FOOD PROCESSING

Evaporative Cooling's New Twist©

Although it's old (and proven) technology, vacuum/evaporative cooling evolves to meet today's needs.

By Lou Decker, Contributor

Vacuum or evaporative cooling technology has been used in the food industry for many years. Lettuce, spinach, cabbage and other leafy vegetables have been vacuum cooled since the early 1940s. Typical installations were portable or semi-portable, in some cases enclosed trailers, to facilitate handling the product in or near the fields. The product then was driven to a cooperative facility where large chambers would hold loads of produce, just picked and crated.

Cooling the product this quickly enhanced shelf life and enabled the product to be shipped long distances to the market and still maintain the field freshness. The process then evolved to transporting a product to a process plant and cooled prior to distribution.

Vacuum cooling serves a vital role in today's market. But there's a new twist: Current technology has made the process more efficient. Manual operation has turned into push-button automation. Instead of co-op facilities using the technology, now processing plants are using vacuum cooling to provide the finished product to foodservice outlets or retail stores**.**

Foods such as potatoes, soups, sauces, fruits, chick peas, some meat products and, of course, vegetables are ideal for vacuum cooling. Most can be cooked and cooled in the same vessel, thereby minimizing handling. Retort capacities can be sized for 3,200 lbs. of product and kettles for 50-800 gal.

Companies currently using this cook/cool technology in retorts include St. Clair Foods in Memphis, Tenn., which processes potatoes for salads and other items. Cedars Mediterranean Foods, Ward Hill, Mass., processes chick peas for hummus. The retorts were supplied by Allpax Products LLC Covington, La., as shown in Figure at right. A typical Allpax retort showing internal baskets of product which is then cooked or vacuum cooled. See Figure 1.

Lee Industries Inc., Philipsburg, PA., furnished kettles for the purpose of cooking and cooling soups, sauces and other liquid products. This technology is used by several Fortune 500 international and domestic companies. See Figure 2 below.

Figure 1. Allpax Retort

Why vacuum cooling versus other forms of cooling/refrigeration? Some foods are cooked in the traditional ways, they then have to be be transported to refrigerated rooms, cooled either by mechanical refrigeration using Freon, ammonia or air blast coolers. All of which may do an adequate job, but it takes time to reach required temperatures not to mention the additional handling or transportation time. Added handling and time may adversely affect quality, texture or appearance.

Figure 2.Lee Industries

An additional advantage of vacuum cooling is the dearation or removal of air from the product, which will improve the quality and increase shelf life by retarding bacterial growth. Typically moisture-rich products can be vacuum cooled from 240^{o}F to 40-35^{o}F in 12-20 minutes depending on the size of the vacuum system, vessel capacity and product quantity. Since the cooking and cooling occur in the same vessel, the product can then be pumped or transported to the packaging station or next stage of the process.

This saves time and handling while maintaining the product quality. Where a product is heat sensitive, vacuum is used – not to cool, but to maintain a constant temperature to prevent damage and to ensure the proper consistency during heating/cooling.

Some soups or broths may gel at too low a temperature. Some products such as custards and puddings are cooked at temperatures of 100-160 degrees Fahrenheit, but the temperature must be held below the point at which caramelizing will occur. The vacuum system therefore.is designed to maintain that critical pressure/temperature point.

The processing equipment can be controlled by a programmable logic controller to operate at that point or higher. In certain cases where different foods are processed the system can be programmed for different recipes to accommodate variable temperature and pressure as well as product quality and quantity.

Evaporation Principle

Vacuum cooling is achieved by rapid evaporation of moisture in the product. In most vegetables the moisture is contained within the structure of the food; in soups and sauces, the moisture may be part of the recipe added before or after the evaporation.

Evaporation occurs under vacuum, whereby the boiling temperature of the product's moisture is reduced by lowering the pressure below atmospheric. At standard atmospheric pressure 760 torr or 14.69 psia water boils at 212 degrees Fahrenheit. However, at a reduced pressure, in a vacuum, water boils at a much lower temperature. For example, at 370 torr (or 7.35 psia) water boils at 179 degrees Fahrenheit at 6.3 torr boiling occurs at 40 degrees Fahrenheit.

Without control, a vacuum system could reach freezing at 32 degrees Fahrenheit or 4.8 torr. This relationship is referred to as the vapor pressure of water at various temperatures. Data is widely published for water and other liquids.

Energy in the form of heat, which is required to change water from a liquid to vapor, comes from the product itself. Evaporation of 1 lb. of water from the product will cool approximately 1,000 lbs. of product by 1o F. Evaporation is frequently referred to as "flash" or "flash cooling." The actual cooling of the product is the result of the latent heat in BTUs or amount of thermal energy absorbed by the liquid in the flash process. Thermal energy is transferred from the product resulting in a loss of the sensible heat in the product and a resultant decrease in its temperature.

Vacuum systems are also used for chilling water for various applications and processes. In these cases due to the above function .the water is its own refrigerant eliminating the need for chemical refrigerant.

The amount of water evaporated from the food product typically ranges from 1-5 percent. The longer the product is exposed to the vacuum or the lower the temperature/pressure, the more moisture is removed. But this results in surface drying of the product; therefore, care must be taken to control the surface texture and perhaps color. During cooling of potatoes in a retort, for example, moisture is controlled by a fine mist of water sprayed onto the product which absorbs the moisture maintaining texture and color.

Processing of sauces, soups and viscous liquids, mixing or agitation is required. Since it is important to minimize temperature layers in the product, the pattern of agitation and speed is important. Horizontal agitation is recommended for most viscous the materials, whereas vertical agitation is used for low-viscosity products.

Occasionally, regardless of the type of agitation or speed the product becomes concentrated and additional water or another liquid must be used for taste enhancement either before or after processing.

Vacuum cooling of light fluids/products is not without some inherent problems. Milk, chicken broths some soups and high protein-content products tend to foam and sometimes erupt when the vacuum is first turned on .This eruption/foaming results in "carry-over" into the vacuum system, affecting its performance and, most importantly, decreasing the yield. This eruption usually stops when a certain pressure/temperature is reached. With proper control, the reaction can be minimized and perhaps eliminated.

Evaporation Source

There are basically two different methods of creating the required vacuum for cooling, depending on the ultimate temperature to be achieved and the time required to reach the temperature. An additional deciding factor in the process design may be the quantity of product to be cooled. The two methods to be considered are Steam Ejector Systems and Hybrid Systems.

- Steam Ejector Systems. These use the simplicity of steam jets, which have no moving parts and therefore are basically maintenance-free. They are motivated by steam using water in inter-stage condensers, usually shell & tube design. With operating temperatures in the range of 35- 80 degrees Fahrenheit, multi-stage systems are typically more efficient, larger capacity, simple to operate and more cost effective. Steam jet systems are based on the principle of using steam as the motive fluid, entering at a high pressure and low velocity and passing through a converging/diverging nozzle, which decreases the pressure and increases the velocity.

An increase in velocity of the steam entrains the process gas (e.g. air, water vapor, etc.) creating a vacuum. This mixture is then recompressed within the diffuser by conversion of the velocity energy back to pressure energy. After recompression the gases are considerably less than the motive pressure, but higher than the suction pressure. The combined mixture flow is the total of the two flow rates, motive plus suction.

The mixture then discharges into a condenser operating at an intermediate pressure, allowing for the majority of the process vapor and motive steam to be condensed before passing on to the next stage. The required product temperature and pressure determine how many stages are required. Typically a product temperature of 350^{o} F requires a three-stage vacuum system; for temperatures of 800^{o} F and above a single or two stage unit may be adequate.

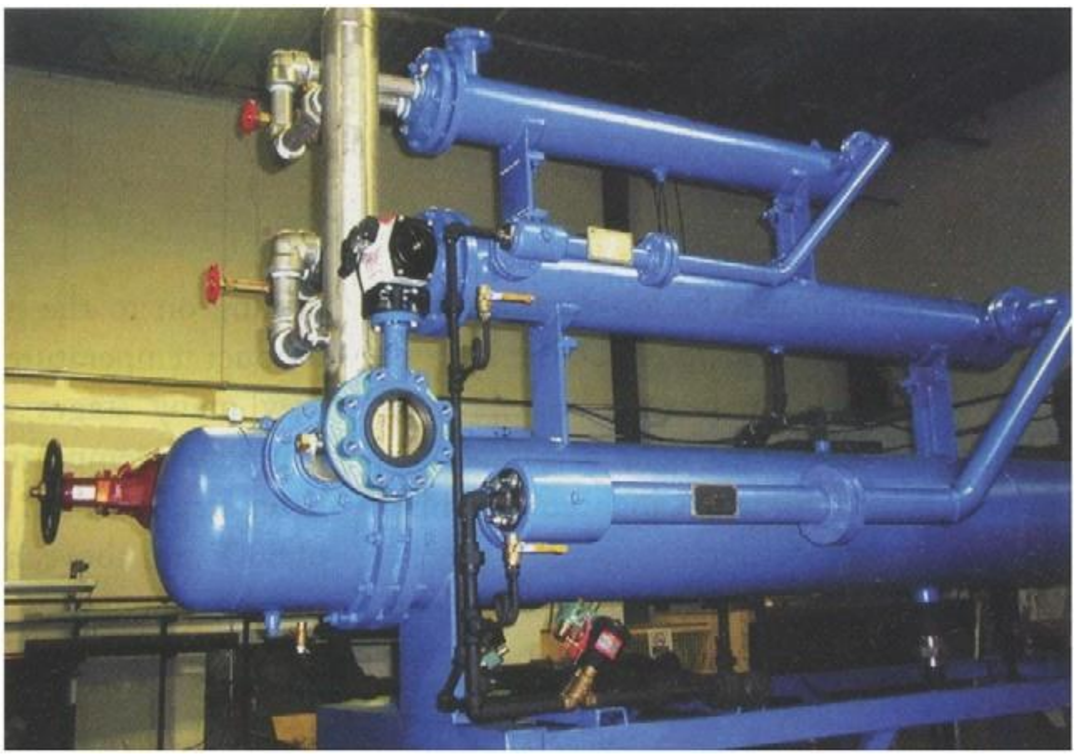

Figure 3. This three-stage Fox ejector system is the source of the vacuum cooling process

- **Hybrid** System: To reduce the steam consumption and also facilitate a low level installation of the vacuum system, a hybrid unit is recommended. A hybrid vacuum system is a combination of steam ejectors, discussed above, an intercondenser and a liquid ring vacuum pump. The steam jets operate at motive pressures as low as 5-10 psig achieving the same low suction pressures or product temperatures. The liquid ring pump then handles the discharge from the intercondenser operating at an intermediate pressure, discharging to atmosphere.

The liquid ring vacuum pump is a non-pulsating rotary vacuum unit whose only moving part, the rotor, is mounted on a shaft offset from the center axis of the pump housing. The rotor turns, throwing the liquid against the outer wall due to centrifugal force. A liquid ring pump forms against the housing wall. Since the rotor is offset, each revolution results in a chamber between the rotor blades being filled with liquid then pushed out a port As this rotation continues and the liquid decreases, the void formed is filled with a gas as the chamber exposes an inlet port. The liquid and gas are then compressed and discharged through another port into an atmospheric tank where they are separated.

The vacuum achieved by a liquid ring vacuum pump depends on the number of stages -- typically, one or two stages -- and most importantly the temperature of the sealant liquid used. The colder the liquid temperature, the lower the vacuum. However, as the temperature approaches the operating pressure, contraction will occur.

An all-ejector-type vacuum system typically requires installation at a height suitable for draining the condensate from the condenser. The recommended height is typically 36 ft. minimum. To facilitate a low-level installation of an all ejector system, the addition of a condensate receiver or a pressure powered pump can be added, which means an additional component is required. The hybrid system can be installed at floor level since the liquid ring vacuum pump has the multiple function of a condensate removal pump and final vacuum stage.

Due to the advantages of evaporative cooling consideration should be given to this technology to enhance product quality, maintenance free ease of operation while using an efficient automated approach.

<u>About Lou Decker</u>

For further information on this technology contact Lou Decker at lou@dectechassociates.com or 908-253-0101.

DecTech Associates LLC is an engineering consulting company focusing on the design and installation of vacuum systems for various industries such as chemical, pharmaceutical, pulp & paper with strong emphasis on food applications that include complete systems with retorts, kettles, cooling towers and support equipment.

Lou has degrees in mechanical engineering from Middlesex College, Rutgers University and a business degree from Uppsala College. He is a Certified Senior Engineering Technologist (NICET), Licensed Stationary Engineer in New Jersey and a member of American Society of Mechanical Engineers (ASME), American Welding Society (AWS) and Institute of Food Technologists (IFT). He has written several articles on vacuum cooling and has over 45 years of expertise.