Water Immersed Cooking and Chilling System

Water immersed cooking and chilling is a cost effective approach to provide quality meats, soups, & sauces for food processing facilities. In this way the method provides high yields of superior products consistently and reliably. Furthermore, the process systems used for water immersed cooking and chilling meet the established guidelines for safety and hygiene (see http://foodsafety.nal.usda.gov), as well as satisfying good manufacturing practices.

The advances in food technology, the availability of improved materials and in particular, the recent developments in automation and controls have contributed to well-designed, efficient water immersed cooking and chilling systems. Carmel Process Solutions (Carmel, Indiana) offers our customers the expertise and provides them the benefits of being a systems integrator. Our “hands on” approach, and experience in the design, installation and operation of these process systems, offers our customers the process flexibility that no other company can suggest or recommend.

What is water immersed cooking and chilling?

Water immersed cooking describes the process in which the particular products to be cooked (meats, soups, sauces, pinto beans and black beans) are sealed into polyethylene or polypropylene bags, loaded onto racks and placed in tanks, into which heated water is circulated. The temperature of the water and the length of time of immersion are critical factors in the cooking process and must be carefully controlled and monitored. The cooking time is defined as that required for the core of the product to reach a specific temperature and the minimum internal temperature for a given product has been established by the FDA. The processing of “ready to eat” foods is also measured in terms of the lethality, a term introduced by microbiologists and food scientists to indicate the ability of the process to destroy bacteria. Lethality performance standards were established by the USDA in 1999 and revised in 2001. It follows that the temperatures required to meet the FDA and USDA standards (see http://www.fightbac.org/content/view/93/2/) will be different for each product and will vary with size, weight and moisture content. The times required to reach the recommended temperatures will similarly depend upon the particular product and upon the size, weight and moisture content. Therefore it is necessary to determine the temperature-time profiles from a series of pilot-scale tests in which the temperature of the water and that of the core of the products are closely controlled and monitored.

The cooking process involves both heat transfer and the migration of water (moisture) from the interior to the surface of the product. Heat is transferred from the water to the product and from the surface of the product to the core by both conduction and convection processes. The conduction of heat depends upon contact between the particles of the product and is the primary mechanism for transfer from the surface to the interior. Heat transfer by convection is the result of gradients of temperature between the water and the product contained in the plastic bag. These gradients are sustained by the movement of the water surrounding the article being cooked, movement that is caused by pumping and/or by agitation.

The foods being cooked all contain water (moisture) and during the cooking process this water moves from the core to the surface to evaporate into the surrounding atmosphere. In the sealed, plastic bags evaporation is partially inhibited and the condensate is retained, allowing the food to “cook in its’ own juices,” which enhances both flavor and texture.
Water immersed cooking in sealed bags essentially avoids the issues related to evaporation and humidity, providing an atmosphere around the product that is beneficial to the flavor, color and texture.

To obtain consistent product quality in water immersed cooking, it is important to maintain a uniform temperature in the water surrounding the sealed bags. It is recommended that the temperature of the water be controlled to ± 2ºF over the total cooking time. Uniform temperature control is best achieved by sparging air through the heated water. A significant benefit of sparging is that the small bubbles of air clean the surfaces of the plastic bags, aiding the transfer of heat from the water.

Water immersed chilling refers to the process of cooling the products that have been cooked by immersion in heated water. The specific heat and the thermal conductivity are the main properties of the products that affect cooling. Thermal conductivity determines the rate at which the heat moves through the product and obviously it will vary for the various foods. Usually a high water content indicates a high thermal conductivity, whereas any fats in the food tend to provide insulation. The rate of cooling depends on the temperature gradient from the surface to the core, as does the rate of heating. The larger the temperature gradient, the higher is the rate of cooling.

USDA regulations regarding safe cooling specify that the core temperature of the products must be less than 40ºF. In addition to the lethality requirement, USDA- FSIS\(^1\) requires establishments to achieve a stabilization performance standard for preventing the growth of spore-forming bacteria. These require that the cooling process of cooked meat products to be sufficient to prevent multiplication of \textit{C. Botulinum} and no more than one log growth\(^2\) of \textit{C. perfringens}. The spore formers can survive the normal thermal processes applied to meat products, and thus can grow to hazardous levels during cooling, if the products are not cooled properly.

Thus, performance standards or criteria are an integral part of the thermal processing of meat and poultry products, and form the basis for designing the processing parameters. These processing systems should be customized on a case-by-case basis tailoring to the product characteristics. As with the cooking cycle, the time required to cool the products to the safe temperature is determined in pilot-scale tests, since it is not feasible to directly monitor the core temperatures of the products in sealed bags.

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\(^1\) USDA Food Safety and Inspection Service (FSIS) is the public health agency in the US Department of Agriculture that is responsible for ensuring that the nation’s commercial supply of meat, poultry and egg products is safe, wholesome and correctly labeled and packaged. (see http://www.fsis.usda.gov)

\(^2\) Log growth refers to the phase of bacterial growth in which the rate becomes exponential, i.e., the logarithm of the rate is linear with time. (see http://en.wikipedia.org/wiki/Bacterial_growth)
The Design of the Process System

Our typical process system for water immersed cooking and chilling typically contains the following equipment; it is assumed that the customer currently owns a boiler or steam generator. If not, Carmel Process Solutions can provide a new unit.

- Stainless Steel Insulated Cook Tanks (sized to customer’s production requirements)
- Stainless Steel Chill Tanks (sized to customer’s production requirements)
- Ice Builder or Water Chiller
- Operator Platform
- Overhead Gantry Crane System
- Sanitary Centrifugal Pumps
- Heat Exchangers
- Sanitary Valves
- Sanitary Filters/Strainers
- Sanitary Process Piping
- Process Controls and Instrumentation

Cooking Process:

Water immersed cooking requires an efficient means of heating the process water, additionally, maintaining the water at precise temperatures throughout the cooking cycle is vital to the cooking process. The following are two types of heat exchangers that can be utilized.

Indirect: (Shell n Tube, Plate n Frame, or Scrape Surface Exchangers)

- Two or more fluid flow paths – NOT permitting direct mixing of fluids
- Promoting the transfer of heat from one fluid to another across a thermally conducting, impermeable, barrier such as tube wall or plate.
- Higher maintenance costs along with more floor space requirement than direct heat exchangers

Direct: (Direct Steam Injection – Hydro-Thermal Corp)

- Transfers heat by injecting precise amounts of steam directly into the water
- More efficient energy usage (100% thermal efficiency) versus indirect heat exchangers
- Precise temperature control by use of internal modulation of steam
- Energy savings of 20-25% versus indirect heat exchangers
- Less costly to maintain and uses very little, if any, floor space

Note: For additional information on the effectiveness of direct steam injection heaters, See more technical writings by Hydro-Thermal Corporation

2 Hydro-Thermal DSI Valves
Chilling Process:

We advocate the use of water immersed cooling by using either an Ice Builder (non potable) or Falling Film Water Chiller (potable).

Non Potable Chilled Water: Ice Builder

- Ice that is built up in an ice builder is non potable and shouldn’t be used as the process water in the chill tanks. Ice water coming from the ice builder has its own closed loop water system that circulates between the ice builder and one side of a heat exchanger. Potable water is then circulated between the heat exchanger & the chill tanks in its own closed loop system.

Potable Chilled Water: Falling Film Water Chiller

- The primary application for a Falling Film Chiller is to cool food-grade liquids that will become an ingredient of a food product, or that will come into contact with a food product. These units are available for DX, recirculated, and flooded refrigerant controls for R-717 (ammonia), R-22 (HCFC), R-404A (pentafluoroethane), and all other conventional refrigerants. A closed loop water system is installed between the water chiller and chill tanks.

Sanitization Practices in Water Immersed Processes

The cleanliness of water immersed processes is insured by the selection of 304 stainless steel as the material of construction for the tanks, racks, heat exchangers and process piping. Sanitary valves and pumps are incorporated into the system. When required the tanks and the components of the system are cleaned manually, since the limited space in the tanks makes it difficult to use clean-in-place (CIP) technology. Recently, concerns with regard to food safety and liability have led the industry to include disinfection and even sterilization of the process equipment.

A biocide is added to the water that is circulated to and from the chilling tanks to maintain sanitary conditions throughout the cycle. The preferred biocide is either chlorine water or sodium hypochlorite, although ozone is now being used fairly widely. Studies by an independent testing division of NSF International\(^3\) concluded that treatment of process equipment with ozonated water for only 30 seconds met the sanitary standards. However, ozone does not provide a residual disinfectant in the water, which can be a limitation in circulating systems. Other biocides that are being evaluated by the food and beverage industries include chlorine dioxide, peracetic acid and ultra-violet light.

The biocidal effectiveness of chlorine water is the result of the formation of hypochlorous acid (HOCl) as the chlorine gas is dissolved into water. However, if the pH of the solution becomes alkaline (pH>9) the acid is largely dissociated, leaving the hypochlorite ion in solution. The ion is significantly less effective as a biocide than the undissociated acid. The high pH of commercially available solutions of sodium hypochlorite (pH typically 11 or higher) means that only the hypochlorite ion is present in the solution, making these solutions weaker biocides than chlorine water. The biocidal effectiveness of solutions of hypochlorous acid and sodium hypochlorite is reflected in the oxidation-reduction potentials (ORP) of the solutions.

\(^3\) NSF International is an independent organization that is committed to ensuring that public health standards are met. (see http://www.nsf.org)
The ORP is a measure of the ease of transfer of electrons to a platinum probe immersed in the particular solution, i.e., the oxidizing or reducing power of the species in the solution. Biocides are oxidizing agents and the ORP (in millivolts) for biocides will be positive, with respect to the Ag/AgCl reference electrode against which it is measured in ORP meters. The ORP for hypochlorous acid will be significantly larger than that for the hypochlorite ion, in solutions of approximately the same concentration. The ability of the circulating water to maintain the required sanitary conditions can be monitored and controlled by measuring the ORP and pH of the water.

**The Control System**

The main component of the control system is the programmable logic controller (PLC), often regarded as the brains of the automation and control processes. The PLC may be viewed as a small, industrialized computer that has been developed to provide reliability in a plant environment. It scans digital and analog sensors and switches, reads the control programs, (e.g., the temperature-time profiles for each product), makes calculations to control the valves, lights and relays in the system. Information can be exchanged with operator interfaces (HMI) and supervisory control and data acquisition (SCADA) software packages. Recent developments have made it possible for critical data to be communicated from the factory floor to the business level of the company. Data is collected and may be stored either electronically or with a chart recorder. This capability is important in establishing and maintaining compliance with today’s sanitary and safety regulations.

The process control system should balance the need for accuracy and reliability, yet provide flexibility. With today’s technology the control system can be made “user friendly.” Furthermore, with the availability of smart sensors, intelligent valves, central SCADA systems and integrated PID control logic, every function in the system can be automated to operate at the required levels of accuracy.

**Why will it be advantageous to work with Carmel Process Solutions LLC?**

The proper selection of the process equipment and the control system is critical to the success of the process. The systems offered by Carmel Process Solutions, that are to be used for water immersed cooking and chilling, are based upon the knowledge gained by working with the food industry, awareness of advances in meat technology, selection of materials and “hands on” experience with all of the components to be used.

One of Carmel Process Solutions’ customers is a leading meat supplier to one of the largest fast food chains in the country. Here are some of the products being used in our systems; Barbacoa, Carnitas, Adobo, Beans, & Taco Meat. Carmel Process Solutions diligently remains current in terms of the significant improvements in the controls and instrumentation that we provide. This leads to better monitoring of all of the components in the system and to consistently obtain higher yields of products having superior flavor, color and texture from the water immersed cooking and chilling processes. Carmel Process Solutions can offer systems for water immersed cooking and chilling that provide a better overall process operation with lower capital expenditure. Give us a call today and see how we can bring together your ideas and our expertise.