Tech

Topics

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Evaporator System Basics

Today, more than ever, the cost of energy represents a very significant part of the cost of operating a rendering plant. The recent rapid rise in energy costs has caused rendering plant operators to look for ways of improving the energy efficiency of plant operations. There are many ways of accomplishing this goal, and one of the most effective is to use the energy present in the waste vapor from the cooking operation. By using a waste heat evaporator, this energy can be used to help evaporate the water in the raw material prior to the cooker. The result is a reduction in the amount of boiler steam required to cook the raw material and a corresponding increase in energy efficiency.

The use of an evaporator is key in implementing this strategy. Available in many different shapes and sizes, selecting the best evaporator for a given application can sometimes be a confusing and even intimidating task. Technical terms like falling film, forced circulation flash, and multiple effect can add to the confusion. The following takes a brief and not-too-technical look at the most common types of evaporators, how they work, and some of their applications.

Evaporator Requirements

The basic task of an evaporator is simple: to remove water from a solution or slurry by evaporation. Evaporators are distinct from dryers in that the concentrate discharged from an evaporator is always in liquid form. The discharge from a dryer is in solid form, generally a flowable powder or meal. The feed to an evaporator is always in liquid form and remains so even after the water is evaporated.

The physical process of evaporation requires the input of energy in the form of heat to convert a liquid into vapor. Since all evaporators use the process of evaporation to remove water, every evaporator requires a source of heat to operate. The heat source for almost all evaporators is water vapor, either in the form of boiler steam or waste vapor from another process.

A second requirement for all evaporators is a means to transfer heat energy from the heat source into the evaporator liquid. Most evaporators use a tubular heater called a shell and tube heat exchanger for this purpose. In the heat exchanger shell, water vapor condenses on the outside of the tubes thus giving up its heat energy, called latent heat. The evaporator liquid, which is inside the tubes, absorbs the heat given up by the water vapor. This increase in heat causes the water in the evaporator liquid to boil. As the water in the evaporator liquid boils, it forms bubbles of water vapor in the liquid much like a pan cooking on a stove. As these bubbles reach the surface of the evaporator liquid and burst, the escaping water vapor carries some of the evaporator liquid with it.

The final requirement for an evaporator is a means of separating the evaporated water vapor from the evaporator liquid, which is called the vapor body.

The heat exchanger and the vapor body are connected together to form an evaporator. Almost all evaporators operate in the same way. Evaporator liquid is circulated through the heat exchanger tubes to absorb heat and then discharged into the vapor body to give up the water vapor that is boiled off. In most evaporators, a centrifugal pump is used to circulate the evaporator liquid through the heat exchanger and vapor body. The circulating rate of the evaporator liquid depends on the type of evaporator and the evaporator liquid.

The pressure in the vapor body of an evaporator determines the boiling point of the water in the evaporator liquid. If the pressure in the vapor body is atmospheric, the water will boil at 212 degrees Fahrenheit (F). This requires the use of boiler steam as a heat source in the heat exchanger shell to achieve proper heat transfer. Lowering the pressure in the vapor body (by pulling a vacuum on the evaporator) lowers the boiling point of the water. For example, at 22 inches of mercury vacuum, the water will boil at 152 degrees F. Under these conditions, waste vapor at atmospheric pressure and 212 degrees F can be used as a heat source in the heat exchanger. For this reason, evaporators are widely used in waste heat recovery applications.

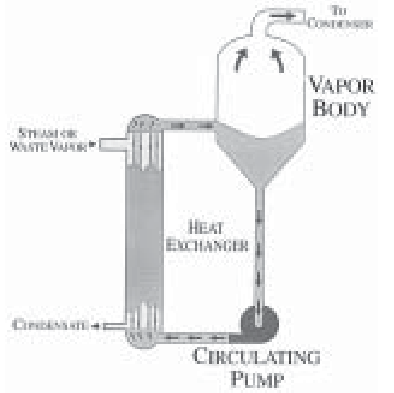
In many applications, several evaporators are connected together in series to form an evaporator system. When this is done, the water boiled off in one evaporator is used as the heat source for the next evaporator in line. In these systems, the individual evaporators are called effects and the system is referred to as a multiple effect evaporator. The significant advantage of this arrangement is that it allows the original heat input to the system to be re-used in each effect. This greatly increases the thermal efficiency of the system.

Evaporator Types

The primary difference between the various types of evaporators is the way in which the heat exchanger and vapor body are connected together and their physical relationship to each other. The most common evaporators fall into three types: rising film, falling film, and forced circulation flash.

In a typical rising film evaporator, the heat exchanger is mounted vertically and the

Rising Film Evaporator

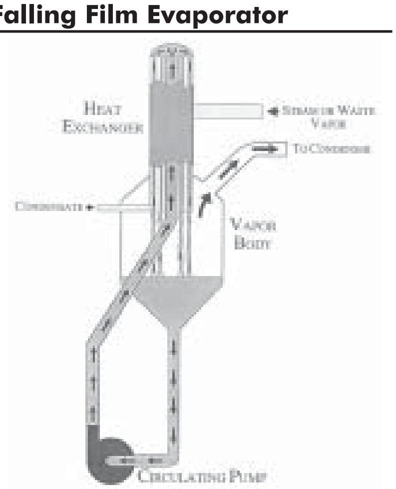


evaporator liquid flows in an upward direction through the tubes. Water in the evaporator liquid boils as the liquid rises in the tubes. This boiling action helps force liquid up and out of the tubes. The liquid and vapor leave the heat exchanger together and enter the vapor body. After vapor separation, the evaporator liquid flows from the vapor body through the circulating pump to the heat exchanger.

Like the rising film evaporator, the heat exchanger in a falling film evaporator is vertically mounted. In this case, however, evaporator liquid is pumped to the top of the heat exchanger and flows in a downward direction through the tubes. Boiling of water in the evaporator liquid occurs as the liquid flows down through the tubes, which helps to force the liquid down and out of the tubes. Liquid and vapor from the heat exchanger tubes enter the vapor body directly for vapor separation. A circulating pump is required to maintain proper evaporator liquid flow.

In the forced circulation flash evaporator, the heat exchanger is

Falling Film Evaporator



mounted horizontally, although vertical mounting is possible. The evaporator liquid is pumped by the circulating pump through the heat exchanger tubes where heat is absorbed. Unlike the rising and falling film evaporators, this evaporator is specifically designed so that no boiling occurs while the evaporator liquid is in the tubes. When the evaporator liquid enters the vapor body, however, some of the water in the liquid boils and is "flashed" off. The vapor body, or "flash chamber," separates the vapor and liquid. The liquid leaving the flash chamber returns to the circulating pump.

The selection of what type of evaporator to use depends on the operating conditions and economics of the specific application. Rising film evaporators have longer residence times and are more sensitive to solids loading in the evaporator liquid. They are generally used for clean liquids where short residence times are not critical.

Falling film evaporators are more commonly used than rising film types. They are compact, usually have shorter residence times, and make use of gravity to aid the flow of liquid through the tubes. They are less sensitive to solids loading than rising film units, but more sensitive to liquid distribution across the tubes. In a falling film evaporator, poor liquid distribution can cause inefficient heat transfer and tube-plugging problems. Both rising and falling film evaporators are susceptible to tube coating in the heat exchanger, which reduces heat transfer and may require periodic tube cleaning.

Forced circulation flash evaporators are used in applications where heat exchanger tube coating is a problem. Higher liquid velocities and the lack of boiling in the heat exchanger tubes help to prevent the tubes from coating. The circulating pump horsepower is higher than rising or falling film units due to increased liquid pumping rates.

Most evaporator applications in rendering involve the use of waste heat, usually vapors from a continuous cooker or dryer.

Evaporators are used to concentrate wastewater streams, concentrate water pressed from hydrolyzed feathers, dry restaurant grease, and evaporate water from raw material. In some rendering systems, evaporators are used as cookers. This application requires that the raw material be finely ground and fat added to form a slurry that will flow easily through the evaporator tubes.

Almost all evaporators used in rendering applications are either falling film or forced circulation flash types. The economics of the specific application will dictate which type of evaporator should be used. Falling film evaporators are generally used when the potential for tube coating is minimal, whereas forced circulation flash evaporators are preferred when tube coating may be a significant problem.

Evaporator construction details are as important as selecting the proper type of evaporator. In rendering applications, the recommended material of construction for evaporators is Type 304 stainless steel. Although stainless steel is more expensive initially, its greater service life as compared to carbon steel will more than offset the cost difference. It is also recommended that the evaporator design and construction conform to the standards specified by the Tubular Exchanger Manufacturers Association (TEMA). Requiring conformity to TEMA specifications helps assure uniform quality of construction regardless of the evaporator manufacturer. Evaporators subject pressures in excess of 15 pounds per square inch must be built in accordance with the American Society of Mechanical Engineers Boiler and Pressure Vessel Code. Besides being good practice, this is a legal requirement in almost all areas of the United States.

The vapor body design must be large enough to prevent any carryover of the evaporator liquid with the vapor stream as it leaves the vapor body. Conservative design (i.e., large diameter) in this area will pay for itself in the future in reduced

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operating problems and water treatment costs. For heat exchanger tube size, again, large is generally better. Most evaporators in rendering applications today have two-inch diameter tubes to enhance heat transfer and reduce tube-plugging problems.

It is impossible to cover all the details of evaporator design, selection, and operation in just a few pages. There are, however, a number of knowledgeable evaporator suppliers to the rendering industry. The best approach to evaporator selection is to make use of them as a resource in the selection process. ❖

Forced Circulation Flash Evaporator