AS SEEN IN THE SEPTEMBER ISSUE OF
RSES Journal

ENERGY RECOVERY for Industrial Applications

Learn about how fixed-plate heat exchangers work in industrial heating/cooling applications and a real-world example of the energy savings achieved using them.

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Energy-recovery systems are systems in which two media or processes with different energy levels exchange energy. The purpose of this article is to discuss air-to-air energy recovery in HVAC systems within industrial applications.

Air-to-air energy recovery involves taking energy from one air stream and adding that energy to a different air stream. The air streams are made to pass each other, without mixing, through a heat exchanger. In a typical application, one air stream may be air exhausted from a building and the other may be make-up air added to the building.

During the heating season when the inside building air is warmer than outside air, the energy from the warmer building air is "recovered" and added to the incoming outside air to make it warmer. Energy is also recovered during the cooling season when the cooler air inside the building is used to cool the warmer outside air.

Although there are many energy-recovery methods, this article will focus on the fixed-plate heat exchanger in industrial environments. This type of heat exchanger may be favored in these applications because it requires less maintenance than other types, is easy to clean and has no moving parts.

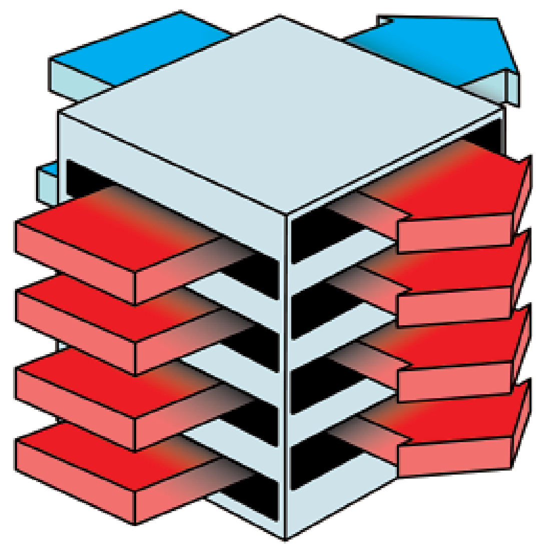

Figure 1 This illustration depicts the perpendicular air flow from one layer to another in a fixed-plate heat exchanger.

How it works

Although other materials are used, fixed-plate heat exchangers are typically constructed from aluminum. Flat sheets are used to form air channels in alternating layers. One layer allows air flow in one direction and the other allows air flow in a perpendicular direction (see Figure 1).

These layers are built up forming a block with a large surface area from which to transfer energy between the opposing air streams. In some designs, the aluminum sheets are made to create turbulence and enhance the heat-transfer efficiency.

Following are a few design considerations for plate heat exchangers:

Pressure differential—Plate heat exchangers are rated for a maximum pressure differential. Pressure differential is caused by the forces associated with the plenum pressures surrounding the heat exchanger acting on the plates themselves. Fan placement within the system has the greatest effect on the pressure differential.

Condensation—When a surface is cooled below the dew point of the air, condensation will form. This is typically seen during the heating season in cold weather when the warm inside air passes over the cold plates. These applications will require a means to capture the condensate and drain it away from the unit.

Air velocity—The velocity of the air must be low enough to allow condensate to drain back toward the direction of air flow.

Freezing/freeze protection—Condensate will freeze when the plates are cooled below freezing. This should be avoided. Freezing will reduce the performance by blocking air flow, and in some cases may damage the heat exchanger.

To prevent this, face and bypass dampers can be used to divert outside air flow from around the heat exchanger, passing a lower volume of cold air through the heat exchanger, which allows the building exhaust air to warm the plates. A typical controls arrangement would be to sense the exhaust air leaving the heat exchanger and modulate the face and bypass damper to keep this temperature high enough to prevent freezing. This bypass can also be used at other times where it is not desired to have the outside air pass through the heat exchanger. One application would be a heat-only application in the summertime when the outside air may be cooler than the inside air.

Efficiency—The efficiency of the heat exchanger is typically certified by an independent testing agency. It is critical that the temperature and air flow be as uniform as possible across the entire face of the heat exchanger in order to achieve the rated efficiency. It is important to avoid sharp bends in the air immediately before and after the heat exchanger.

Industrial applications

The complete system requires that the heat exchanger be mounted in an enclosure in a way that isolates the two air streams. Once this is done, air can be blown or drawn through each air stream. Once the indoor air passes through the heat exchanger, it is exhausted outside. When it is colder outside than it is inside, the outside air entering the heat exchanger will be made warmer. In industrial heating applications, this means that the air leaving the heat exchanger will require less energy to heat than the cooler outside air. This reduces the requirements of the heat source and in some cases, may eliminate the heat source entirely. The same is true in a cooling application using outside air.

Once the heat exchanger is incorporated into an enclosure, the energy-recovery module can then be mated with supply and exhaust fans for the two air streams. A common application is shown in Figure 2. Note the outside air flow entering from the top left going down through the heat exchanger, into the air handler and down into the building. The building exhaust air is drawing up from the lower left, into the heat exchanger and out the top right.

A typical direct-fired, make-up air unit is shown on the lower right in Figure 2. In this example, the outside air is warmed from 0°F (-17°C) to 42°F (5.6°C) prior to entering the air handler, greatly reducing the Btu requirements of the gas burner. If the conditions were reversed and it was a hot day and this was an air-conditioned plant, the warmer outside air would be cooled prior to entering the make-up air-cooling unit.

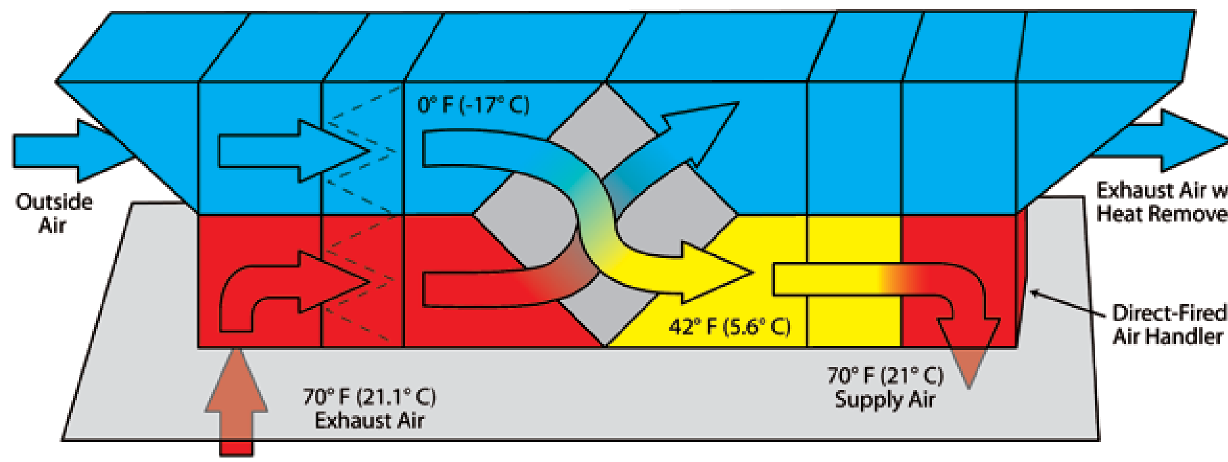

Figure 2 **Once the heat exchanger is incorporated into an enclosure, the energy-recovery module can then be mated with supply and exhaust fans for the two air streams. A common application is depicted here.**

Energy-savings case study in a heating application

Many facilities require exhaust and make-up air. One of the most efficient ways to heat this air is with direct-fired air handlers. The entire Btu content of the products of combustion goes toward heating the air. If this outside air were heated with an indirect-fired system, a portion of the products of combustion is exhausted outside. To illustrate the potential savings in a scenario such as this, a typical Midwest manufacturing facility will be used as an example:

- →Exhaust air: 30,000 cfm
- →Make-up air: 30,000 cfm
- →Average winter temperature: 32°F (0°C)
- →Gas cost/therm: $1.10
- →Hours of operation per week: 120
- →Desired space temperature: 65°F (18.3°C)
- →Heat-exchanger efficiency: 60%
- →Building exhaust-air temperature: 70°F (21.1°C)
- →Length of heating season: 30 weeks
- →100,000 Btu = 1 therm

The formula to calculate the Btu required to heat a volume of air is: 1.08 x cfm x (temperature of air desired – temperature of incoming air). So, the calculation for the above example is:

1.08 x 30,000 x (65 - 32) = 1,069,200 Btu required to heat the volume of air in this example.

The formula to calculate annual heating costs is: Btu/100,000 x hours/week x weeks x cost per therm. So, the calculation for the above example is:

1,069,200/100,000 x 120 x 30 x $1.10 = $42,340.

In this example, the comparison will be to an older indirect-fired heating system that is poorly maintained. This type of system could be only 70% efficient or worse. To calculate the total required Btu as compared to a 100% efficient system, divide Btu for the 100% efficient system by 70%: 1,069,200/70% = 1,527,428. Resulting in operating costs of: 1,527,428/100,000 x 120 x 30 x $1.10 = $60,486.

With energy recovery, the Btu needed is less because the incoming air is pre-heated. This temperature is the difference in the air stream temperatures multiplied by the efficiency, added to the outside air temperature: (70 - 32) x 60% + 32 = 55.

This results in reduced Btu and annual energy costs: 1.08 x 30,000 x (65 - 55) = 324,000 Btu. So, 324,000/100,000 x 120 x 30 x $1.10 = $12,830.

Total annual savings using direct-fired with energy recovery vs. a 70% efficient system:

$60,486 - $12,830 = $47,656 annual savings.

Summary

Industrial facilities requiring make-up air for ventilation are excellent applications for flat-plate heat exchangers and direct-fired heating. These facilities often require outside air for ventilation and to replace exhaust air. The exhaust-air energy recovery reduces the required heating energy, and direct-fired heating uses nearly all of the energy available from the fuel source to heat the outside air. As demonstrated in the example above, this combination can result in significant energy savings.

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