

# HEAT RECOVERY FOR PROCESS EFFICIENCY.

Even when fuel prices are low, companies in energy-intensive industries can see a benefit and enjoy a relatively short payback from utilizing some type of heat recovery system to improve the efficiency of their process.

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# **TABLE OF CONTENTS**

- 3 Abstract**
- 4 Introduction**
- 5 Basic Heat Recovery Methods for Process Heating**
- 6 Heat Exchanger Types**
- 7 Air-to-Air Heat Exchanger Selection Guide**
- 8 Flow Configurations for Air-to-Air Heat Exchangers**
- 9 Things to Consider Before Selecting a Heat Exchanger**
- 10 Plug In for Energy Savings**
- 11 Conclusion**
- 12 About the Author**

# ABSTRACT

In many industrial applications, the waste heat in the form of heated air or steam is unused and allowed to escape up the stack. Implementing ways to capture waste heat can improve efficiency while helping processors save money. This article talks about how installing an effective air-to-air heat exchanger helps you recover this resource and increase energy efficiency of the plant.

# INTRODUCTION

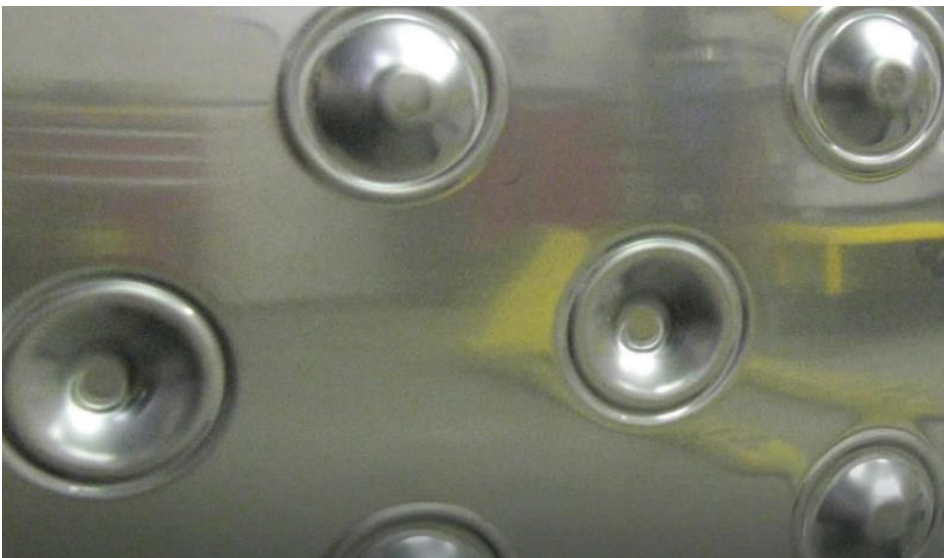
# 1

**With an ever-increasing focus on energy efficiency and improving system performance, industrial processors are looking for ways to achieve these goals while reducing costs and material usage wherever possible.**

One proven way to increase energy efficiency and reduce fuel usage is to recover heat from industrial processes. Waste heat is unused heat given off by a process or equipment in the form of thermal energy -- that is, heat which is not being captured to heat some other product or process. Waste heat can be thought of as free energy.

Though, of course, there is a cost to create it, waste heat is thermal energy you would otherwise let escape up the stack rather than using in your process. Implementing ways to capture waste heat can improve efficiency while helping processors save money.

Even when fuel prices are low, companies in energy-intensive industries can see a benefit and enjoy a relatively short payback from utilizing some type of heat recovery system to improve the efficiency of their process.



*Plate Type Heat Exchanger*

# BASIC HEAT RECOVERY METHODS FOR PROCESS HEATING

## 2

The most straightforward method of capturing waste heat energy is a heat exchanger. A heat exchanger is a device used to transfer heat from one medium – typically air, gas, or fluid – to another medium. The two media are separated by solid wall, a plate or tube.

The exchanger uses the properties of thermodynamics and fluid mechanics to heat or cool one medium to the desired temperature. A basic schematic of a process oven with heat recovery demonstrates the general process (figure 1).

In many industrial applications, the waste heat will be in the form of a gas. Usually, it is heated air or steam. Thus, air-to-air heat exchangers are quite common in industrial applications. (Air-to-air heat exchangers are also found in many commercial buildings, HVAC systems, and even in some modern houses.)

Air-to-air heat exchangers are used for many industrial applications:

- Heat recovery for preheating the same process or other processes
- Combustion air pre-heating
- Oven/furnace makeup air preheating
- Fume preheat on catalytic/recuperative thermal oxidizers
- Secondary heat recovery on regenerative oxidizers
- Heat exchange and recovery for Volatile Organic Compound (VOC) concentrators

One of the benefits of using a heat exchanger to recover waste heat is that they are designed and built such that the air containing the waste heat does not come into contact with the new, clean process air. This is particularly helpful when the exhaust has excess dirt or dust particles that could contaminate products or equipment elsewhere in the process.

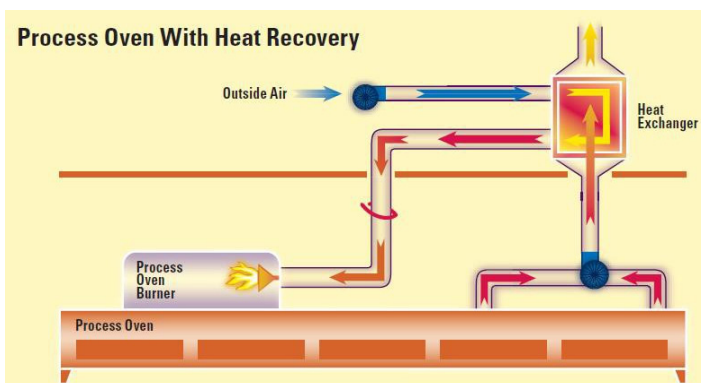


Figure 1. The most straightforward method of capturing waste heat energy is through the use of a heat exchanger. Shown here is a basic schematic of a process oven with heat recovery.

# HEAT EXCHANGER TYPES

# 3

## The most common types of air-to-air heat exchangers are tubular type and plate type.

**Tubular:** Tubular type heat exchangers use a series of tubes to allow the exchange of heat between the two media. The waste stream passes over the tubes, pre-heating the process stream flowing inside the tubes. Depending on the needs of the application, the configuration can be reversed such that the waste stream flows through the tubes and the process air flows over the tubes. For ease of cleaning, make sure the dirty stream flows through the inside of the tubes.

Tubular-type heat exchangers are not as effective at transferring heat as plate types. However, they can withstand higher temperatures, can be made out of exotic materials, and take a lower pressure drop. They tend to weigh more than plate types, and improper install and consistent high-low temperature cycling can promote cracking of the tubes. Additionally, due to the reduced effectiveness of the tubular type, the exchangers end up being big and long, taking up additional space in the plant. The size can also increase the stress on the tube end welds.

**Plate:** Plate-type heat exchangers use a series of nested plates to allow the exchange of heat between the two media without the two air streams coming into contact with each other.

**Dimple and Sinusoidal:** The two most common plate styles are dimple plate and wave/sinusoidal plate. Dimple-plate types are better for process streams that are dirty and could potentially cause clogging between the plates. Sinusoidal- or wave-plate types offer the best heat transfer effectiveness. The basic premise behind the plate technology is to have a pattern in the plate that causes a lot of turbulence in the air as it flows around the plates, which increases heat transfer. (Figures 4a and 4b)

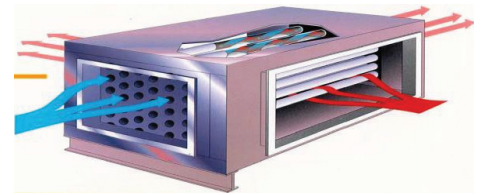


Figure 2: Tubular-type heat exchangers use a series of tubes to allow exchange of heat between the two media.



Figure 3: Plate-type heat exchangers use a series of nested plates to allow the exchange of heat between the two media without the two air streams coming into contact with each other.



Figure 4a: Example of Dimple Plate Heat Exchanger

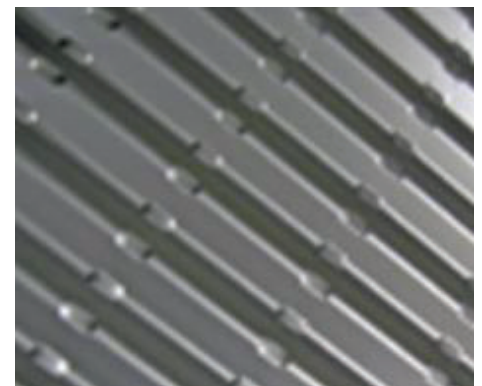


Figure 4b: Sinusoidal or wave-plate exchangers offer the best heat transfer effectiveness.

# AIR-TO-AIR HEAT EXCHANGER SELECTION GUIDE

# 4

## AIR-TO-AIR HEAT EXCHANGER SELECTION GUIDE

Tubular



Sinusoidal Plate



Dimple Plate



|                             |   |   |   |
|-----------------------------|---|---|---|
| Temperature                 | Low to High   | Low   | Low   |
| Price                       | Lower   | Highest   | Moderate  |
| Heat Transfer Effectiveness | Lower   | High  | Medium  |
| Flow Configurations         | Variety   | Variety   | Variety   |
| Process Air Cleanliness     | Dirty   | Clean   | Moderate  |
| Easy to Clean?              | Yes   | No  | Moderately  |
| Key Differentiators         | High temperature heat recovery, Customizable flow configurations. | Compact, High Heat Transfer Effectiveness, Lighter Weight | Thick Plates for abrasive/corrosive applications, In-Line dimples accommodate dirtier streams |
| Choose When                 | Robust heat recovery is needed, high temperature applications     | High heat transfer effectiveness is required              | Process air is dirty, abrasive, corrosive   |

Table 1: When considering a heat exchanger design, plate or tube spacing is a key factor in heat exchanger performance.

# FLOW CONFIGURATIONS FOR AIR-TO-AIR HEAT EXCHANGERS

# 5

Another important consideration when selecting a heat exchanger is what type of flow configuration makes most sense for the process. Given that each exchanger will carry two flowing media, transferring heat between them, four flow configurations are available for plate-type heat exchangers.

IU – One vertical stream and one in a “U” pattern

LL – Both flows in an “L” pattern

IZ – One vertical stream and one in a “Z” pattern

LU – One “L” flow and one in a “U” flow

Each configuration has its pros and cons. One thing to be aware of when selecting a flow configuration is any potential “ineffective zone.” In those areas, hot and cold spots are created by the airflow pattern, and limited heat exchange is taking place.

In any given flow configuration, there are two things going on:

1. Separate ineffective zones exist for each side (pass) of the exchanger. Certain ineffective zones are created in each of the flow patterns except for the (I) pattern.
2. The ineffective zones can change location depending on flow rate. For example, in a “U” flow pattern, at low flow rates, the ineffective zone is on the far side of the exchanger. With high flow rates, the ineffective zone is on the near side of the exchanger.

For air-to-air heat recovery in waste heat applications, a vertical flow pattern (IU) is best the configuration for heat transfer. It heats the process air most evenly and has fewer ineffective zones. It also is easiest to clean for applications such as food, where washdown is required. Water or cleaning solutions can literally be pumped into the top of the exchanger, and the solution will flow down in the direction of gravity without concern of getting caught in the exchanger.

The LL Flow pattern where each stream flows in an “L” shape – is the most common for heat recovery applications. It transfers heat less effectively and the air to be heated will be a little hotter on the far side of the exchanger. The ineffective zones are on either side of the L flows, creating two ineffective zones instead of just one.

The IZ flow pattern - one vertical pattern and one in a Z pattern - is less common. It can be useful to help fit in an existing space. It also creates two ineffective zones on either side of the exchanger.

The LU flow pattern – one in an L pattern and one in a U pattern -- also has two ineffective zones. Depending on the orientation of the heat exchanger, debris or condensation can collect in the bottom.

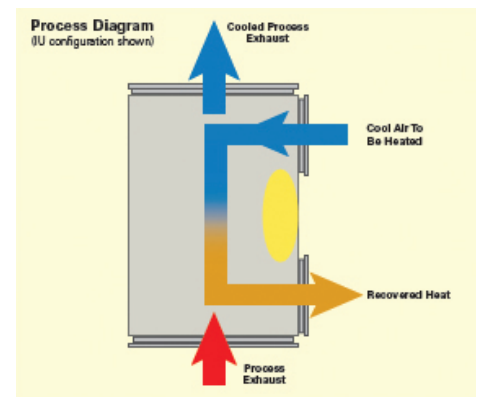


Figure 5: A vertical flow pattern (IU) is the best configuration for heat transfer. It is the most effective, heats the process air most evenly, and has fewer ineffective zones. The potential ineffective zone is shown in yellow in this diagram.

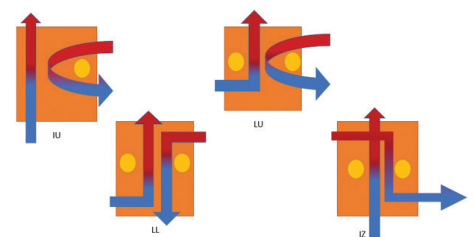


Figure 6: Flow configurations and associated potential ineffective heat transfer zones.



# THINGS TO CONSIDER BEFORE SELECTING A HEAT EXCHANGER

# 6

When selecting an appropriate heat exchanger for your process, consider things such as durability, exchanger life expectancy, ease of installation, maintenance required, ease of cleaning, and space available to install the exchanger.

Dimple-plate type heat exchangers tend to be the most durable of the three types because thick plates are used, and they are designed to withstand dirty process air streams. Tubular heat exchangers have a shorter life expectancy because the expansion and contraction of the tube material -- due to temperature changes over time -- makes the tubes more susceptible to wear and breakage. Sinusoidal- plate-type exchangers tend to be more fragile, with thinner plates. They must be monitored closely to ensure they do not overheat. Overheating could cause failure of the plate, and lose heat transfer effectiveness, and compromising cleanliness of the process air stream.

It is also important to ensure that the filter for the air intake to the process and exchanger is replaced on a regular basis. Excess debris in the filter could cause airflow to the exchanger to be compromised, reducing the effectiveness and performance of the unit. Additionally, if the filter is dirty or not properly installed, dirt and dust could make its way into the equipment and cause plate failures.

Lastly, it is important to remember that when considering a heat exchanger design, plate or tube spacing is a key factor in heat exchanger performance. (Table 1) Tubes or plates packed more closely can offer more heat transfer surface area in a smaller footprint. The tradeoff is they are more difficult to clean, and you may experience a higher pressure drop across the exchanger. Tubes or plates packed less closely are less effective but easier to clean. The tradeoff is you may have a smaller pressure drop across the exchanger.

# PLUG IN FOR ENERGY SAVINGS

# 7

Another type of tubular heat exchanger is known as a plug-in recuperator. As the name implies, it is plugged into the exhaust stream, paired with an eductor, and uses waste heat to preheat the combustion air. Table 2 shows the potential fuel savings that can be achieved when using preheated combustion air (PCA) from any heat exchanger like the plug in recuperators. This data is calculated based on the difference of available heat with and without a recuperator. Keep in mind this data is for preheated combustion air only, not for process air.

## FUEL SAVINGS ACHIEVED USING A PLUG-IN RECUPERATOR

| Furnace Exhaust Temp °F | PREHEATED COMBUSTION AIR TEMPERATURE °F |     |      |      |      |      |
|-------------------------|---|-----|------|------|------|------|
|                         | 600                                     | 800 | 1000 | 1200 | 1400 | 1600 |
| 2400                    | 26%                                     | 32% | 38%  | 43%  | 47%  | 51%  |
| 2200                    | 23%                                     | 29% | 34%  | 39%  | 43%  | 47%  |
| 2000                    | 20%                                     | 26% | 31%  | 35%  | 39%  | 43%  |
| 1800                    | 18%                                     | 24% | 28%  | 33%  | 37%  | 40%  |
| 1600                    | 17%                                     | 22% | 26%  | 30%  | 34%  |      |
| 1400                    | 15%                                     | 20% | 24%  | 28%  |      |      |
| 1200                    | 14%                                     | 19% | 23%  |      |      |      |
| 1000                    | 13%                                     | 18% |      |      |      |      |



Figure 7: Types of plug-in recuperators

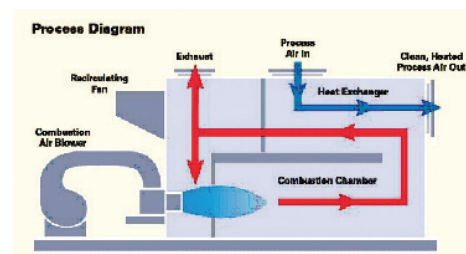


Figure 8: Process Flow Diagram for heater system

## WHOLE SYSTEM THINKING

When a heat exchanger such as a sinusoidal plate type is paired with a complete system – which includes a burner, controls, recirculation fans, and all system components – it can be inserted into a process where it is critical to have a supply of clean, indirectly heated process air.

Recirculating heaters are designed to prevent the products of combustion from getting into the process airstream. This is especially important in applications such as food and beverage, pharmaceuticals, and automotive paint finishing.

Figure 8 shows a schematic of a burner/heater system.

Figure 9 shows an Indirect Air Heater, which combines an ultra-low NOx burner with a sinusoidal plate heat exchanger for low emissions, highly effective process air heating.



Figure 9: An indirect air heater, which combines an ultra-low NOx burner with a sinusoidal-plate heat exchanger can provide low emissions and effective process air heating.

# CONCLUSION

Energy equals money, and waste heat is essentially free energy. If you are looking for ways to improve the overall efficiency of your process, improve fuel savings and, ultimately, save money, consider installing a heat exchanger to recover process heat in almost any application.

# ABOUT THE AUTHOR

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