Understanding Culinary Steam

An Online Continuing Education Course for Engineers

Course Number: M-2089

Credit: 2 Hours / 2 PDH / 2 CPD

Understanding Culinary Steam

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Disclaimer & Cautions:

This course is not a safety training course for working around steam systems or their proper safe installation. Be sure to engage trained professionals to obtain the necessary training before attempting any work or adjustments around a steam system. The focus of this course is on how to deliver high-quality steam and use it to provide food safety and consistent food operations. There are several specific areas that even the casual observer to the system must be aware of and seek training as needed:

Boiler Operation: Boilers and steam generators require specialized training to operate properly. Improper operation can be extremely dangerous.

Pressurized piping system: Steam piping for culinary steam often run at pressures around or above 125 psig. No work on the system should be performed on components while they are under pressure. Only skilled and trained maintenance individuals should do this work under a developed lock out tag out system with the release of any stored energy.

Hot surfaces: Some parts of culinary steam systems may be exposed directly to the air with a guard but without insulation. These surfaces will often be hot enough to burn on contact even after steam pressure has been removed. Be careful around these surfaces.

Chemicals: Chemicals used for system treatments are concentrated in their containers before injection. Only trained maintenance personnel with specialized training should handle these chemicals.

Steam: Steam itself in dry form is an invisible gas that can burn on contact. Although steam can usually be seen as it condenses in the air and forms a visible white stream, it is at a temperature that can cause immediate burns.

What is Culinary Steam:

Steam that is used for direct contact with food product must follow guidelines to assure that it is clean and safe for human consumption. This starts with the proper use of steam system treatment chemicals and continues with the proper filtration and treatment of the steam prior to direct injection. Steam used in this manner is referred to as Culinary or Sanitary Steam. In certain food industries, there are specific requirements that must be met to satisfy FDA, USDA, or other state or federal agencies. Typically, the standard for culinary steam for those regulatory agencies is in reference to the 3A standard (see definitions below). Culinary steam can be thought of as steam without any harmful or undesirable ingredients that does not carry with it any undesirable residues of the actual steam system or steam generation. Through proper handling of the steam, the resultant condensate that becomes part of the food is safe for human consumption.

Why use Culinary Steam:

Culinary steam requires special handling of the steam and a prescribed method to make sure the steam contains no undesirable or harmful ingredients. Certainly, there are other methods to heat products. Alternates would include a wide variety of heat exchangers that use steam jackets to keep the steam from direct contact with the food. These heat exchangers include: mixing kettles fitted with steam jackets, double and triple tube heat exchangers, swept surface heat exchangers, shell and tube heat exchangers, plate heat exchangers, and others. Additionally, non-steam options, like direct electric and ohmic heating, use of other heat transfer fluids, direct gas-fired vessels, and other options also exist. Culinary direct-injected steam may provide unique benefits for a particular food product, but it is not suited for all food products. Looking at the pros and cons of culinary steam, direct injection can give further direction to the beneficial use of direct culinary steam injection:

There are several pros to using direct injection steam over indirect:

- The equipment to direct inject steam is mechanically simpler than indirect methods.
- Direct steam injection is the most efficient at heating the product. Almost 100% of the energy from the steam is transferred into the food product.
- There is no heat exchanger to foul.
- Large amounts of heat can be transferred into the product with little surface area of injection versus indirect methods.

- Product side of injection is easily kept clean by proper design without constant mechanical wiping or scraping of the heat transfer surface.

Of course, there are times when direct injection of culinary steam may not be the desired method:

- Product does not have enough water in it to allow for the additional water added by the steam collapse into condensate (e.g., peanut butter, chocolate).
- Moisture regulation of the final product is desired to be controlled with absolute minimum of variation.
- It is desirable to whip or emulsify the product as part of the heating process.
- Product cannot tolerate the steam temperature of direct injection.
- Large particulates present that require long residual heating times
- No steam system or experience exists in the facility.

Basic Definitions and Steam Properties for this course:

The following definitions are provided to enhance understanding of this course:

3-A Sanitary Standards Inc: 3-A is an organization that maintains many standards as it relates to sanitary standards for food and pharmaceutical production. Their standard “3-A 609-03 Accepted Practice, Method of Producing Culinary Steam” is one of the leading standards referenced by regulatory agencies. USDA-Dairy, USDA-FSIS, FDA, and a number of the regulatory departments in states will refer to this standard. This course generally aligns with this 3-A Accepted Practice with further explanations around the proper use of each component and the calculations around water addition to product.

CFR: The Code of Federal Regulations or CFR is a compressive set of rules and regulations for the federal government and all agencies. It is divided into 50 titles. Title 21 has specific requirements for food products.

Condensate well: When a large steam main is fitted with condensate traps, just tapping the condensate trap into the bottom of the main with the small pipe size of the condensate trap will not be effective. Because of the steam velocity, a good share of the condensate will be carried across the opening of the condensate. By creating a larger size bottom takeoff of the steam main, the condensate will have a better opportunity of dropping out of the high-velocity steam. A trap is fitted at the bottom of this condensate well. Failure to use condensate wells can cause the main not to drain properly and allows the development of damaging two-phase flow.

Culinary Steam: Culinary steam is steam created and safe for use in direct contact and as part of food products. Culinary steam consists of high quality (see definition of quality below) steam that does not contain unwanted particulates or chemicals. It may be used as a surface treatment or for cooking the food product. Culinary steam is sometimes referred to as Sanitary Steam in the food industry.

> *Note: Steam is regularly used to heat water and solutions that are used to clean food product contact surfaces. Some food manufacturers require that if direct injection steam is used for this heating purpose, the steam must be culinary steam.*

Enthalpy: Enthalpy is the amount of thermal energy that is contained in the steam. English system units are BTU/lb_m and SI system units are kj/kg. English units will be used in this course. Enthalpy is represented for water as fluid with the symbol "h_f" and for water as vapor (steam) with the symbol "h_g."

Enthalpy – Heat of Vaporization: Of special value with the use of steam is the amount of energy that water requires in order to change from a fluid to vapor. This is called heat of vaporization, enthalpy of vaporization, or latent heat of vaporization. In approximate rough terms, when water changes from fluid to vapor while remaining at the same temperature, it takes 1000 times more energy than raising the temperature of the water just 1°F. As a corollary, when the steam turns back from steam to fluid water, the steam releases that same 1000 times more energy than by lowering fluid water by 1°F. This physical property of water/steam is why it is so often used for heating applications both in direct and indirect methods. Heat of vaporization is represented by the symbol "h_{fg}."

Enthalpy – Heat of Fusion: When looking at water property tables, two additional enthalpy values may be shown, h_{sf} and h_s. These values refer to the enthalpy of the heat of fusion, h_{sf}, which is the energy needed to convert fluid water to a solid (ice). This is sometimes referred to as the heat of melting. Similarly, h_s refers to the enthalpy that solid water contains. Neither of these values is needed when working with culinary steam calculations.

PID Control: PID is a very common control scheme that allows rapid response and precise control of processes. For this course, a PID control scheme may be used for the steam control valve referenced later. PID gets its name from the response types that work together: Proportional, Integral, and Derivative. The PID control algorithm within the controller takes into account how far away the process is away from the setpoint (Proportional), what the sum of the error from the setpoint is over time (Integral), and how quickly the process response is occurring (Derivative).

PRV: Pressure Reducing Valve. A PRV is used to bring system steam pressure down to injection pressures.

Psia versus psig: It is important to note that most steam tables are written in psia or absolute pressure, while most readings taken from a running system are psig or gauge pressure. At sea level 0 psig equals 14.7 psia. Corrections may need to be made based on the actual elevation of the process being calculated.

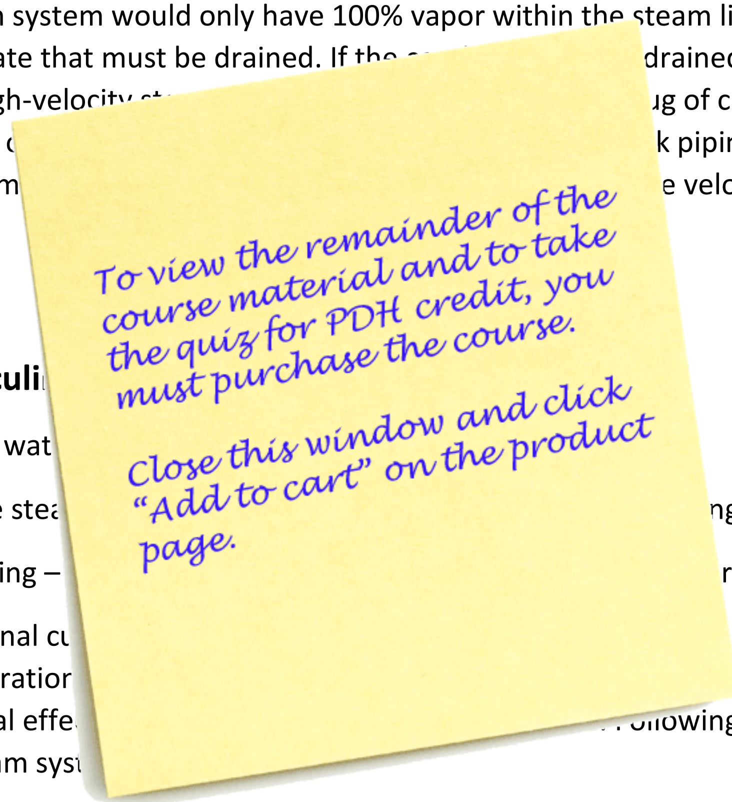
Religious compliance: This course does not cover special requirements that will be required in order to obtain religious food certifications. The primary area that can be of concern is condensate return to the boiler. Condensate returned from a non-accepted food process (even if indirect) may cause all the steam to be unacceptable for heating (direct or indirect) for the religiously-accepted product. Certifying agencies (e.g., for Kosher, Halal, etc.) can provide information on their additional requirements.

Specific heat: Each material requires a different amount of heat to raise its temperature one degree. Sometimes specific heat of a product is referred to as the heat capacity of the product. Water requires approximately 1 BTU energy per lb. of water to raise its temperature 1°F. Water is said to have a specific heat of 1. In contrast, Olive Oil has a specific heat ≈ 0.5 In simple terms. This means that it takes half the amount of heat to raise the temperature of olive oil 1 degree F as it takes to raise the temperature of water 1 degree F. English units for specific heat are Btu/(lb°F). When looking at specific heats for culinary steam-cooked products, C_P is always used. C_P is also referred to as the Isobaric specific heat. C_V, isochoric specific heat is not used for direct injection calculations.

Steam quality: Steam quality is at the heart of this course. Steam quality is measured as a percentage of dry steam within the vapor steam flow. 100% quality means the steam flow is 100% vaporized water. 95% quality steam means that 5% of the steam flow mass is in the form of liquid water droplets. When a reference is made to having “completely dry steam,” the meaning is that the quality of the steam is near 100%. The portion of the steam that may contain water droplets (condensate) contains no heat of vaporization and adds water to the final product without adding significant energy for heating the product. One of the main purposes of the final culinary steam treatment is to make the steam as dry as possible.

Superheated Steam: When 100% quality saturated steam is heated beyond the saturation temperature, the steam is said to be superheated. Superheating does not occur in a regular culinary steam system and is not of concern for this course. Pressure drop across the PRV in the culinary steam final conditioning will slightly improve the steam quality but does not move the steam into the superheated realm.

Two-phase flow: The ideal steam system would only have 100% vapor within the steam lines. In reality, some fraction of the steam condenses and creates condensate that must be drained. If the … drained properly and a large amount of condensate accumulates, the high-velocity … ug of condensate to develop into a high-velocity liquid slug of water. The velocity … k piping at a reduction or change of direction area. This is due to the huge mom … e velocity of the vapor steam flow.



There are three major parts of a culi…

1. Steam Generation – incoming wat…

2. Steam Transport – moving the stea… ng

3. Culinary steam final conditioning – … roduct

The focus for this course is the final cu… n great detail, but it is important to review several aspects of both the generatio… oblems in the generation and transport of the steam can have a detrimental effe… ollowing is the review of each of the three major parts of a complete culinary steam syst…