Air-to-Air Cross Flow Flat Plate Heat Exchangers

An Introduction

Presented By

XeteX®

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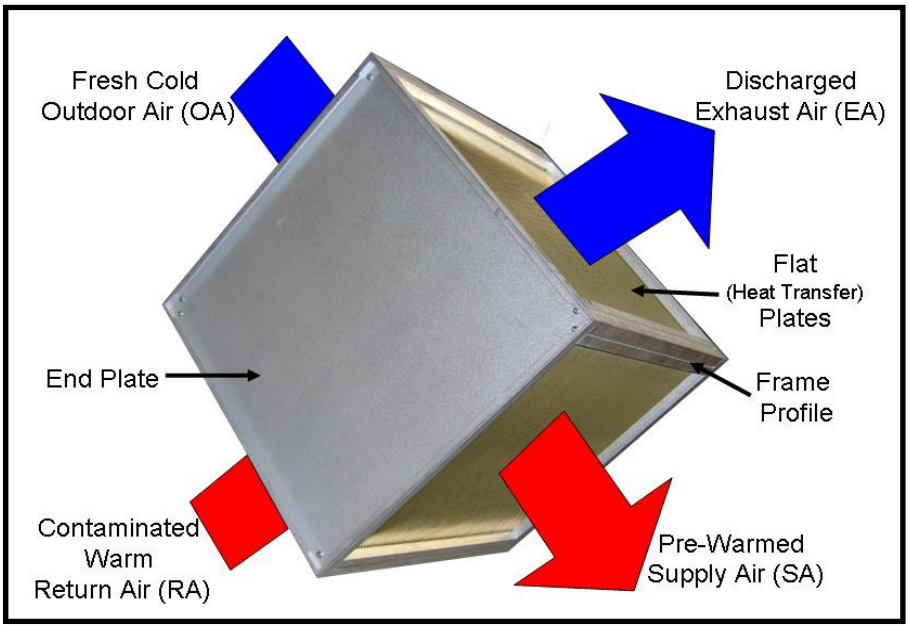
Purpose

The purpose of this document is to provide general information typically not found in product guides about air-to-air, cross-flow, flat-plate heat exchangers. Topics covered include condensation, fully developed air flows, freezing and frost control, leakage, pressure differentials, and dos and don'ts.

Introduction

In flat-plate heat exchangers, two airstreams cross by each other. In typical HVAC applications:

- One of these airstreams consists of air being removed from the ventilated space. The part of this airstream upstream of the exchanger is commonly called "return air." When it emerges from the opposite end of the exchanger, is called "exhaust air" and is typically discharged outdoors.
- The other airstream is the fresh outdoor air being supplied to the ventilated space. The air in this airstream upstream of the exchanger is called "outdoor air." On the opposite end of the exchanger, the fresh air flowing out is called "supply air" because it is supplied to the ventilated space.



Cross Flow Flat Plate Exchanger Basics—Heating Mode Depicted

The flat plates can be made of various materials (e.g. aluminum, plastic, resin coated paper, etc.). In the exchanger, they form a stack, aligned parallel to each other and separated by a certain spacing. The two airstreams flow through the channels formed between the flat plates. Each airstream flows into alternating channels—i.e., supply air in one channel, return air in the next, supply in the one after that, etc.—so while they pass near each other, they never mix.

Sensible energy from the warm air flowing through one side of the exchanger is transferred to the cold air flowing through the other. Some flat plate exchangers also transfer latent (moisture) energy from the high-vapour-pressure side to the low-pressure side of the plates.

In applications such as process cooling, the return air is used to pre-cool incoming fresh air. In non-HVAC applications such as equipment cooling, one air flow can operate in a closed-loop providing contaminate-free cooling, while the other airflow is simply scavenger air—outdoor air brought through the exchanger to cool the closed-loop air, then discarded outdoors.

Condensation in Heat Exchangers

Condensation occurs when an airstream containing water vapor is cooled down to the saturation point. Typically this occurs under winter conditions when heat from the return airstream is transferred to the supply airstream. At atmospheric pressure, the saturation point is determined by the temperature and water content of the air (relative humidity or absolute moisture content). As an example, the saturation point (i.e., condensation temperature) is given below for several dry bulb and moisture conditions.

Return Air Temperature	Relative Humidity	Absolute Moisture Content (lbm water/lbm dry air)	Condensation Temp
68 °F	40%	.0058	42.8 °F
68 °F	20%	.0029	25.5 °F
104 °F	20%	.0092	55 °F
212 °F	10%	.0690	115 °F

The first case above is a rather common value for the return air condition in HVAC applications. If the temperature of the outdoor air is 17.6 °F or below, an exchanger operating at 50% efficiency will cause the return air temperature to drop to the saturation point and water will condense in the exchanger. For more efficient exchangers (that transfer more heat), the outdoor temperature does not have to be as low for the return air to reach this point.

From a heat transfer perspective, condensation increases the exchanger's winter efficiency. When water condenses, it releases heat. When it condenses in an exchanger, some of this heat is transferred to the incoming outdoor air, providing more energy to warm the supply airstream. Although heavy condensation may cause an increase in pressure drop due to a slight narrowing of the air channels as water collects on the plate surfaces, this change is negligible.

Typically, selection programs take into consideration in their calculations the amount of moisture in the return air and the increased efficiency caused by condensation.

Condensate Design Guidelines

When designing systems with flat plate exchangers, it is important to take condensation into account. The heat exchanger should be oriented so that the condensing water can easily flow downward into a drain pan and out of the unit. Also, to ensure that no condensate leaks into the supply airstream, the pressure in the dry airstream should be higher than in the condensing airstream.

When the return airstream is configured to travel up through an exchanger, its velocity should be lower than 590 fpm. (At speeds below about 590 fpm, water will not be blown up through the exchanger by the velocity of the airstream.) In situations where there is a large volume of condensate, water can partially restrict the channels in an upward-flowing airstream causing the fans to pulsate. A downward return/exhaust airstream, working in the same direction as gravity, is the best way to ensure that water rapidly drains from the exchanger.

In applications with large amounts of condensation, limestone and other minerals or contaminants may deposit on the plate surfaces. Over time, this will influence the performance of the exchanger. Exchangers should, therefore, be positioned to provide access for cleaning.

Typically, return air containing corrosive vapors in moderate concentrations will not damage the heat exchanger surfaces unless condensation occurs. Even if, however, there is no condensation under normal operating conditions, it may occur during start-up or shut-down of the unit. It is therefore important to vent the unit thoroughly during start-up by sequencing the blowers so that the return air blower always starts first and stops last. This way, as it is just getting started, the moist return airstream never faces the fully-developed heat sink of the cold supply airstream. Backdraft dampers can also help protect the unit during out-of-service periods.

Fully Developed Airflows

It is very important to be aware that the vast majority of performance calculations (for efficiency, pressure drop, etc.) used by selection programs for air-to-air plate heat exchangers assume the following:

- The velocity profiles entering the heat exchanger are completely even, i.e. the airflow rate is uniform across the entire exchanger.

- The temperature profiles of the airstreams as they enter the heat exchanger are also completely even.

These are the only realistic conditions upon which a general calculation of air-to-air plate heat exchangers can be based. They also make it possible to compare the performance of different exchangers on an even basis. All deviations from these assumed conditions will reduce a heat exchanger's efficiency. It is very important to take this into account when designing an air handling unit.

An even velocity distribution is best achieved by avoiding sharp airflow bends immediately before and after the heat exchanger and by positioning the blowers on the exit side of the heat exchanger so they operate in a draw-through manner, i.e. pulling the air through the exchanger.

If the pressure drop that each airstream undergoes while passing through the heat exchanger is very low, the airflow through it may be uneven. In such cases, uniform air flow can be achieved by placing a filter bank, or another restriction that creates a pressure drop, just before the exchanger.

Other things to take into account in the design of an air handling unit are:

- Condensation—It is important that any condensate be able to leave the heat exchanger without restricting the air flow. Completely horizontal plates should be avoided.

- Leakage—Air that is bypassing the heat exchanger or leakage between the two airstreams in the heat exchanger will reduce performance and may also result in cross contamination of particles, odors, and condensate between the two airstreams. Preventing leakage requires a good seal between the heat exchanger frame and the air handling unit. It is also important that the internal leakage in the heat exchanger be as low as possible (see also "Leakage and Sealing of Heat Exchangers," below).

Freezing in Heat Exchangers

As described above, condensation occurs under winter conditions when the supply airstream takes enough heat from the return airstream to cool it down to the saturation point. Freezing occurs when this condensing water comes into contact with plate surfaces at or below 32 ^{o}F.

As described above, the saturation point of the return air depends on its temperature and relative humidity when it enters the heat exchanger. Air containing a lot of moisture will have a high saturation temperature.

In a cross flow heat exchanger the temperature distribution of the leaving air is naturally uneven. There will be one "warm" and one "cold" corner of the exchanger.

If freezing occurs, it will start in the cold corner, blocking one side of the return airflow channels. The blockage will slowly build and the exhaust airflow rate will gradually decrease. If nothing is done, this can continue until the return airflow channels are completely blocked. Although the ice (or snow) will normally not damage the exchanger, it will affect operation.

The outdoor air must be well below freezing to cool the return-air sides of the plates below 32 °F. As a rough rule of thumb, freezing will occur when the temperature of the outdoor air is below approximately 17^{o}F. (This assumes that the supply and return airflow rates are equal and that the return air contains enough water so that condensation will occur.)

Prevention of Freezing

Frost Control

The goal of a Frost Control System is to prevent frost, not get rid of it. Once frosting or icing begins, it grows rapidly if not immediately caught and controlled. When heavy frosting or icing occurs, it is recommended that the cold outside airflow be reduced or shut off while maintaining the warm return airflow to perform the defrosting. To prevent frost, a number of methods exist:

- Full Bypass—Bypass the cold outside air around the exchanger when it is below a certain temperature (e.g. 23 ^{o}F) and allow the warm return air to heat the exchanger.

- Face-and-Bypass—when the exhaust air temperature indicates that freezing can or is occurring, bypass just enough of the outdoor airstream to keep the return airstream just above freezing.
- Cold Corner Bypass—Mechanically block the air channels in a part of the heat exchanger to reduce the cold airflow in the cold corner of the exchanger.
- Traversing Frost Control—Temporarily block portions of the outdoor air channels and give these portions time to defrost.
- Pre-Heat—In very cold conditions, preheat the outdoor air before it enters the heat exchanger so that it is not cold enough to cause freezing in the return airstream.

It should be noted that highly efficient exchangers will transfer more heat away from the return airstream. This will both increase the amount of water condensing and lower the temperature in the return airstream, thus causing freezing to start faster than in low-efficiency exchangers.

Over a whole year, if the more efficient exchanger requires a significant amount of bypass to prevent freezing, it is therefore not always the case that more energy can be recovered with a higher-efficiency exchanger.

Air Flow Configurations

Configuration of air flows must be strongly considered, especially in colder climates or in high return air moisture applications. Refer to Appendix A—Air Flow Configurations in Cold, High Moisture Applications.

Heat Exchanger Materials and Corrosion Resistance

The following table is a guideline for choosing plate material when different substances are present in the airstream. We recommend that, when possible, actual tests be conducted to verify that the chosen material will work as expected.

Corrosion Resistance Table

Resistance to Corrosion at Normal Temperatures

A=Excellent, B=Good, C=Fair, D=Poor, *=No Information

Substance	*Aluminum*	*Epoxy Coated Aluminum*	*Stainless Steel 304*
Acetic Acid	A	A	A
Acetone	A	A	A
Ammonium Hydroxide	D	A	A
Ammonium Sulphate	C	A	A
Bakery Vapors	A	A	A
Beer	A	A	A
Benzene	A	*	A
Boric Acid	A	A	A
Calcium Chloride	B	A	C
Carbon Dioxide	A	A	A
Carbon Tetrachloride	B	*	C
Carbonic Acid	A	A	A
Chlorine, water	C	A	C
Chloroform	*	*	A
Chromic Acid	B	B	B
Citric Acid	B	A	A

Copper Cyanide	D	*	*
Creosote	*	*	*
Diesel Oil	A	A	A
Ethyl Alcohol	A	A	A
Ethylene Dichloride	*	*	*
Fatty Acids	B	A	A
Ferric Chloride	D	A	*
Fluorine Gas	D	*	D
Formaldehyde	*	A	A
Fruit Vapors	A	A	A
Fuel Oil	A	A	A
Gasoline	A	A	A
Glycerin	A	*	A
Glycol	A	*	A
Hydrochloric Acid	D	A	D
Hydrocyanic Acid	*	*	C
Hydrofluoric Acid	D	A	D
Hydrogen Peroxide	C	B	A
Hydrogen Sulphide	D	A	B
Jet Fuel	A	A	A
Kerosene	A	A	A
Lactic Acid	C	A	A
Lube Oils	A	A	A
Mercury	*	*	*
Milk	A	A	A
Mineral Thinner	A	*	A
Molasses	A	A	A
Nitric Acid	B	*	A
Oils & Fats	B	A	A
Oleic Acid	B	*	*
Oxalic Acid	C	*	C
Petroleum Oils	A	A	A
Phosphoric Acid	*	A	A
Photographic Chemicals	*	B	A
Potassium Permanganate	*	*	A
Silver Cyanide	*	*	*
Soaps	C	A	A
Sodium Hydroxide	D	B	A
Sodium Hypochlorite	D	B	C
Stearic acid	B	A	A
Sulphur Dioxide	D	D	A
Sulphuric Acid	C	B	A
Sulphurous Acid	C	A	A
Syrups	A	A	A
Tannic Acid	C	A	A
Tetrahydrofuorane	*	*	A
Toluene	A	A	A
Tricresylphosphate	B	*	A
Turpentine	A	B	A
Urine	D	B	A
Vegetable Oils	A	A	A
Vegetable Vapors	A	A	A
Vinegar	D	A	A
Vinyl Acetate	*	*	A
Water, Fresh	A	A	A
Water, salt	D	A	A
Whiskey	A	A	A
Wine	*	A	A
Xylene	A	*	A
Zinc Sulphate	D	A	B

The above information is accurate to the best of our knowledge and experience but no guarantee is expressed or implied.

Applications with Horizontal Installations

Internal stability of the plate structures will dictate the maximum possible span of a heat exchanger in a horizontal position. Exceeding the stated maximum span increases the risk of the plates settling or deforming under their internal weight. Settling and deformation can occur during normal operation, but is more likely during shipment as the unit experiences rough roads on a truck bed. Limits on module spans can be overcome by using multiple smaller exchangers (e.g., a 60" x 60" x 18" exchanger could be replaced by four 30" x 30" x 18" exchangers).

If heavy condensation is expected in the heat exchanger, it is important to make sure that the condensate can leave the heat exchanger without restricting airflow. Horizontal installations should generally be avoided in such applications. With normal condensation, however, installing the exchanger at an angle of 5.7° (i.e., 1' rise over 10' run) sloped down in the direction of the exhaust airflow will be enough to ensure proper condensate drainage.

Leakage and Sealing of Heat Exchangers

A perfect 100%-sealed flat plate heat exchanger is not possible to manufacture. The exchanger will always have some small amount of leakage. The design of the air handling unit should limit leakage from the return air side to the supply side. This is achieved by ensuring that the pressure in the supply airstream is higher than that in the return airstream.

Heat Exchangers in Hygienic Applications

One of the most important requirements when using a heat exchanger in a hygienic application is to have very low leakage from the return to the supply airstream.

Some exchangers use a sealing compound along their plate edges. Others have non-folded, sealed seams. Look for exchangers that have very low leakage (internally and externally), of around 0.1% of the nominal air flow at a pressure difference of 1.5 inches w.g.

For heat exchangers without special sealing, the typical maximum leakage (internally and externally) is about 1% of the nominal airflow at a pressure difference of 1.5 inches w.g.

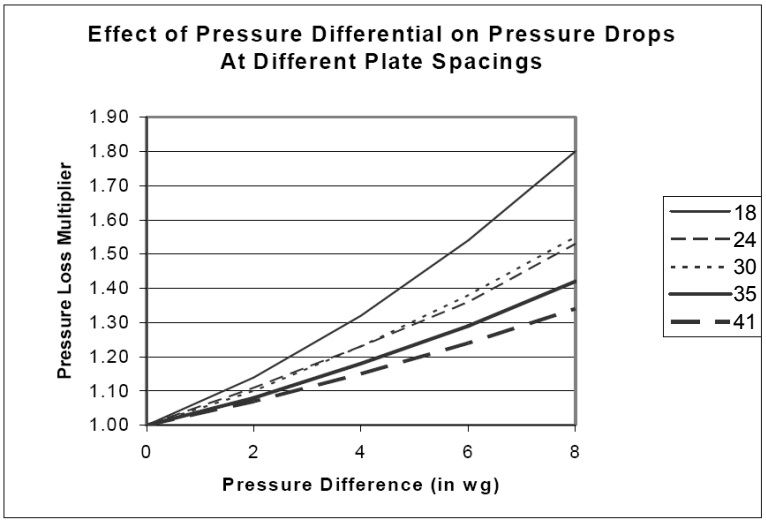
Pressure Differential

The *pressure drop* an airstream undergoes while traveling through a heat exchanger is dependent upon the air velocity in the exchanger channels and the channel geometry. *Pressure differential* is a different parameter. It is the difference between the pressures in the two airstreams that travel through the exchanger. If the plates (which form the channel walls) in the heat exchanger are subject to a differential pressure (e.g. the pressure is high in the return airstream and low in the outdoor airstream), this differential pressure will bend the plates. The amount of deflection will depend on plate material and thickness, plate design, how the plates are internally supported, and on the magnitude of the differential pressure itself.

When the pressure differential is great enough to bend the plates, the channels on one side of the exchanger (supply or return) will be narrower and the pressure drop through them will increase. The channels on the other side of the exchanger will be correspondingly wider and the pressure drop through them will decrease.

Selection programs implicitly assume that any plate deformation due to differential pressure is negligible. The effect of differential pressure for any particular application must, therefore, be separately considered when selecting a heat exchanger. For typical applications with a 1.0 inch w.g. pressure differential, the effect of plate deformation should actually be negligible and not require any further adjustments. At high differential pressures, however, estimated pressure drops should be adjusted.

The diagram below illustrates the effect of differential pressure on typical heat exchangers. This diagram is not provided as a basis for design. Rather, it is shown to demonstrate the general impact of differential pressures.



Pressure Differentials for Heat Exchangers

Pressure differentials that will permanently deform the plates in an air-to-air flat plate exchanger are to be avoided. The maximum differential pressure to which the exchanger will actually be subjected must never exceed the stated maximum value. This maximum value varies for different heat exchanger manufacturers and models. Consider the following example:

> The return airstream is drawn-through the exchanger by a downstream fan, so the pressure entering the heat exchanger is –1.6 inches w.g. Pressure drop in the heat exchanger is 1.28 inches w.g. so the pressure at the exhaust exit side is –2.88 inches w.g. (–1.6 – 1.28).
>
> The supply airstream is pushed-through the exchanger by an upstream fan so the pressure at the supply-side inlet is 3.37 inches w.g. The pressure drop in the heat exchanger is 1.06 inches w.g. so on the supply exit side the pressure is 2.3 inches w.g. (3.37 – 1.06).
>
> The maximum pressure difference at steady state and with both fans running in this case is 6.25 inches w.g. (+3.37 – (–2.88)).

Note that the fans will deliver a pressure that can be much higher than the design point if the they are allowed to start against closed dampers. Even if the design conditions are safe, the heat exchanger may then be submitted to pressures that are high enough to cause permanent damage.

In the following example both exhaust and supply side fans are arranged in a draw-through configuration:

> The return side pressure entering the heat exchanger is –1.6 inches w.g. Pressure drop in the heat exchanger is 1.28 inches w.g. so the pressure at the exhaust exit side is –2.88 inches w.g. (–1.6 – 1.28).
>
> On the supply side, pressure at the exchanger inlet is –1.04 inches w.g. and the pressure drop in the heat exchanger is 1.06 inches w.g. so on the supply exit side the pressure is –2.1 inches w.g. (–1.04 – 1.06).
>
> The maximum pressure difference at steady state and with both fans running is 1.85 inches w.g. (–1.04 – (–2.89)). With only the exhaust fan running, the maximum pressure difference is 2.89 inches w.g. (0 – 2.89) compared to ambient pressure.

Starting fans against closed dampers is still a concern, but the maximum pressure difference is lower with both fans pulling (or both pushing) instead of one fan pushing and one pulling air through the exchanger.

Again, all pressure differentials across the heat exchanger plates will cause the channels to deform. For small pressure differentials of 1 inch w.g. or less, the deflection in most exchanger plates will hardly be measurable. But at higher pressure differentials, the channel containing the higher pressure airstream will expand (lowering the pressure drop that airstream will experience traveling through the exchanger) and the channel containing the lower pressure airstream will contract (increasing the pressure drop it undergoes).

Heat Exchanger Selection

A wide variety of flat plate heat exchangers are available with numerous plate materials, designs, plate sizes, plate spacings, and widths. Engineers can therefore choose from several alternatives for performance (efficiency and pressure drop) for every application.

The selection and performance calculation are preferably made with a selection program. In order to make a good selection and to speed up the selection process, the following data should be provided and should be as accurate as possible.

Exhaust Air:

- Airflow rates (either at standard air conditions—1 atm and 68 °F—or at the actual temperatures of the airflows under consideration)
- Air temperature
- Moisture content (e.g., relative humidity, wet bulb temperature, etc.)

Supply Air:
- Same data as for exhaust air

Required performance:
- Expected efficiency
- Maximum allowed pressure drop in the heat exchanger (see above for more information about the effect of differential pressure on the pressure drop)

Restrictions Regarding Dimensions:
- Since space is often limited, the maximum allowed diagonal distance (or maximum allowed plate size) should be known before selecting an exchanger.
- Maximum allowed width of the heat exchanger should also be known.

With this data it will be possible to find one or several alternative exchangers that give the required performance.

When the correct heat exchanger size has been determined, several options can also be selected including: integrated face-and-bypass damper, epoxy coated aluminum plates, coated framework, sealing material for higher temperatures, etc.

In the final selection, price versus performance must be evaluated.

Useful Terms

In the HVAC energy recovery industry, many terms have come to be universally understood. Some of the more common and useful technical terms are described here:

Return Air:
This is the air being exhausted from the ventilated space. In winter it is the warmer airstream and in summer it is the cooler. To save energy, heat exchangers use this airstream to pre-heat (in winter) or pre-cool (in summer) the supply airstream. It is commonly measured in cfm (cubic feet per minute) or scfm (standard cubic feet per minute—meaning the equivalent volume of air at standard conditions of 1 atm and 68 °F).

Supply Air:
This is the air that is supplied to the ventilated space. It is pre-heated (in winter) or pre-cooled (in summer) in the heat exchanger. It is measured in the same units as Return Air.

Relative Humidity:
This is the amount of moisture air contains relative to the maximum possible moisture content of that air. (The maximum possible humidity varies with air temperature and pressure.) It is expressed as a percent.

Absolute Humidity/Moisture Content:
This is the amount of water the air is carrying in absolute terms. It is measured as a mass of water per a mass of dry air (e.g., kg water / kg dry air).

Effectiveness (temperature efficiency of the heat exchanger):
One of the most important and commonly-used ways to measure how well a heat exchanger performs is by its effectiveness.

The effectiveness on the hot side of the exchanger is defined as:

$$\varepsilon_h = \frac{\dot{m}_h}{\dot{m}_{\min}} \frac{t_{h,in} - t_{h,out}}{t_{h,in} - t_{c,in}}$$

and the effectiveness on the cold side as:

$$\varepsilon_c = \frac{\dot{m}_c}{\dot{m}_{\min}} \frac{t_{c,in} - t_{c,out}}{t_{c,in} - t_{h,in}}$$

where

- ε is effectiveness (%),
- $\dot{m}$ is the mass flow rate of an airstream (scfm),
- t is temperature (°C or °F),
- c is cold side; h is hot side,
- *in* is into the exchanger; *out* is out from the exchanger, and
- *min* refers to whichever airstream has the lower mass flow rate.

When the fluid flow rates for each airstream are equal on both sides of the exchanger (or, more accurately, when the flow rates multiplied by the specific heats in each airstream are equal), the hot and cold effectivenesses will also be equal.

The effectiveness really shows how much heat is transported to (or from) the supply air as a percentage of the total magnitude of the heat source (or sink) provided by the return air.

Pressure drop:
The price you have to pay for the heat recovery is the pressure drop in the heat exchanger. The pressure drop is most easily described as friction between the fluid and the wall surface in the heat exchanger. This friction must be overcome by using fans or pumps to force the fluid through the exchanger channels—and operating those fans takes energy. Normally the pressure drop is given in Pa or inches water gauge (in w.g.).

Transferred heat or Power:
When the flow rates and either the entering temperatures of the air or the effectiveness of the exchanger are known, it is easy to calculate the amount of heat that is transferred from the hot to the cold airstreams according to the following formula. The amount of heat transferred is

usually measured in W or Btu/hr. The amount of heat absorbed or released is:

$$q = \rho \cdot \dot{V} \cdot c_p \cdot (t_{out} - t_{in})$$

where, in metric units,

- q is the amount of heat transferred (W),
- $\dot{V}$ is air volume flow (m^3/s),
- ρ is fluid density (kg/m^3),
- c_p is specific heat of fluid (J/kg°C),
- t is temperature (°C), and
- *in* is into the exchanger; *out* is out from the exchanger.

This equation is valid for either airstream. If the result is positive, that means that the airstream absorbed heat. If it is negative, the airstream lost heat.

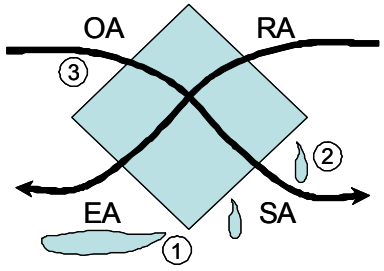
Dos and Don'ts

Do	Don't
Observe stated max temperatures for exchanger materials, sealants, and coatings.	Never exceed max allowed temperature.
Observe stated max allowed pressure differential for exchangers. And note that pressure drop will be affected before maximum value is reached.	Never exceed allowed max pressure differentials. Don't forget to take into account in the system design the increased pressure drop at high pressure differentials.
Take condensation into account in the design. The heat exchanger should be oriented so that the condensing water easily can drain downward and means to collect the water and flush it out from the unit should also be employed.	Don't orient the heat exchanger plates completely horizontal. Just a few degrees inclination will help condensate drain off the plates.
Take freezing into account in the unit design and provide means for defrosting or bypassing. Also provide means to allow melt water to get out of the exchanger.	Never allow the heat exchanger to completely frost up. It may damage the plates.
If there are corrosive substances in the air, an epoxy coated aluminum or—in extreme cases—stainless steel exchanger should be chosen.	Don't use ordinary aluminum where there is salt water mist in the air or for swimming pool applications where chlorine is present. Epoxy-coated exchangers should be used.
Please observe the restrictions regarding maximum module widths for horizontal applications.	Don't forget to inform the manufacturer when the exchanger will be mounted horizontally so that the maximum module width can be determined.
Take the good sound dampening characteristics of the plate heat exchanger into account in the unit design. It may obviate the need for a sound dampener.	
Please follow the instructions regarding lifting and handling of the heat exchanger in order to avoid damage.	Don't lift the heat exchanger in such a way that it can be damaged.
Should it be necessary, make sure that the unit design makes it possible to get access for cleaning the heat exchanger. Water, compressed air, or even a mild aluminum-safe detergent can be used.	Don't damage the plates when using mechanical means for cleaning and don't use very high pressure water directly against the plates.
Allow airstreams to enter the heat exchanger with an even distribution. An uneven velocity or temperature distribution will negatively affect efficiency. Locate the fans downstream from the heat exchanger so they are pulling air through the exchanger.	Don't design with sharp bends directly before or after the exchanger. Don't design so that the pressure drop in the heat exchanger is very small. Air distribution can be improved by placing a filter or another restriction that creates a pressure drop just upstream of the heat exchanger.
Heat exchangers are not totally air tight, so take leakage into account. Air that bypasses the heat exchanger or leakage between the two sides of the heat exchanger will reduce performance and may also carry particles, odors, and condensate between the two airstreams. Keeping a good seal between the heat exchanger frame and the air handling unit is as important as selecting an exchanger with low internal leakage.	Don't design so that the pressure in the return airstream is higher than in the supply airstream because the contaminants from the return air will tend to leak into the supply side.
During start up, normal operation, and shut-down, make sure that the max allowed differential pressure is never exceeded.	Never start fans against closed dampers, this can subject the exchanger to the full pressure the fan is capable of exerting, which may be far higher than the maximum allowed for the exchanger. Never allow fans to run at higher speeds than design speed.

Appendix A—Air Flow Configurations in Cold, High Moisture Applications

The following are air flow recommendations, from most desirable to least desirable, relative to the heat exchanger:

1. Air-Flows In From Top

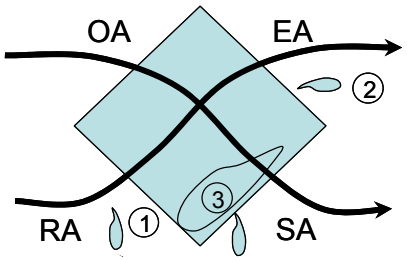


RA to EA condensate easily runs out of the exchanger with low risk of icing (1).

Any RA to SA leakage will drain down to warm, non-icing areas (2).

OA is on top blowing down, so no leakage in OA to cause icing (3).

2. Air-Flows In From Side, OA on Top

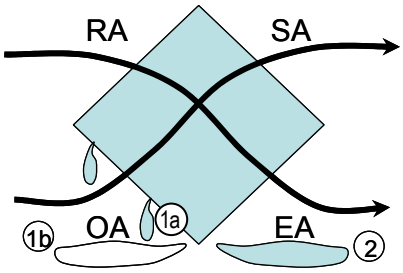


RA to EA condensate will drain down to warm areas with low icing risk (1).

Some risk that the RA to EA condensate will be blown into the EA section of the unit (2).

Some risk that the RA to EA condensate will not drain, but be suspended in the exchanger and could restrict airflow (3).

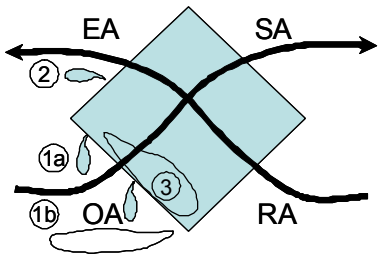
3. Air-Flows In From Side, RA on Top



Some risk that the RA to EA condensate will leak to the cold OA area (1a) causing icing (1b) and possible unit leakage.

RA to EA condensate easily leaves the exchanger (2).

4. Air-Flows In From Bottom



Some risk that the RA to EA condensate will leak into OA area (1a) causing icing (1b) and unit leakage.

Some risk that the RA to EA condensate will be blown into the EA section of the unit (2).

Some risk that the RA to EA condensate will not drain, but be suspended in the exchanger and could restrict airflow (3).

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