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REDUCING TOTAL PACKAGE OXYGEN

The basics of a foaming device in beer bottling with heated, ultra-pure water

Many experts agree that the taste and quality of most beers is best when it is first filled into their containers (Bamforth & Krochta, 2010). Later, the presence of oxygen in the liquid results in oxidation, a major contributor to degrading beer flavor, quality and color. According to Robertson (2013) even oxygen levels as low as 1 ppm can lead to detectable flavor and color problems in beer. Oxidation also negatively impacts the beer's shelf life. This paper describes the implementation in a large-production beer bottling operation of a foaming device using heated, ultra-pure water. It summarizes the case study findings that a properly designed ultra-pure water heater will improve operations and contribute to reducing total package oxygen (TPO) in the packaged beer.

Oxygen is introduced in various stages throughout the brewing process. Klein and Dunand (2008) give an example of the expected ranges of oxygen pickup (see Table 1). Robertson explains that brewing, through fermentation, actually reduces the level of oxygen in beer down to 40 to 50 ppb prior to packaging. The oxygen is mostly introduced during the filling process, when air enters the package, and the level can reach 250 to 500 ppb.

Brewers use various methods to reduce oxygen in bottled beer. They aim for oxygen levels of less

than 50 ppb immediately after packaging, and seek to hold that level for as long as possible (Robertson). After packaging, oxygen can find its way into beer from penetration through the package closure and/or package material.

Total package oxygen provides insight into O₂ levels in beer

It is common practice for commercial brewers to measure total package oxygen (TPO) and use this value to evaluate the oxygen

level in the final packaged beer. TPO includes the dissolved oxygen in the liquid, and the amount of oxygen in the head space of the package. The equation for TPO is shown in Table 2, where TPO is the sum of DO (dissolved O₂ in liquid) plus HO (O₂ in headspace not removed prior to crowning).

Along with other process measurements, ongoing TPO measurements provide brewers with statistical assurances that quality parameters are being met and that the beer being packaged will maintain its expected flavor, quality and color over the desired shelf life.

In addition, TPO measurements also provide quantitative values against which new ideas for changes in bottling operations, machinery and process can be evaluated.

Using heated, ultra-pure water for lowering TPO in beer bottling operations

To lower TPO, beer bottling operators have developed various methods for displacing the air or atmospheric oxygen present in the container. Early systems included bottle knockers and ultrasonic vibrations to induce foaming. Newer systems have experimented with the use of CO₂ or liquid nitrogen (Oliver, 2012).

According to Oliver, a method used to expel air from the headspace of a bottle of beer is called jetting, and it has been found to be reliable and easy to implement and control. Oliver goes on to explain that this method uses “a fine stream of high pressure, and often high temperature sterilized water, to energize the beer, causing a controlled rise of bubbles and foam from deep within the beer, through the headspace just as the closure is placed on the container.”

A typical beverage bottling plant ... and where to find the jetting device

For better clarity on how a jetting device operates, the main components of a beverage bottling plant are described below and displayed in Figure 1.

In a typical bottling plant, the bottles first travel through a conveyer into a rinsing station. A second conveyer transfers the rinsed bottles into a beverage filling machine.

A common beverage filling machine has a rotary design in which each rotor receives and holds a bottle for filling, and filling occurs simultaneously at multiple rotors. Each bottle receives a predetermined amount of liquid beverage. The filled bottles then travel further along the beverage bottling plant to a bottle closing station. The closing station contains the jetting device and a device that crowns each bottle. The crowned bottles then continue on to a labeling station.

Table 1: Expected oxygen levels throughout the brewing process

Brewing Process	Oxygen Level
In wort	6–14 + ppm
Fermentation	<30 ppb
Filtration	1–200 ppb
Bright beer after filtration	1–200 ppb
Beer at the filler	1–200 ppb
Package dissolved oxygen (bottle)	30–250 ppb
Total package oxygen	50–450 ppb

A closer look at jetting as a foaming device

Figure 2 provides specific information on the operation of the jetting device located in the bottle crowning station. Since the jetting device requires ultra-pure water, the potable water must first be treated to remove any substance that may affect the beer. Chlorine, sediment and minerals are of particular concern to brewers, and therefore should be removed prior to entering the system to avoid negative effects on the beer or machinery (Oliver).

The purified water is typically supplied at 80 to 90 psi. To get precise control of the final water stream, a high-pressure pump is used to control and maintain the proper pressure. A pressure regulator reduces the purified

water supplied to the high-pressure pump to 25 psi. This allows the high-pressure pump and a variable frequency drive (VFD) to more accurately obtain the final desired pressure of 140 psi. The VFD gets feedback from a pressure transducer.

The pressurized ultra-pure water now flows through filter housings, a flow meter, a pressure transducer and an ultra-pure water heater. The results are a supply of 170 to 200 mL/minute of filtered, ultra-pure water at the desired supply pressure of 140 psi and 190 °F temperature. The jetting water flows through an insulated pipe or tubing, where it is dispensed through a 15 mL nozzle and into each beer bottle.

Critical design factors of a jetting device

Our specific case study appears to match with Oliver, who indicates that successful water pressure is 10 to 17 bar (145 to 246 psi) in a nozzle size of 0.2 to 0.25 mm (0.008 to 0.010 inches).

Pressure, nozzle orifice size and distance from the crowner are important parameters that affect overall results and are adjusted based on package size, beer characteristics and line speed. Most importantly, the desired goal is repeatability, reduced costs and maintaining a quality beer taste. Oliver goes on to explain that the nozzle should be cleaned regularly.

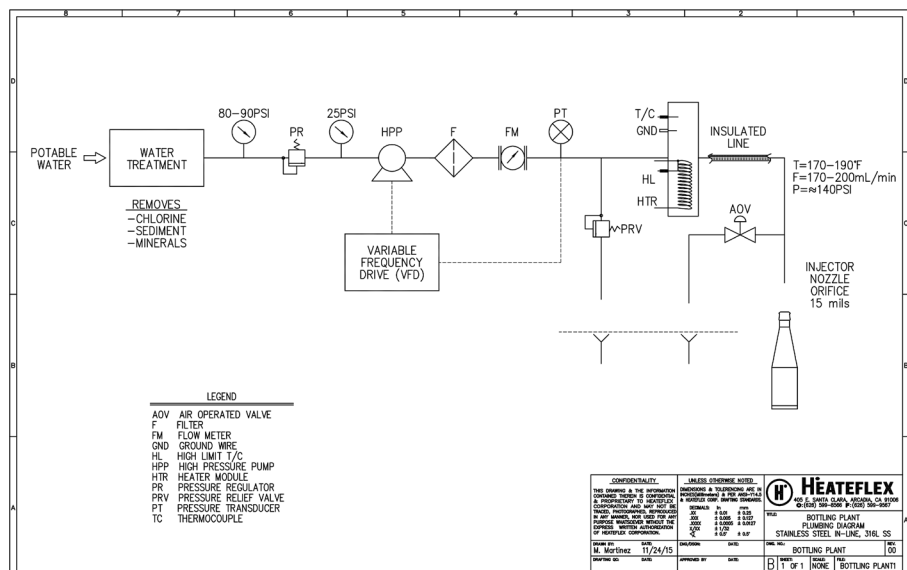


Fig. 1: Main components of a beverage bottling plant

An out-of-spec nozzle can impact air entrapment, produce unacceptable loss of liquid or result in improper fill levels.

Identifying the in-line heater and design factors that contribute to lower TPO

Very little attention has been given to the role of an electric in-line heater in jetting devices. The brewing industry has traditionally focused on steam-heated jetters, which require an expensive boiler. By carefully considering the design factors of the in-line heater selected, we found that improvements in producing the correct foaming characterizations could be obtained.

One concern is the process purity. Every component of a beer bottling line needs to maintain the brewer's high cleanliness standards and sanitary conditions. A heater is no different.

We selected a sanitary stainless steel heater that featured a sanitary interface between the heater and the vessel. Typically, heaters use either pipe threads or a bulky flange, and each can introduce areas for particle entrapment and bacteria growth. The heater's sanitary interface provides an ultrapure design that is also easy to clean, and selecting a heater made of electro-polished, 316 L stainless steel also assures cleanliness.

Table 2: TPO Equation

TPO = DO + HO	
Where:	
TPO	= Total Packaged Oxygen
DO	= Oxygen dissolved in liquid
HO	= Oxygen in container headspace

Another process purity design factor was to keep the jetting nozzle as sterile and dry as possible to minimize cleaning and downtime of the bottling line. Heat at 165° F kills bacteria and keeps the nozzle dry. The heater has the capacity to operate at a higher temperature to ensure that this targeted sanitary heat of 165° F is obtained when it reaches the jetting nozzle tip.



Fig. 3: The Heateflex Sanitary In-Line Heater

Another area of concern is safety, particularly with respect to the pressure vessel used and the electrical characteristics of the heater. We addressed concerns about the vessel being able to handle the operating pressures by ensuring the heater housing (pressure vessel) was ASME U-stamped. An ASME U-stamped vessel can only be fabricated by a nationally board certificated manufacturing facility, where a third-party inspector evaluates the plant's quality control manuals and welder testing every two years. The pressure vessel also includes a built-in pressure relief valve, which prevents unsafe pressures from developing in the heater.

Electrical safety is addressed through the use of a grounded heater. In addition, the heater selected included a process thermocouple that measures the temperature of the liquid, and a separate over-temperature thermocouple embedded in the heating element. The over-temperature heater thermocouple provides a faster signal to control circuits than would a separate redundant liquid sensor. This faster signal allows the control circuit more time to safely react to varying conditions.

Oxygen in the liquid may also be introduced through fittings and plumbing where air can be aspirated in. These cases can be difficult to find, because the liquid does not visibly leak out. The heater we selected includes sanitary, tri-clover fittings at both the inlet and the outlet to provide a reliable seal.

Overall, the heater selected should provide consistent reliable results, be of sanitary design and be safe. Figure 3 depicts the heater developed by Heateflex for the TPO reduction application, and Table 3 summarizes the product's design factors and benefits.

Conclusion

The basics of using a jetting device with heated, ultra-pure water were shown to reduce TPO in beer through producing correct foam characteristics. Oxygen in beer causes oxidation and degrades beer flavors, quality and color. Oxygen in beer mostly enters the process during filling.

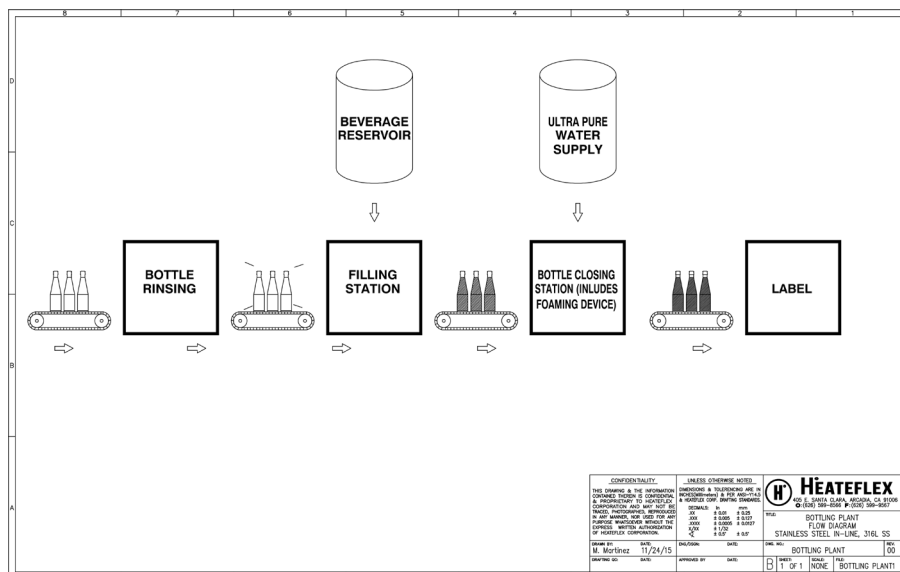


Fig. 2: Jetting device operation in detail

Table 3: Heater Design Factors and Benefits

Heater Design Factors	Benefits
Sanitary design interface between heater and vessel	Ultra-pure design for sanitary processing. Eliminates fitting threads, bulky flanges and areas for particle entrapment by featuring a proven tri-clover fitting interface.
ASME U-stamp vessel	Confirms that the vessel wall thickness, material of construction, and welds meet the ASME standards for pressure and temperature. Also guarantees that a third-party inspector witnessed the hydro-testing and verified design and certification.
Stainless steel 316 L, Electro-polished wetted surfaces	Maintains water ultra-pure. Easy to clean.
Proper tri-clover clamps on vessel, inlet and outlet	Prevents air from entering liquid lines.
NEMA 4X enclosure	Protects personnel by insulating hot surfaces. Protects tools by insulating the heater from a splashdown environment.
Integrated over-temperature thermocouple on heater	Improves safe operation with faster response to over-temperature conditions, because thermocouple is located on the heater, not in the process fluid.
Built-in pressure relief valve	Required safety component in place.
Additional safety features: grounded system and integrated process thermocouple	Required safety features in place.

TPO is the sum of the oxygen dissolved in the beer and the oxygen in the container headspace. Brewers use the TPO measurements as an indicator of the quality of their bottling process, and they also help determine the expected shelf life of their product.

Using heated, ultra-pure water in a jetting (foaming) device was found to lower TPO in beer bottling operations. An improved heater in the foaming device can contribute to improvements in the beer packaging and reduce TPO. An ideal heater includes a sanitary interface design, an ASME U-stamped vessel, and integrated safety sensors and features. □

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