# Heat Exchangers

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## 1. HEAT EXCHANGERS

Put simply, a heat exchanger is a device used to transfer energy from one medium to another. HVAC applications are wide and varied, as they transfer energy (mostly in the form of heat) through working fluids such as air, water and refrigerant. Most heat exchangers consists of two working fluids, a primary stream that either absorbs or rejects energy and a secondary stream that conversely rejects or absorbs the energy from the primary stream. This energy is seen in the form of temperature only (heat). In some 'air to air' examples, latent energy (temperature and moisture) can also be transferred.

The amount of energy that is transferred by the heat exchanger is known as its 'effectiveness' or 'efficiency'. If a heat exchanger were to be able to transfer the entire energy from one medium to another, it would be rated at 100% efficiency.

Other important properties of heat exchanger performance include

- Pressure Drop – the amount of energy lost in pushing the working fluid through the heat exchanger at a given velocity
- Fluid Velocity – dictates the overall required size of the heat exchanger required for a given flow rate

## 2. AIR-AIR HEAT EXCHANGERS

Each year, building owners spend thousands of dollars on heating and cooling the interior and outdoor air required for optimal indoor air quality. Much of that energy is wasted when it is exhausted from the building. By implementing heat recovery technology to capture the energy embodied in heated or cooled exhaust air, HVAC plant size and running costs can be significantly reduced. An air to air heat exchanger can be used to perform this function, of which there are various types.

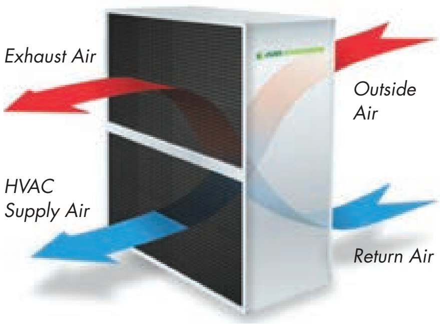


Figure 1 Complete Assembled Air-Air Heat Exchanger

### 2.1 Plate type

A plate type heat exchanger comprises numerous air guiding passages which are separated by a 'transfer media' such as aluminium, plastic or cellulose. The orientation and direction of flow of adjacent air passages can be used to describe the type of plate heat exchanger.

#### 2.1.1 Cross Flow

Cross flow heat exchangers have their primary and secondary streams operating in a perpendicular orientation to each other. This provides a convenient means of attaching inlet and outlet connections to the heat exchanger; however it inhibits the overall efficiency. As primary air travels through the heat exchanger, it transfers with weaker secondary air that has already lost some of its energy.

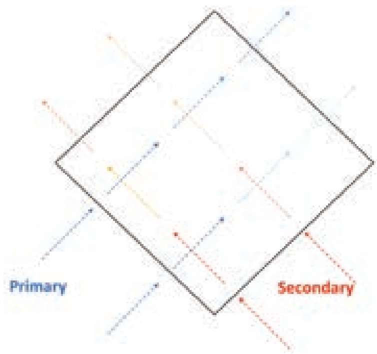


Figure 2 Cross Flow Heat Exchanger 2D

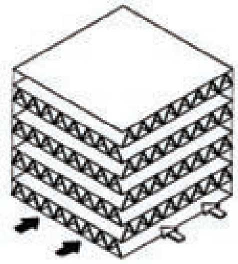

Figure 3 Cross Flow Heat Exchanger 3D (courtesy of http://www.sciencedirect.com)

#### 2.1.2 Counter Flow

A counter flow heat exchanger has the primary and secondary air streams directly opposing each other. This leads to a higher efficiency as primary air progressively transfers with 'stronger' secondary air that holds more of the energy of its initial state.

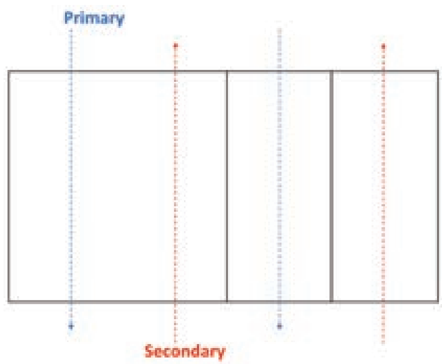


Figure 4 Counter Flow Heat Exchanger

#### 2.1.3 Mixed Counter/ Flow

A mixed counter/cross flow heat exchanger provides the high efficiency of a counter flow type with the ability of easily separating the inlet and outlet connections. The arrangement shown below is a 'Z' style heat exchanger, where the majority of transfer is counter flow with some cross flow regions at the inlet and outlets.

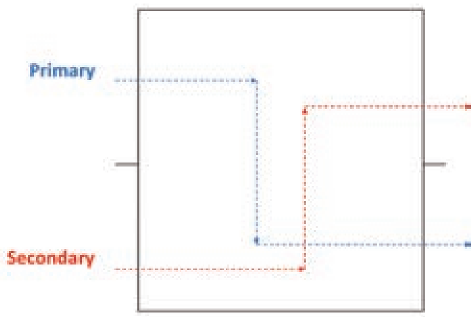


Figure 5 'Z' Flow Heat Exchanger 2D

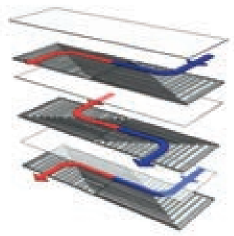

Figure 6 'Z' Flow Heat Exchanger 3D

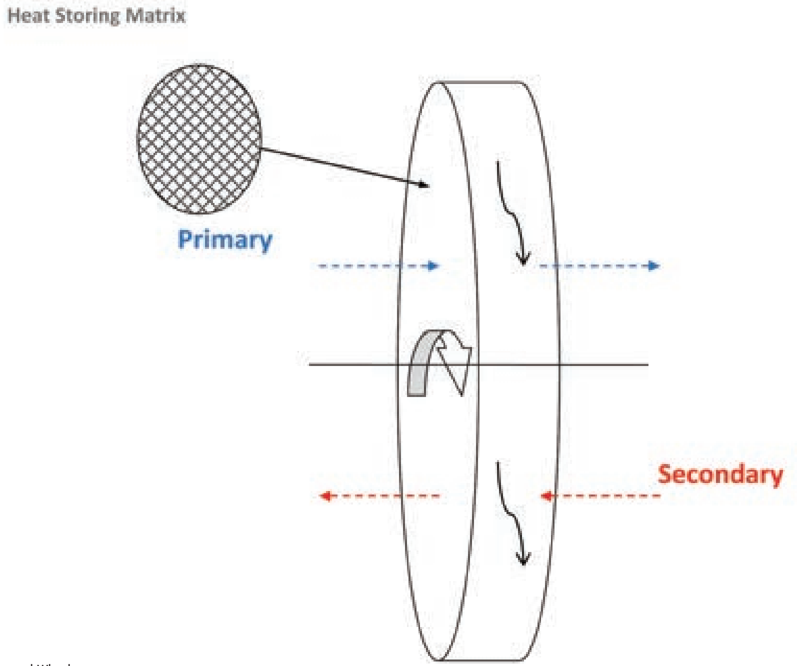


Figure 7 Thermal Wheel

### 2.1.4 Enthalpy and Sensible Only

Air to air plate heat exchangers can also be divided into 'sensible only' or 'enthalpy' types. Sensible systems transfer temperature only. In an enthalpy system the heat exchanger is able to transfer moisture in addition to temperature. To achieve this, a cellulose transfer media is used (similar to paper) which allows moisture to pass through in the form of vapour. The enthalpy type heat exchanger can be particularly useful in hot humid climates.

For drier climates and in heating applications, a sensible only heat exchanger is more advantageous. Utilising a transfer media of aluminium, steel or plastic, this heat exchanger will only transfer temperature.

### 2.2 Thermal Wheel

A thermal wheel looks very different to the plate heat exchanger, yet its concept of transferring energy from one path to another remains the same. Primary air is directed into one section of the wheel through a solid 'heat storage matrix' which absorbs some of the energy. The wheel is continuously rotating and as the heat storage matrix travels to the opposing side, a secondary air stream passes through it and the energy in the storage matrix is then transferred into the secondary air stream. The thermal wheel can have high efficiencies comparable to a counter flow plate heat exchanger; however some of this is lost in the power input required to rotate the wheel. As it is a moving component, the additional maintenance costs also need to be considered.

### 2.2.1 Enthalpy and Sensible Only

An aluminium heat storage matrix will normally be used in sensible only transfer. The aluminium surface can be applied with a hygroscopic coating which will allows for adsorption and release of water vapour providing both sensible and latent transfer.

### 2.2.2 Desiccant

The thermal wheel can also have a desiccant coating (typically silica gel) applied for the purpose of dehumidifying the air stream. Moisture in the primary air is absorbed into the desiccant, and then the secondary air stream is used to 'regenerate' the moisture filled desiccant. The secondary air needs to be at an elevated temperature, normally heated by a water or refrigerant coil.

## 3 APPLICATIONS

### 3.1 Tempering Outside Air

The majority of applications in a building HVAC system use air to air heat exchangers to pre cool or pre-heat outside air. The minimum amount of outside air required is dictated by AS1668 ventilation rates, however to improve indoor air quality designers often recommend higher amounts of outside air. In addition, accreditation services such as GBCA Green Star and NABERS IEQ promote greater amounts of outside air.

There are also special applications such as pools, gyms and laboratories, where high outside air change rates lead to the use of heat exchangers.

The majority of heat exchangers are not sold on their own and instead are factory installed into a packaged air handling system with the required fans, electrics, controls, casing, and heating/ cooling mechanism.

### 3.2 Ventilation Only Units

Ventilation only units comprise of the heat exchanger as well as supply and exhaust fan (primary and secondary) and are commonly known as 'Energy Recovery Ventilators' (ERV's) or 'Heat Recovery Ventilators (HRV's). They are used to pre-condition the outside air before supplying into another air conditioning system. This can be achieved by using the energy recovery ventilator in series or parallel

### 3.2.1 Series Operation

Tempered outside air from the ERV is supplied directly into a separate air conditioning system. This is more often used when low volumes of outside air are required. The ERV can handle all of the required outside air on a project, and then supply this into a larger AHU, which does the remainder of the cooling or heating.

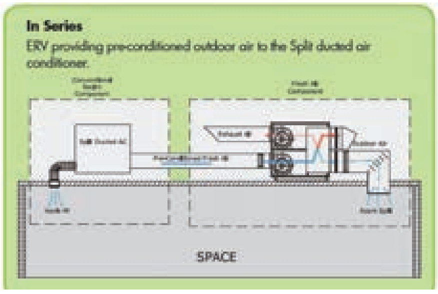


Figure 8 Ventilator in Series Operation

### 3.2.2 Parallel

The ERV will supply pre-conditioned outside air directly into the space. This will then mix with the already conditioned internal air (handled by a separate system). This can sometimes be easier to install, particularly on retrofits. Care must be taken to ensure there is adequate air distribution to allow the outside air and indoor air to mix. This can be particularly important in high humidity climates, where humid outside air may be directed towards cold supply air grilles resulting in condensation.

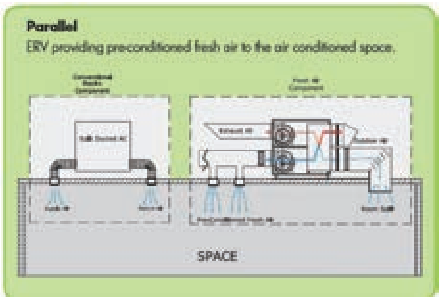


Figure 9 Ventilator in Parallel Operation

### 3.2.3 Chilled Water Units

This is a very common way of utilising the heat exchanger. Essentially chilled and/or hot water coils are installed into a ventilator system which will handle the supplementary cooling. Initially outside air passes through the heat exchanger, which cools and pre-conditions (summer) or pre-heats (winter) the air. The air then passes through inbuilt chilled and/or hot water coils and is further cooled to the required supply air temperature.

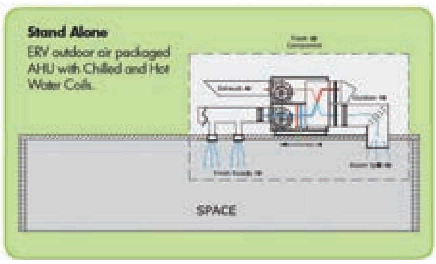


Figure 10 Chilled Water Unit

### 3.2.4 DX Packaged Units

The complete packaged solution is to have the heat exchanger coupled with a direct expansion heat pump system. In the schematic below, outside air enters the unit at A (35°C, 14.2g/kg). Simultaneously, the cool return air from the building enters at 1 (24°C, 9.2g/kg) through a separate inlet. The return air will absorb up to

75% of heat and humidity from outside air. Thus, the outside air enters the refrigeration system at a much cooler and drier state B (26.8°C, 10.5g/kg) which later is cooled to a nominal temperature at C (130C).

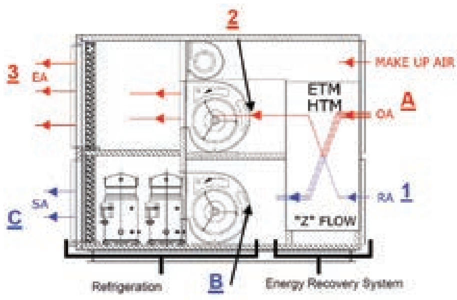


Figure 11 DX Packaged Unit with Heat Recovery

## 4. HELPFUL CALCULATIONS

### 4.1 How to Calculate Heat Exchanger Efficiency

The **sensible transfer efficiency** of a heat recovery unit can be expressed, in its simplest terms, as:

$$\mu_t = \frac{(\mathbf{t_{pout}} - \mathbf{t_{pin}})}{(\mathbf{t_{sin}} - \mathbf{t_{pin}})}$$

μt = temperature transfer efficiency

tpin = temperature of primary air before the heat exchanger (DB)

tpout = temperature of primary air after the heat exchanger (DB)

tsin= temperature secondary air before the heat exchanger (DB)

The **latent transfer efficiency** of a heat recovery unit can be expressed, in its simplest terms, as:

$$\mu_x = \frac{(\mathbf{x_{pout}} - \mathbf{x_{pin}})}{(\mathbf{x_{sin}} - \mathbf{x_{pin}})}$$

μx = latent transfer efficiency

xpin = moisture content of primary air before the heat exchanger (kg/kg)

xpout = moisture content of primary air after the heat exchanger (kg/kg)

xsin = moisture content of secondary air before the heat exchanger (kg/kg)

The **enthalpy transfer efficiency** of a heat recovery unit can be expressed, in its simplest terms, as:

$$\mu_h = \frac{(\mathbf{h_{pout}} - \mathbf{h_{pin}})}{(\mathbf{h_{sin}} - \mathbf{h_{pin}})}$$

μh = enthalpy transfer efficiency

hpin = enthalpy of primary air before the heat exchanger (kJ/kg)

hpout = enthalpy of primary air after the heat exchanger (kJ/kg)

hsin = enthalpy of secondary air before the heat exchanger (kJ/kg)

### 4.2 How to Calculate Total Heat Exchanger Capacity

The **sensible only heat exchanger capacity** can be calculated from:

$$HX_{sensible} = (t_{pout} - t_{pin}) \times Airflow \times 1.213$$

HXsensible = sensible capacity (w)

tpin = temperature of primary air before the heat exchanger (DB)

tpout = temperature of primary air after the heat exchanger (DB)

Airflow = primary airflow rate (l/s)

The **latent heat exchanger capacity** can be calculated from:

$$HX_{latent} = (x_{pout} - x_{pin}) \times Airflow \times 2.9$$

HXsensible = sensible capacity (w)

xpin = moisture of primary air before the heat exchanger (kg/kg)

xpout = moisture of primary air after the heat exchanger (kg/kg)

Airflow = primary airflow rate (l/s)

The **enthalpy heat exchange**r **capacity** can be calculated from:

$$HX_{enthalpy} = (h_{pout} - h_{pin}) \times Airflow \times 1.184$$

HXenthalpy = total capacity (W)

hpin = temperature or primary air before the heat exchanger (kJ/kg)

hpout = temperature or primary air after the heat exchanger (kJ/kg)

Airflow = primary airflow rate (l/s)

Further the **enthalpy heat exchanger capacity** should be the addition of the sensible plus latent portions.

## 5. SIZING A TOTAL SYSTEM WITH HEAT RECOVERY

Determine minimum outside airflows (may be affected by GBCA Green Star, NABERS IEQ, or general IAQ requirements)

↓

Calculate the heat exchanger capacity based on OA airflows at design condition

↓

Determine heat loads of each zone as per conventional design

↓

Deduct the heat exchanger capacity(s) from these loads

↓

Select equipment with coil/refrigerant capacity based on the remaining load

Sizing a system with heat recovery is not much different to the conventional process. The heat load just needs to be adjusted to take into account the heat exchanger energy saving. The flow chart opposite shows the general steps to sizing a system with heat recovery.

## 6. WHICH HEAT EXCHANGER TYPE TO USE?

The below table provides a guide to the benefits of each heat exchanger.

| Heat Exchanger Type | Typical Transfer Media | Typical Efficiency | Typical Pressure Drop | Price | Relative Maintenance |
|---|---|---|---|---|---|
| Cross Flow Plate Sensible | Aluminium | 60% | Low | Low | Low |
| Cross Flow Plate Enthalpy | Cellulose | 60% | Low | Low | Low |
| Mixed Counter Flow Plate Sensible | Plastic Film | 75% | Medium | Medium | Low |
| Mixed Counter Flow Plate Enthalpy | Cellulose | 75% | Medium | Medium | Low |
| Thermal Wheel Sensible | Aluminium | 80% | Medium | High | High |
| Thermal Wheel Enthalpy | Aluminium with hygroscopic coating | 75% | Medium | High | High |