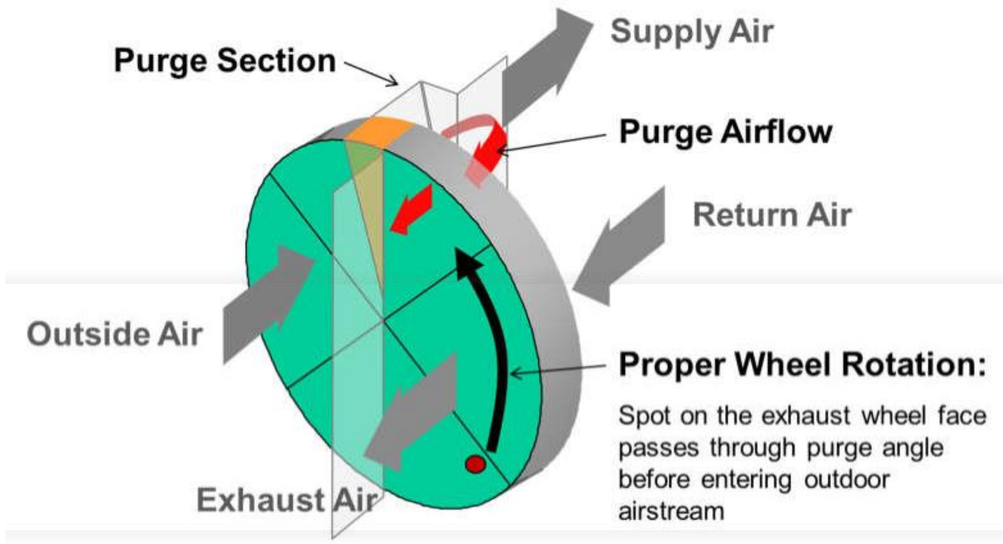


Figure 4 Illustration of the purge section and correct rotation direction for purge operation

W-8. With the ERV system operating normally with all bypass(es) closed, measure and record the static pressures in each of the four compartments around the exchanger. If the ERV has more than one operating mode, repeat this process. See also Figure 5 **Field Recording Sheet for ERV Exchanger Operating Parameters (Wheel)**.

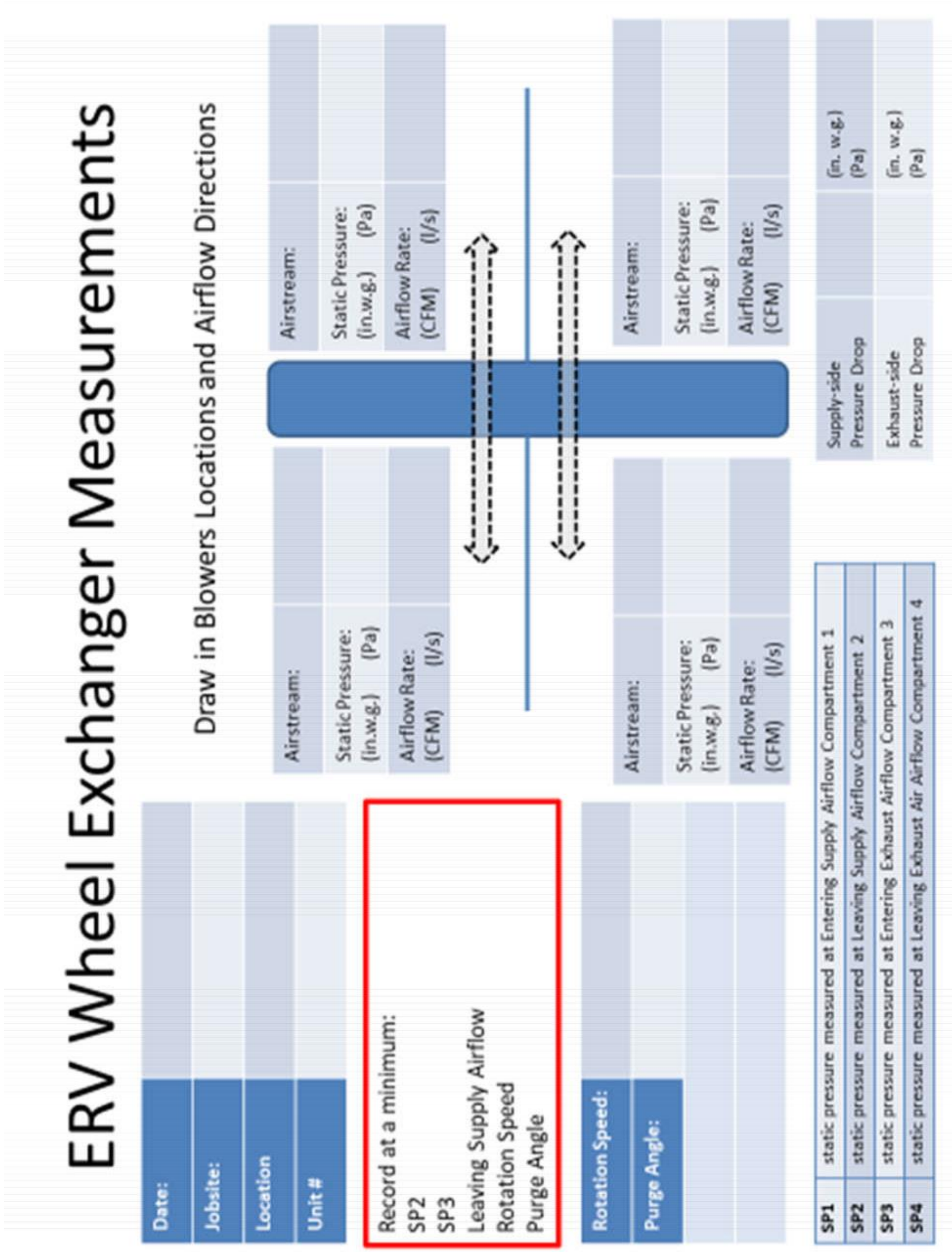


Figure 5 Field Recording Sheet for ERV Exchanger Operating Parameters (Wheel)

Evaluation for leakage (energy wheels)

A. **Leaving Supply Airflow** static pressure (SP2) should be at least 0.5 in. w.g. greater than the **Entering Exhaust Airflow** static pressure (SP3) measured near the wheel faces. This means there is a positive static pressure differential, pushing air from the supply to the exhaust.

B. Positive pressure differential means the pressure at the **Leaving Supply Airflow** outlet of the wheel is higher than the entering exhaust inlet of the wheel. As shown in Figure 6, this causes seal leakage in the desired direction: from supply air to the return air to be exhausted.

C. Pressure differential is frequently different than the original design anticipation, refer to the original commissioning report that identified pressure differential. If the static pressures have changed since commissioning, the EATR may be different than intended during design.

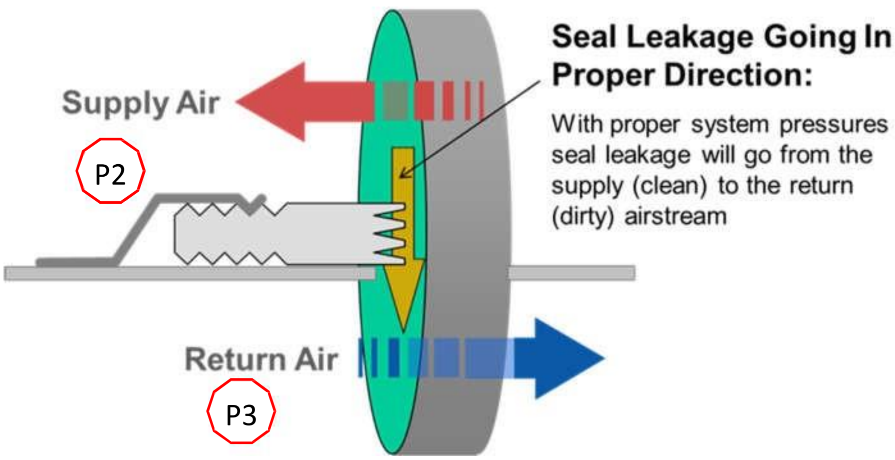


Figure 6 Supply static pressure should be higher than return static pressure.

D. If the **Static Pressure Differential** is not at least 0.5" (with SP2 > SP3), ask the ERV manufacturer for an EATR rating.
Provide at minimum:

SP2
SP3
Rotation Speed
Purge Angle (if one is used)
Leaving Supply Airflow Volume.

To determine the **Leaving Supply Airflow** Volume, measure it directly if possible.
Request the estimated *exhaust air transfer* as a volume rate (e.g. in CFM) at the specific operating condition.

ERV exchanger on-site inspection: plates

NOTE: this section also applies to Heat Pipe exchangers with co-located ducts

Inspection with system turned off (plates)

P-1. Clean the exchanger surface as recommended by the manufacturer, or simply clean the exchanger with a vacuum and soft brush (use a HEPA vac if possible, and always if the unit is inside a building). Some exchangers can be washed, others cannot.

P-2. Check the exchanger for any splits that connect adjacent compartments, shrinkage, or broken seals around the framing.

P-3. Determine the general layout of the system and identify the four compartments adjacent to the energy recovery exchanger. Also identify any bypasses between compartments.

Inspection with System Operating (plates)

P-4. With the ERV system operating normally with all bypass(es) closed, measure and record the static pressures in each of the four compartments around the exchanger. If the ERV has more than one operating mode, repeat this process.

P-5. Refer to Table 1 Static Pressure Designations at Compartments adjacent to Exchanger for a key to the static pressure designations. See also **Figure 7 Field Recording Sheet for ERV Exchanger Operating Parameters (Plate)**.

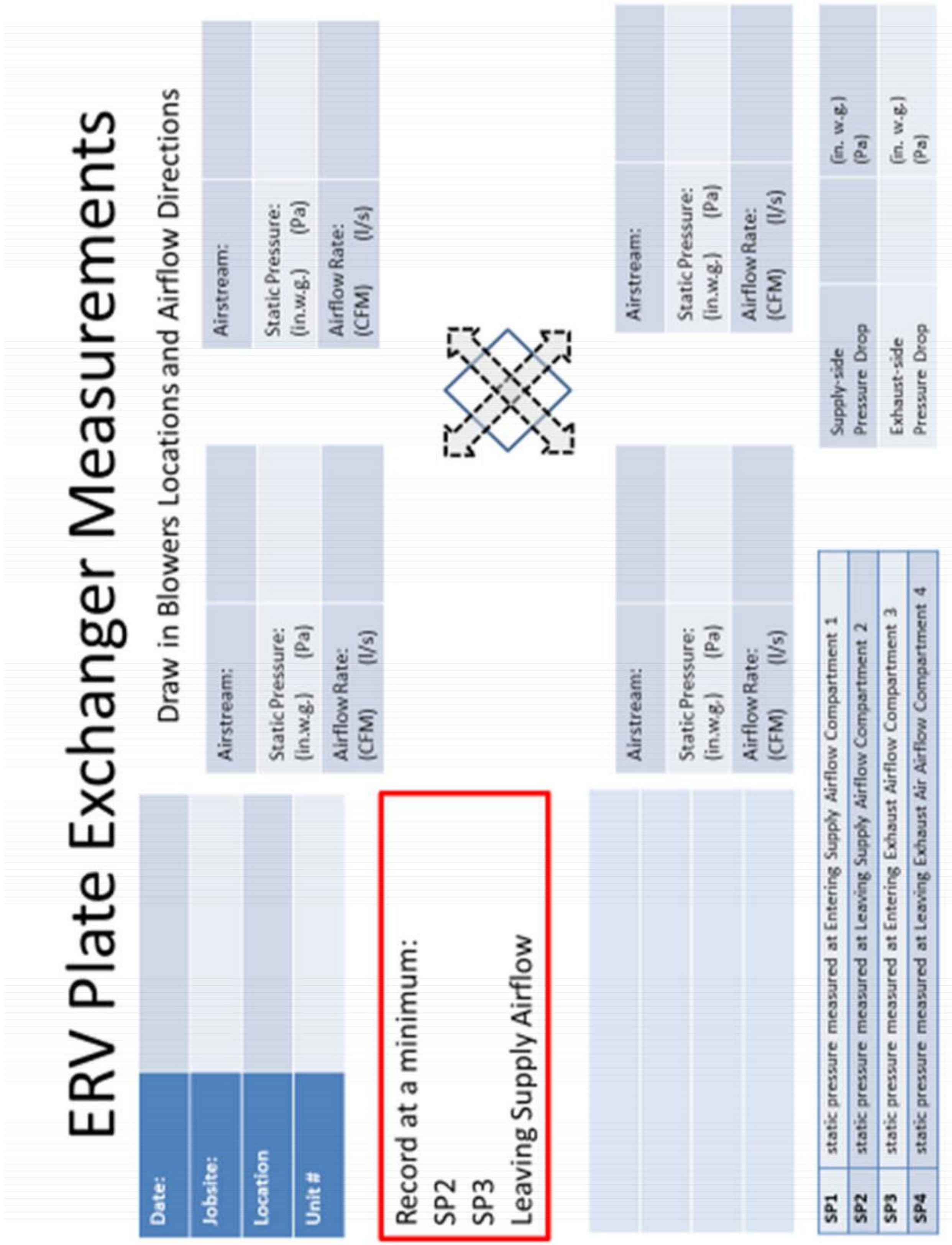
P-6. For each operating mode, measure or estimate the airflow rate in at least the ERV **Entering Exhaust Airflow** and the ERV **Leaving Supply Airflow** compartments.

Evaluation for leakage (plates)

A. SP1 should be higher than SP2. If not, there is no outdoor air flow, compartments are misidentified, or outdoor airflow is backwards.
B. SP3 should be higher than SP4. If not, there is no exhaust air flow, compartments are misidentified, or exhaust airflow is backwards.
C. If SP3 is greater than SP1 or SP2, there is a driving force for *exhaust air transfer* into the supply.
D. If SP4 is greater than SP1 or SP2, there is a driving force for *exhaust air transfer* into the supply.
E. If SP1 is a negative pressure, check again that the Outdoor air path is not obstructed (see G-7). After cleaning or replacing filters measure the pressures again.
F. If there is a driving force for *exhaust air transfer* to the supply (condition C or D), ask the ERV manufacturer for an EATR prediction. Provide at minimum:

    SP2
    SP3
    Leaving Supply Airflow Volume.
    (To determine the **Leaving Supply Airflow** Volume, measure it directly if possible.)
    Request the estimated **Exhaust Air Transfer** as a volume rate (e.g. in CFM) at the specific operating condition.

NOTE: Some manufacturers of plate exchanger units provide charts which correlate pressure differences between the inlet and outlet compartments to the flow rate. Describe the condition of the exchanger to the manufacturer and ask whether these charts remain valid.



ERV Plate Exchanger Measurements

Draw in Blowers Locations and Airflow Directions

Date:	
Jobsite:	
Location	
Unit #	

Record at a minimum:
SP2
SP3
Leaving Supply Airflow

Airstream:	
Static Pressure: (in.w.g.) (Pa)	
Airflow Rate: (CFM) (l/s)	

Airstream:	
Static Pressure: (in.w.g.) (Pa)	
Airflow Rate: (CFM) (l/s)	

Airstream:	
Static Pressure: (in.w.g.) (Pa)	
Airflow Rate: (CFM) (l/s)	

Airstream:	
Static Pressure: (in.w.g.) (Pa)	
Airflow Rate: (CFM) (l/s)	

Supply-side Pressure Drop		(in. w.g.) (Pa)
Exhaust-side Pressure Drop		(in. w.g.) (Pa)

SP1	static pressure measured at Entering Supply Airflow Compartment 1
SP2	static pressure measured at Leaving Supply Airflow Compartment 2
SP3	static pressure measured at Entering Exhaust Airflow Compartment 3
SP4	static pressure measured at Leaving Exhaust Air Airflow Compartment 4

Figure 7 Field Recording Sheet for ERV Exchanger Operating Parameters (Plate)

Units or Systems using Heat Pipes, Run-around loops and Thermosiphon exchangers with air gaps

When these systems are built with the supply and exhaust sides separated by a physical distance/air gap between the two airstreams, systems using coil energy recovery (runaround) loops, heat pipes, and thermosiphon heat exchangers will not have *Exhaust Air Transfer* into the supply airflow. They should be inspected to ensure that:

- airflows are being maintained at design levels,
- filters are in good condition,
- fluid flow rates are per design;
- refrigerant charges are correct.

Remediation of systems with ERV exchangers

If repair, remediation or modification of the system or the ERV exchangers is deemed necessary, additional considerations apply.

Overall System Considerations

R-1. In epidemic situations it generally is recommended (see ASHRAE's Building Readiness Guide) to increase **Outdoor Air Ventilation and operate ERV**, in order to increase dilution, while maintaining comfort conditions [6]. The ERV unit or exchanger may be able to accommodate this increase, check the manufacturers specifications and performance rating programs.

R-2. In epidemic situations it is recommended (see ASHRAE's Building Readiness Guide)to disable Demand Control Ventilation (DCV): that is, outside air ventilation should be maintained at maximum viable level. Note that operation of DCV controls can affect leakage in the ERV, by changing flow rates, see below.

R-3. Changes in supply and/or exhaust air flow rates will change pressure differentials at the exchanger.

   a. Decreasing **Entering Supply Airflow** can decrease pressure differential and subsequently increase leakage;

   b. Increasing exhaust flows should generally increase positive pressure differentials (Arrangement 1 and 2) thereby keeping leakage low.

R-4. The system's economizer mode should be properly interlocked with the ERV operation. When in economizer mode, airflows should be bypassing the exchanger.

R-5. If filters in the system are upgraded, the pressure drop through those filters may be higher, either initially or sooner than previously. Fan speed adjustments might be required to maintain airflows. Depending on where the filters are located, and whether fan speeds are adjusted, **Static Pressure Differential** at the exchanger could change, possibly changing EATR. Generally, increased filter pressure drop downstream of the ERV **Leaving Supply Airflow** outlet, or upstream of the ERV **Entering Exhaust Airflow** inlet, will increase the **Static Pressure Differential** and reduce the **EAT** rate, but this must be confirmed case-by-case.

ERV Exchanger or Unit Considerations

R-6. Wheels should have an independent certification like AHRI 1060 of which one of the certified parameters is EATR. EATR is variable depending on airflows, and as explained above, static pressure conditions at the inlets and outlets of the exchanger.

R-7. With certified exchangers the manufacturer should be able to provide correct EATR ratings at many different operating conditions.

R-8. Energy wheel seals typically can be adjusted for correct operation.

- a. Refer to manufacturer's operation and maintenance
- b. If it was commissioned at system start up this information should be in the documentation

R-9. Pros and Cons of adding a purge:

- c. Frequently wheels can achieve 5% or less leakage with proper pressure differential without use of a purge.
- d. Adding a purge can push EATR close to zero, but increases the energy consumption of the system.
- e. If a purge is added the operating characteristics of the fan, the airflows, and the pressure differential will change, required the system to be re-balanced for proper airflows and pressure differentials.

Increasing the Amount of Outdoor Air

If the amount of the **Outdoor Air Ventilation** in existing equipment is to be increased, contact the equipment manufacturer to confirm if this is viable and how to do it.

Many units are designed for airside economizing, so that in economizer mode the outdoor air volume is increased up to 100% of supply flow volume. If the equipment has this mode, the outdoor air could be increased with modification to the controls.

It may be possible to recover energy during this increased outdoor air mode, however if the exchanger was not designed for 100% supply flow volume, the additional air most likely needs to be bypassed around the exchanger.

Re-commissioning ERV systems after an extended building shut down

Step 1: Inspect exchanger

Wheels only: check wheel seals, verify wheel rotation and speed. If wheel motor is connected to a VFD, check variable speed drive for proper operation, and for proper wheel rotation direction. Follow recommendations from VFD manufacturer.

Step 2: Clean exchanger, <u>as recommended by manufacturer</u> (Note: wheel systems are more susceptible to getting dirty during an extended period of non-rotation.)

Step 3: Inspect cabinet, and damper seals

Step 4: change filters if necessary

Step 4: Operate fans and verify pressure differential in the air handling / RTU

Terminology

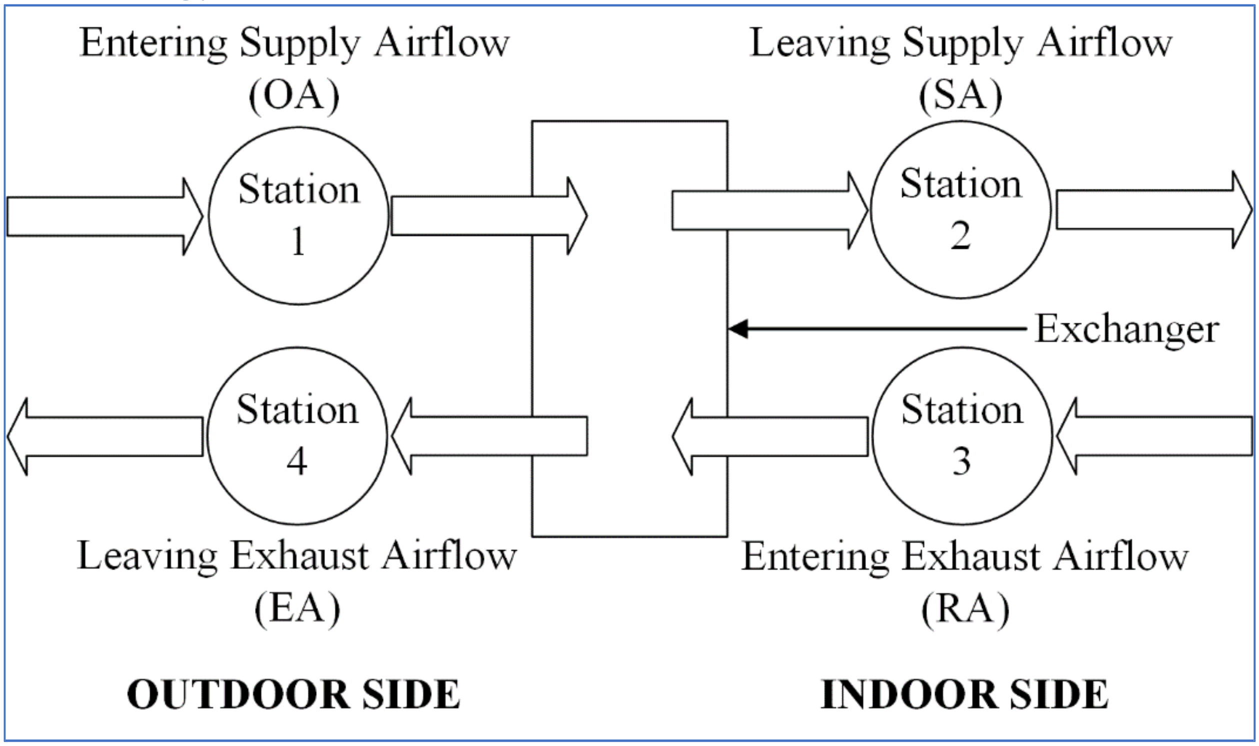


Figure 8 Standard Designation of Airflows at Exchanger

T-1. **Air, Recirculated**: air removed from a space and reused as supply air [4].

T-2. **Air, (Zone) Return**: air removed from a space to be recirculated or exhausted [4].

T-3. **Air, (Zone) Supply**: air delivered (to the zone served by the ERV) by mechanical or natural ventilation to a space and composed of any combination of outdoor air, recirculated air, or transfer air [4].

T-4. **Airflow, Entering Supply**: The supply airstream (outdoor air) before passing through the Exchanger, indicated in Figure 8 as Station 1 [1][7]. Also referred to as outdoor air (OA). The part of the enclosure in which this airstream enters the exchanger is also referred to as Compartment 1.

T-5. **Airflow, Leaving Supply**: The supply airstream (outdoor air) after passing through the Exchanger, indicated in Figure 8 as Station 2 [1][7]. Also referred to as supply air (SA). The part of the enclosure in which this airstream leaves the exchanger is also referred to as Compartment 2.

T-6. **Airflow, Entering Exhaust**: The exhaust airstream (indoor air) before passing through the Exchanger, indicated in Figure 8 as Station 3 [1][7]. Also referred to as return air (RA). The part of the enclosure in which this airstream enters the exchanger is also referred to as Compartment 3.

T-7. **Airflow, Leaving Exhaust**: The exhaust airstream (indoor air) after passing through the Exchanger, indicated in Figure 8 as Station 4 [1][7]. Also referred to as exhaust air (EA). The part of the enclosure in which this airstream leaves the exchanger is also referred to as Compartment 4.

T-8. **Exhaust Air Transfer Ratio** (**EATR**) [1][7]. The tracer gas concentration difference between the Leaving Supply Airflow and the Entering Supply Airflow divided by the tracer gas concentration difference between the Entering Exhaust Airflow and the Entering Supply Airflow at the 100% rated Airflows, expressed as a percentage. (Indicates the percentage of the Supply Airflow which originated as Exhaust air.)

T-9. **Exhaust Air Transfer** (**EAT**): The volume rate of air leaking from the Exhaust Airflow to the Leaving Supply Airflow.

T-10. **Outdoor Air Ventilation**: the process of supplying outdoor air to a space for the purpose of controlling levels in the air of contaminants produced in the space by dilution.

T-11. **Re-entrainment**: The unintended transfer of air from the Leaving Exhaust Air Outlet(s) and Outdoor Inlet(s) due to proximity of exhaust outlet(s) and outdoor air inlet(s), wind conditions, etc.

T-12. **Static Pressure Differential**: Static pressure at the Leaving Supply Airflow outlet minus the static pressure at the Entering Exhaust Airflow inlet [1].

T-13. **Ventilation**: the process of supplying air to or removing air from a space for the purpose of controlling air contaminant levels, humidity, or temperature within the space [4].

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[2] American Conference of Governmental Industrial Hygienists, 1998. Industrial Ventilation—A Manual of Recommended Practice, 23rd Edition. Equation 2.2, page 2-2.

[3] ASHRAE. 2017a. ANSI/ASHRAE/ASHE Standard 170-2017, Ventilation of Health Care Facilities. Atlanta: ASHRAE.

[4] ASHRAE. 2019a. ANSI/ASHRAE Standard 62.1-2019, Ventilation for Acceptable Indoor Air Quality. Atlanta: ASHRAE.

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APPENDIX 1: Estimating total return air recirculation in operational HVAC systems with ERVs

In the following examples both **EATR** and **Re-entrainment** are treated as quantified values. This is done to provide some context. However, as a practical matter, it will be easier to obtain an **EATR** rating for a specific ERV than it will be to estimate **Re-entrainment**.

EATR is tested and measured by manufacturers in order to establish their certified ratings, and these rating have been verified by hundreds of third-party tests at a variety of conditions.

On the other hand, re-entrainment volume, while it can be measured under specific weather conditions by tracer gas test, is specific to the building layout and is highly variable as a function of wind speed and direction. ASHRAE Research Project (RP) 1635 and ASHRAE 62.1 Normative Appendix B provide guidance on how to calculate separation distances and modify dilution factors for specific job sites or applications that could be applicable to various designs of HVAC systems which includes, but are not limited to, energy recovery ventilator (ERV) and dedicated outside air system (DOAS).

Example DOAS and other systems with no recirculation

In systems intended to include no recirculation of air back into the **Zone Supply Air**, the only two sources of transfer of exhaust air to **Zone Supply Air** are **Exhaust Air Transfer (EAT)** and outside-of-the-building exhaust air **Re-entrainment**.

Following are four hypothetical examples of calculations.

Calculation Procedures Examples 1 & 2 Units with Wheels

Procedure: as recommended above, obtain by field measurement and/or specification documents the information listed in Section **Evaluation for leakage (energy wheels)** ERV exchanger on-site inspection, item (D), and request an EATR rating under these operating conditions from the manufacturer.

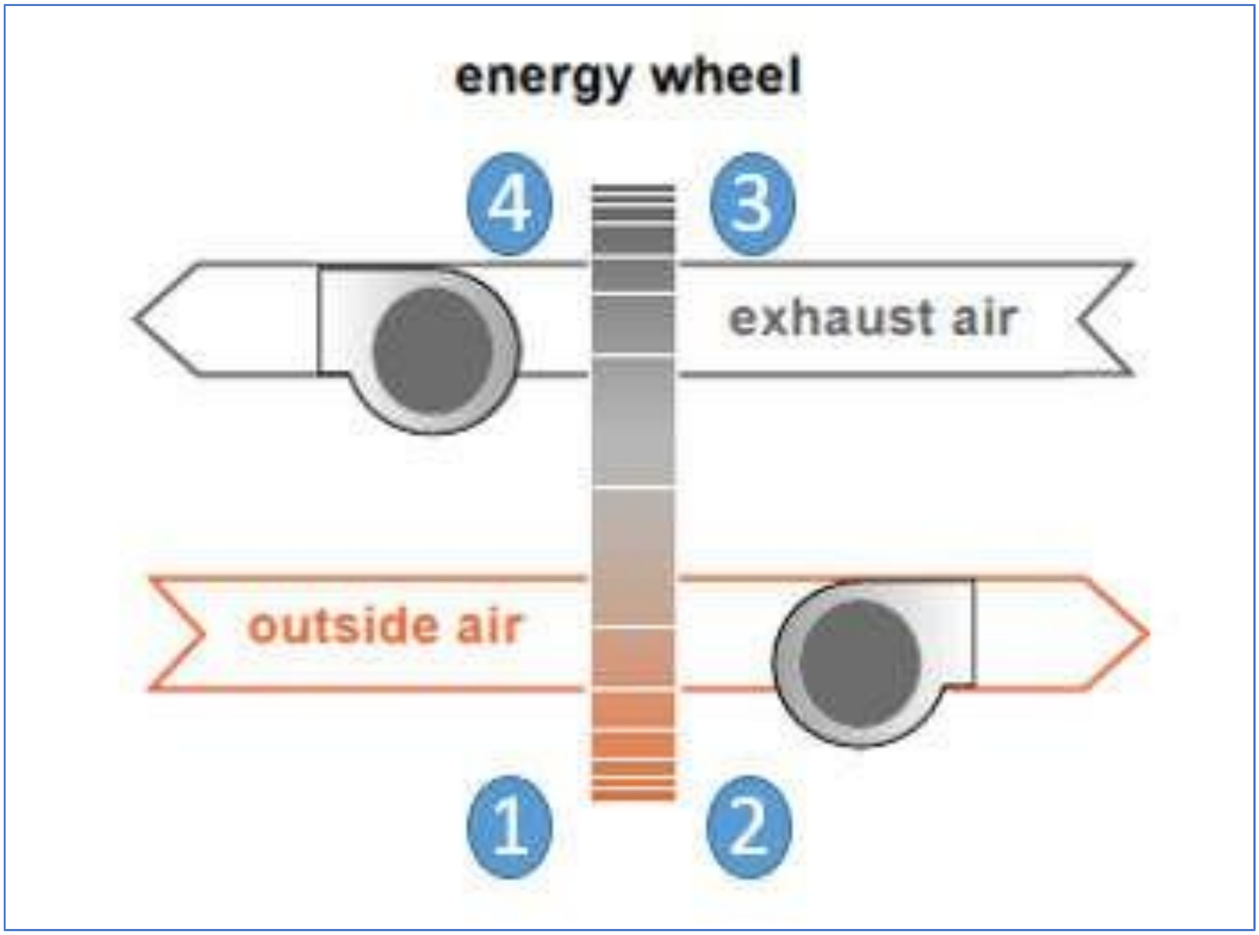

Figure 9 Airflow Layouts in Wheel Exchangers

NOTE: See also Table 1 Static Pressure Designations at Compartments adjacent to Exchanger.

WHEEL	Gross Supply Leaving Airflow (Station 2) (cfm)	Field Measurement of Static Pressures (in.w.g.)				Static Pressure Differential (in.w.g.)	Mfr. Ratings at Conditions
		SP1	SP2	SP3	SP4		EATR
Example 1	5000	-0.5	-1.25	-1.5	-2.25	+0.25	0.7%
Example 2	5000	-0.75	-1.5	-1	-1.75	-0.5	3.0%

In both examples it was possible to estimate the outside-of-the-building **Re-entrainment** ratio at the Outdoor air inlet.

In Example 1 the **Static Pressure Differential** is positive: there is no driving force for leakage at seals from exhaust to supply. The remaining leakage mechanism is carryover, which can be controlled by a purge; for purposes of this example the EATR is 0.7%.

The **Exhaust Air Flow** volume is calculated[8] as shown in Eq. 1:

$$EAT\,[cfm] = Q_2[cfm] \cdot \frac{EATR}{100} \qquad \text{[Eq. 1]}$$

where Q_2 is the Gross Supply Leaving Airflow at Station 2.

- The percent of **Leaving Supply Air** that originated as exhaust is directly expressed by the EATR rating (in this case 0.7%).
- The **Exhaust Air Transfer** rate in this example is 5000 · 0.7/100 = 35 [cfm]

In **Example 2** the **Static Pressure Differential** is negative, there is a driving force for leakage at seals from exhaust to supply, in addition to carryover. For purposes of this example the EATR is 3.0%.

- The percent of **Leaving Supply Air** that originated as exhaust is directly expressed by the EATR rating (in this case 3.0%).
- The **Exhaust Air Transfer** rate in this example is 5000 · 3/100 = 150 [cfm]

If for both examples the **Re-entrainment** amount had been estimated as a relatively low 2% of the 5000 CFM **Gross Supply Airflow**, or 100 CFM, in example 1 the **EAT** was less than the **Re-entrainment**, and in example 2 it was greater.

Calculation Procedures Examples 3 & 4 Units with Plate Exchangers

Procedure: as recommended above, obtain by field measurement and/or specification documents the information listed in Section **Evaluation for leakage (plates)**, item (**F**), and request an EATR rating under these operating conditions from the manufacturer.

If possible, estimate the site **Re-entrainment** as well (see general treatment of **Re-entrainment** in Sections C and System Design Considerations), and provide this information to the manufacturer as well.

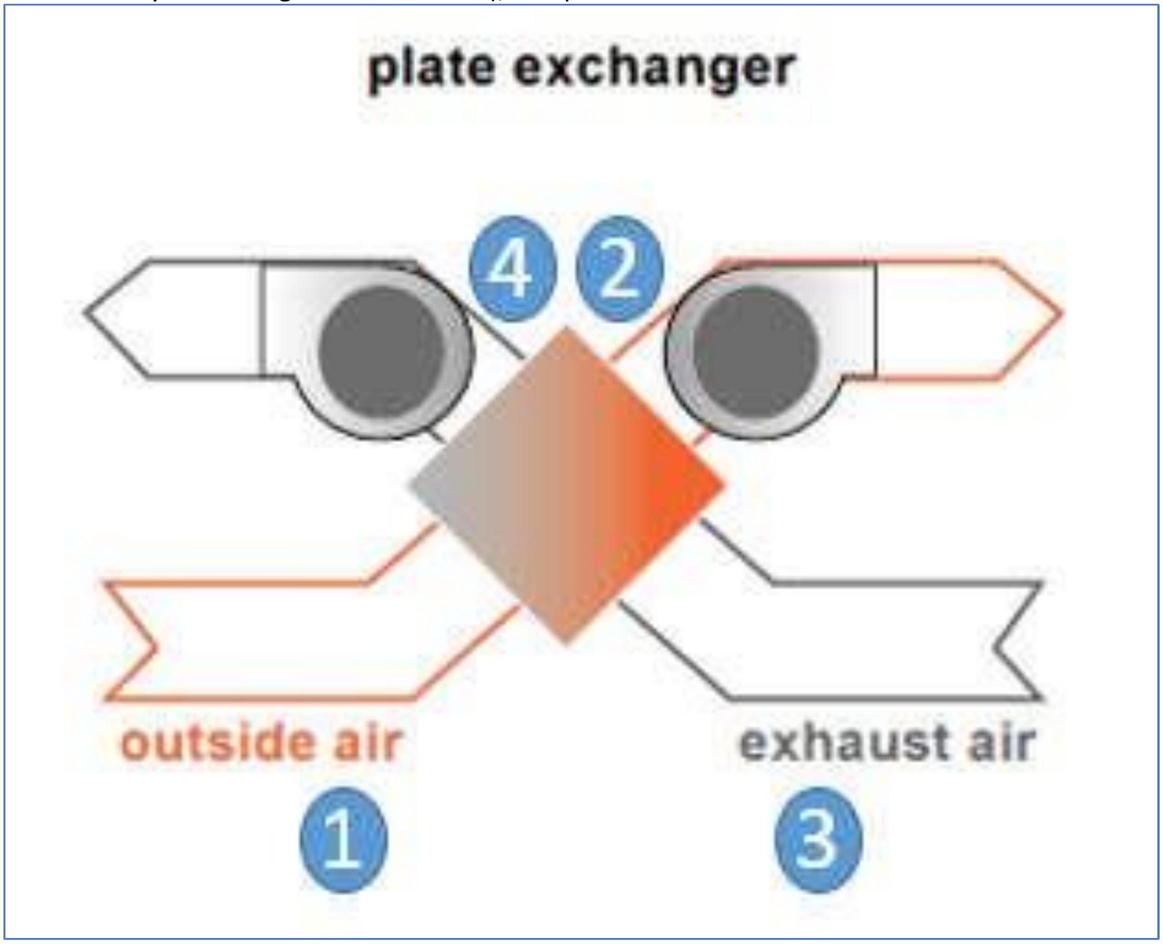

Figure 10 Airflow Layout Cross-flow Plate Exchangers

PLATE	Gross Supply Leaving Airflow (Station 2) (cfm)	Field Measurement of Static Pressures (in.w.g.)				Static Pressure Differential (in.w.g.)	Mfr. Ratings at Conditions
		SP1	SP2	SP3	SP4		EATR
Example 3	5000	-0.5	-1.25	-1.5	-2.25	+0.25	0.0%
Example 4	5000	-0.75	-1.5	-1	-1.75	-0.5	0.9%

In **Example 3** the **Static Pressure Differential** is positive: there is no driving force for leakage (there is no analogue for carryover in plate exchangers). Again using Eq. 1:

- The percent of Supply airflow that originated as exhaust is directly expressed by the EATR rating (in this case 0.0%) and the **Exhaust Air Transfer** rate is accordingly zero.

In **Example 4** the **Static Pressure Differential** is negative, there is a driving force for leakage at seals from exhaust to supply, in addition to carryover. For purposes of this example the EATR is 0.9%.

- The percent of Supply airflow that originated as exhaust is directly expressed by the EATR rating (in this case 0.9%).
- The **Exhaust Air Transfer** rate in this example is 5000 · 0.9/100 = 45 [cfm]

If for both examples the **Re-entrainment** amount had been estimated as a relatively low 2% of the 5000 CFM **Gross Supply Airflow**, or 100 CFM, in both examples **EAT** was less than the **Re-entrainment**.

Example Systems with Recirculated Air

If the air handler recirculates air from the space back to the supply air, the amount of exhaust air transfer at the ERV exchanger will have little impact on the quality of the system supply air. Current ASHRAE STD 62.1 allows for **Recirculation** amounts of 5-10% of the Outdoor air volume depending on exhaust classification. These allowances when applied in systems with recirculated air can be 10-20 times less than the downstream HVAC system. The ASHRAE 62.1 Standard is intended to be a minimum recommendation for all systems. Energy recovery components have an industry certification for **Recirculation** within the device: the EATR rating.

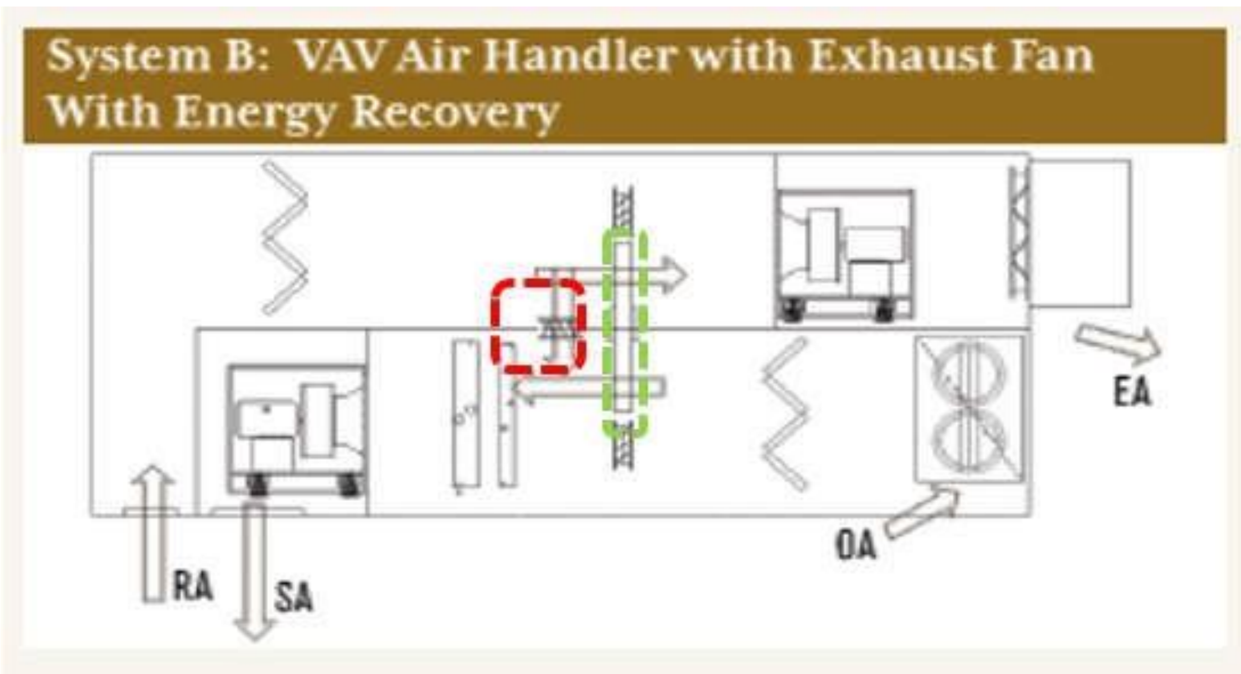

Figure 11 VAV AHU with Recirculation and ERV
Green shows ERV exchanger, Red shows recirculation damper.
Source: ASHRAE Journal May 2014

For System B (Figure 11), System C (Figure 12) or System D (Figure 13), if the ERV exhaust air is from the same space as the return air to the main air handler, refer to the equipment submittals to quantify the amount of air recirculated, as well as the supply airflow volume. The main air handler recirculates air as required to meet space load. Recirculated air could be as high as 85% of the supply air.

As an example, the energy wheel in System B (Figure 11) could be operating at the same airflows and static pressures as In Example 2 discussed above in Calculation Procedures Examples 1 & 2 Units with Wheels.

For purposes of this example, we assume:

Air Handler total supply airflow	25,000 CFM
Recirculation Air in AHU	20,000 CFM
Gross Supply Air from ERV	5000 CFM
As determined in Example 2:	
Exhaust Air Transfer	150 CFM
The total of **EAT** and **Recirculated Air** rates	**20,150 CFM**

of which 99% is due to the intentional system **Recirculation**.

If the **Re-entrainment** amount were to be estimated as a relatively low 10% of the 5000 CFM **Gross Supply Airflow**, or 500 CFM, the total of **EAT**, **Re-entrainment** and **Recirculated Air** would b 20,650, of which close to 97% would be the intentional **Re-circulation Air**.

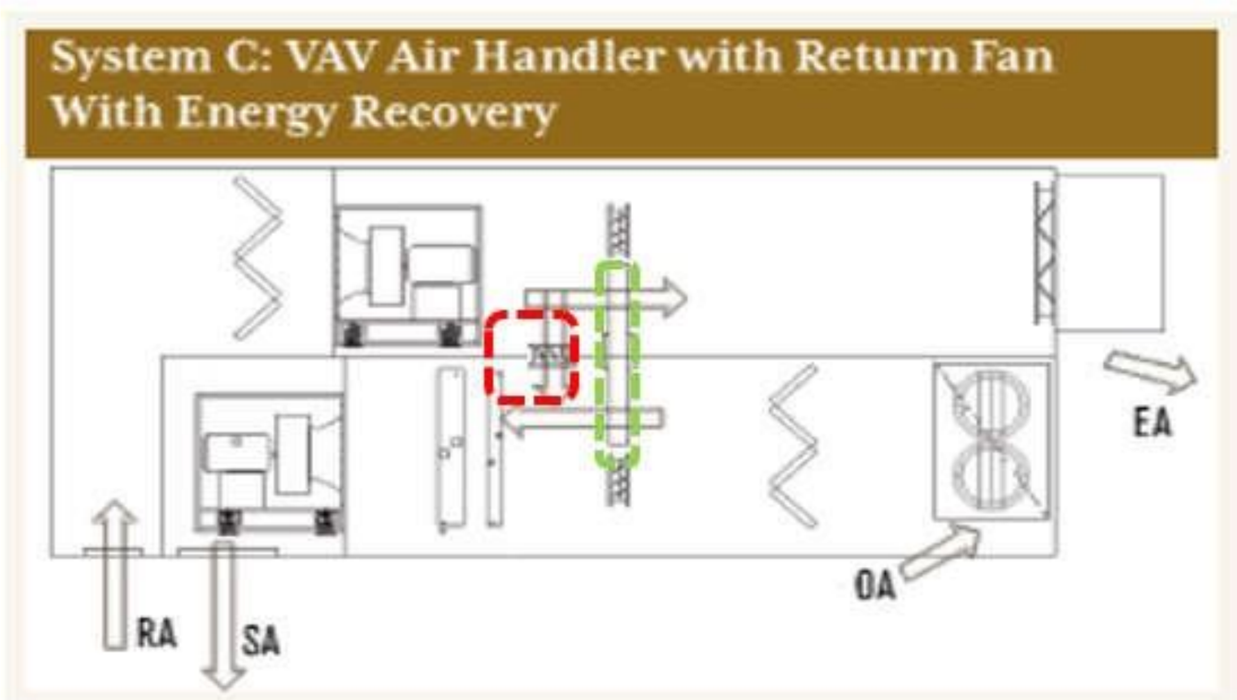

Figure 12 VAV AHU with Recirculation and ERV
Green shows ERV component, Red shows Recirculation damper.
Source: ASHRAE Journal May 2014

If as in system D (Figure 13) the ERV has an exhaust air path that is separate from the **Recirculated Air**, as shown, it is still possible calculate the amount of exhaust air transfer in the exchanger, and add that to the system **Recirculation**, as in the examples above.

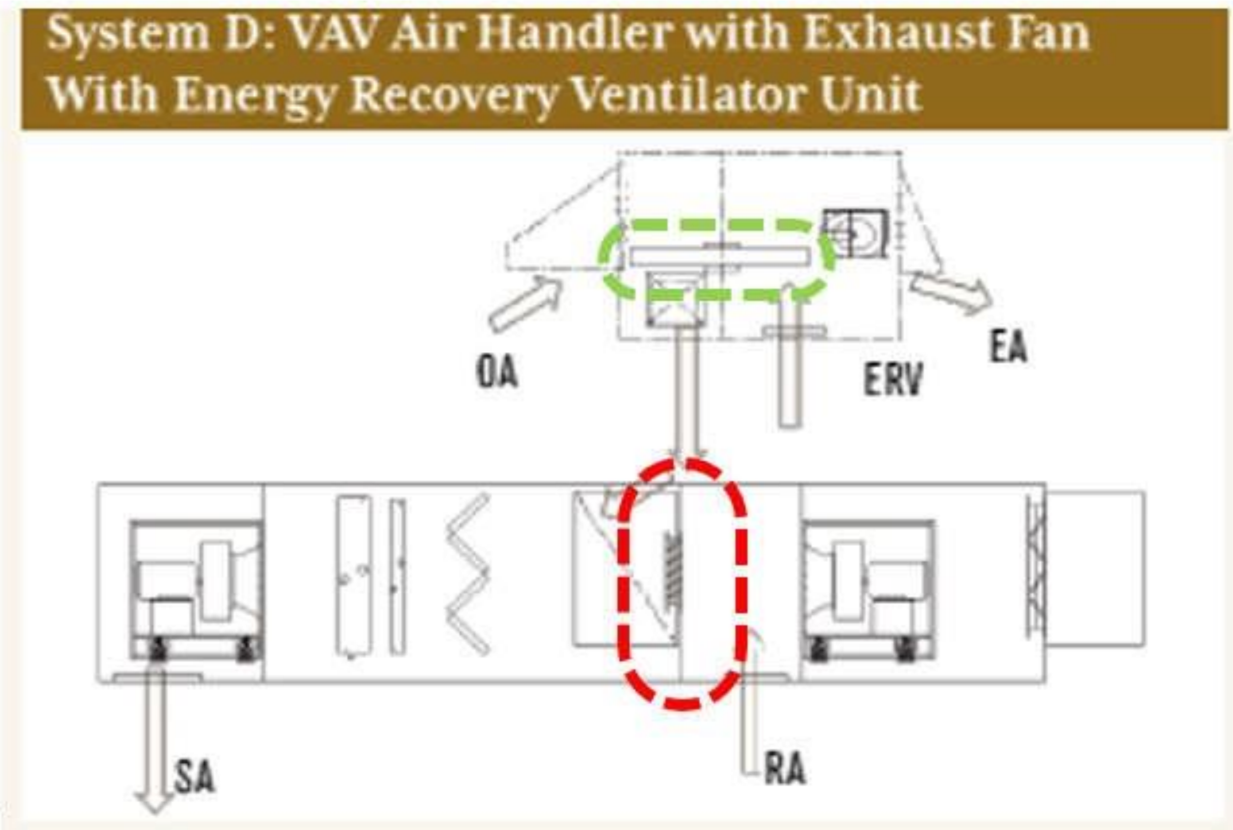

Figure 13 VAV AHU with Recirculation and separate ERV Unit
Green shows ERV component, Red shows Recirculation Mixing Box
Source: ASHRAE Journal May 2014

APPENDIX 2: Dilution principle in outdoor air ventilation

Increasing the outdoor ventilation air supply flow rate (sometimes called the ventilation make-up air flow rate) reduces the concentration of any airborne pollutant generated in the ventilated space, whether a vapor phase pollutant or suspended fine particles and aerosols. For the simple, steady state case (constant ventilation air flow rate and constant pollutant generation rate), the concentration of a pollutant will be inversely proportional to the ventilation air flow rate (reference). This is shown graphically in Figure 14. This assumes that the concentration of the pollutant(s) of interest is negligible in the Outdoor air (one obvious exception is carbon dioxide, which already exists in the Outdoor atmosphere at roughly 400 ppm) and that the supply air is well mixed with air in the ventilated space. When these assumptions are not correct the curve will be shifted, but the basic principal still applies – increased outdoor air ventilation air flow results in lower concentration of a given pollutant.

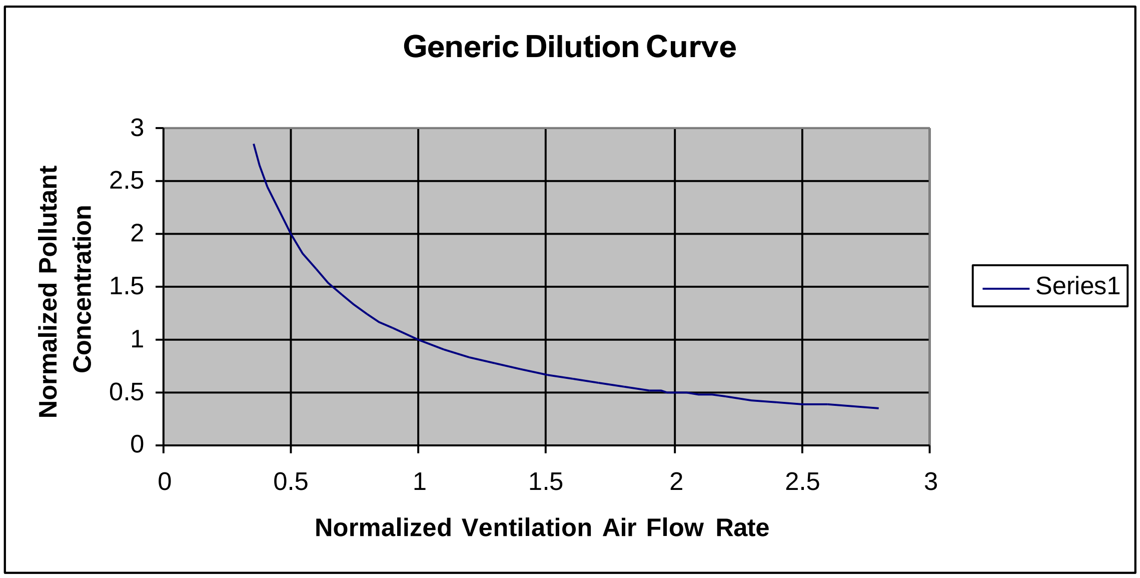

Figure 14 Generalized Dilution Curve

See also: *Industrial Ventilation—A Manual of Recommended Practice, 23rd Edition* [20]

APPENDIX 3: Contributors

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