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CASE STUDY

Measuring Beverage Concentrations at the Filler: Process Optimization by Inline Analytical Technology

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ABSTRACT

Modern breweries today deal with many different product streams. In addition to beer, in today's breweries they also produce beer mixed drinks, soft drinks, and sodas. Process optimization can save a lot of money with such a large range of products and frequent product changes. To address this complexity and to provide immediate feedback, the Oettinger Brewery in Germany decided to improve processes at their filling lines by using LiquiSonic inline measuring technology from SensoTech. The objective of this paper is to discuss the technology of this inline instrument and describe the benefits of adding this equipment to the filler product supply.

In beverage production, high-quality inline measuring technology provides process information in real time to control processes targeted, online, and without delay. Consequently, failed productions and follow-up costs can be avoided. A critical process parameter is represented by the concentration of original gravity, measured in °Plato of the product supplying the filler. To ensure the quality guidelines and the efficient use of energy and raw materials, the original gravity concentration can be continuously measured in various locations along the production stream in a brewery. For example, locations in the brewhouse, at the wort cooler, and at the filter and filler can all be integrated into control systems in a brewery operation. In the production of beer mixed drinks, soft drinks, or sodas with the sensor chosen for this application the online monitoring includes the inline concentration measurement of °Brix during the blending and bottling.

The product range of the Oettinger Brewery in Brunswick, Germany, is wide and ranges from different beer types to beer mixed drinks and fruit spritzers. As a process sequence the classic beer types such as pilsner, wheat, and export are followed by beer mixed drinks such as radler, grapefruit, wheat, cola beer, and nonalcoholic organic soft drinks with malt extract. The numerous products are bottled in separate batches with frequent product changes at the filling lines. The Oettinger Brewery realized quickly that the laboratory analysis for all of the product changes required an excessive amount of manpower and line downtime. "Given our large variety of beverage types and high quality standards, the laboratory analysis is very time consuming, so an online monitoring by reliable inline measuring instruments was required," said Uwe Berkhausen, quality assurance manager of Oettinger Brewery in Brunswick. To maintain the production requirements, after samples were taken at product changes, filling lines were restarted before final quality assurance results were known. Because of the delayed laboratory results, it was not possible to detect process deviations immediately and, in that case, to take countermeasures in time. This delay of information on a small frequency might lead to errors and packaging of the wrong products in the wrong containers. Because this can lead to expensive losses, a solution was required to monitor the processes inline and react quickly and flexibly.

Inline Measurement of °Plato and °Brix

The Oettinger Brewery decided that inline measuring technology was a good solution to their need. It was clear that this technology would maintain the same level of accuracy required to guarantee a constant high product quality. "Our modern facilities meet the highest hygienic standards, and our strict quality management system is based on internationally accepted standards. Therefore, we attach high value to analyses in the production process," said Siegfried Hanisch, head of engineering at Oettinger in Brunswick. In addition to the comparable accuracy the brewery also set requirements for the equipment to include the robustness, low maintenance, and easy process integration of the measuring technology.

Because of the good experience in using the LiquiSonic analyzers installed in the production lines at the headquarters in Oettingen, the branch in Brunswick also decided in favor of those analyzers from SensoTech. The inline measuring technology analyzes the concentration in liquids and is based on sonic velocity measurement that sends a measuring signal 32 times per second. The measuring principle (Fig. 1) is based on a run-time measurement of the ultrasonic signal. For that, the signal is sent from the transmitter to the receiver. Both are completely enclosed in the sensor. Because the sensor distance (d) between the sonic transmitter and receiver is known, it is possible to determine the sonic velocity (v) simply by clocking the travel time (t) of the sonic signal ($v = d / t$). In addition, two Pt1000 temperature probes are integrated in the sensor.

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Because sonic velocity depends on temperature and the substance's concentration, they form a direct relationship. Therefore, from the two values sonic velocity and temperature, the concentration is calculated. The concentration values are temperature compensated and always up to date. The measuring method is independent of the process liquid's color, transparency, and conductivity.

Integrated directly into the process, the real-time analysis provides at any time stable measuring data in order to intervene and make adjustments in the production process. This enhances process safety and ensures the economical production of high-quality beverages. Cost savings are realized by avoiding failed batches and having reduced laboratory analyses. The yield increases by having better facility utilization with less line downtime.

Figure 2 shows the LiquiSonic analyzer, which consists of one or more sensors and one controller.

In the context of a university paper on "Examination of the Measuring Accuracy and Reproducibility of an Original Gravity Meter in Practice," the Weihenstephan Research Center for Brewing and Food Quality confirmed the process capability of the LiquiSonic analyzer at the filler. The studies took place in the Bavarian State Brewery in Weihenstephan. The analyzer was installed before the bottle filler and measured the original gravity content of various Weihenstephan beer types. In addition, the flow detection (flow/stop monitoring) feature in the analyzer was tested. The investigations included several series of tests for each beer type, in which measuring values of original gravity were captured with the LiquiSonic ultrasonic sensor and compared with laboratory values obtained from samples. The samples were analyzed with a laboratory device by using density (oscillating U-tube) for determining the original gravity content. Because the laboratory device also had deviations in the measuring values within a test series, the comparison of the process and laboratory data was done by a statistical analysis with the *t* distribution. So, for each test series the mean value, the standard deviation, and the confidence interval of the process and laboratory data were calculated. For each beer type, Table 1 lists the statistical values of a test series. In each analyzed test series of the studies the confidence interval of the process values overlaps with the one of the laboratory values. This means, statistically, there is no significant difference between the inline LiquiSonic analyzer based on sonic velocity measurement and the laboratory device based on density measurement. So the final result is that no differences in the measuring accuracies between the two methods have been detected. The investigations also verified LiquiSonic's measuring accuracy of 0.05°P and showed statistically that the inline analyzer measured as reliably as the laboratory device. In regard to the flow/stop monitoring it could be seen that this feature worked. This means the LiquiSonic sensor detects liquid flows and standstill. Within a standstill the analyzer keeps the premeasured concentration value. Table 2 lists the concentration values within a standstill. Working with the analyzer during the studies showed that the handling is uncomplicated and user friendly. For example, the sensor installation could be done without bypass, and calibrating and operating the analyzer was easy because of the clear and intuitive controller menu. Furthermore, the product data sets of the different beer types were stored in the controller in advance by SensoTech, which makes the setup for the user straightforward.

In the Oettinger Brewery in Brunswick, LiquiSonic analyzers have been installed at the filler, the lauter tun, and the wort boiler. At the outlet of the lauter tun, LiquiSonic is used to monitor the lautering and to determine the extract concentration at the end of the lautering process (point to cut runoff). Using the technology the water and energy consumption have been reduced, and an economical and reproducible wort production has been realized. The runoff switchover point is of great interest, because energy costs as well as prices of raw materials are increasing continuously. A longer washout of the spent grain means high extract yields and little residual extract in the spent grains. However, a longer washout also results in a longer evaporation and, thus, higher energy costs. So it is important to detect the most efficient point to cut runoff. LiquiSonic provides stable and precise measuring results both in high concentration ranges of original gravity and in low ranges such as during runoff. The installation of the LiquiSonic immersion sensor was done with a

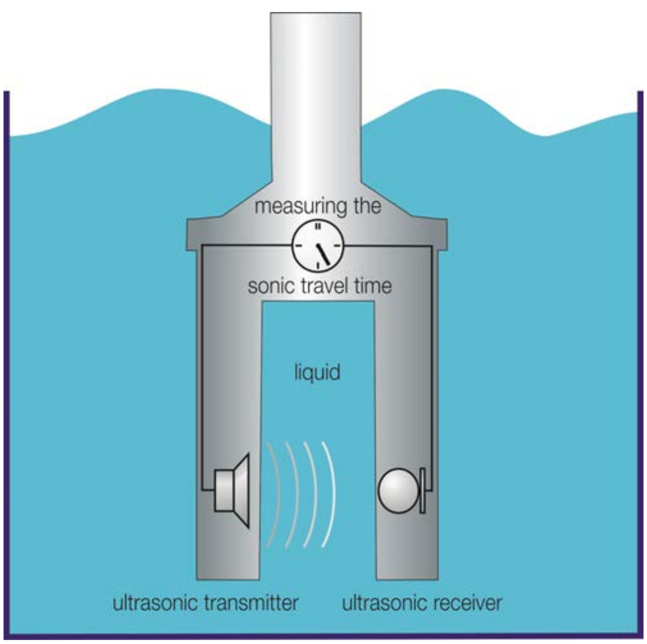

Figure 1. The measuring method of the LiquiSonic sensors is based on sonic velocity that is determined temperature-compensated by a run-time measurement and used to derive concentrations in liquids.

Figure 2. The LiquiSonic analyzer from SensoTech consists of one or more sensors and one controller.

Varivent process connection into a DN 80 (NPS 3) pipe right after the pump. At the external wort boiler, the sensor was integrated into a DN 250 (NPS 10) circulating pipe between wort feed pump and heat exchanger. Here, the analyzer monitors the evaporation and ensures an optimal wort concentration. Alternatively, in breweries the concentration can be measured in the internal boiler. For this purpose, the sensor is installed directly into the boiler and can reach an immersion length of up to 10 ft. By a special sensor design with cleaning adapter, the sensor operates free of deposits. Figure 3 shows the cleaning adapter and Figure 4 its inclusion in the sensor.

Whereas the determination of °Plato is relevant in the brewhouse, in blending processes the °Brix is important to ensure the brand-specific taste of beer mixed drinks, soft drinks, or sodas. The instrument helps to ensure that the final product is produced according to its recipe and that no errors occur in the product-specific bottling to follow. In each filling line of the glass bottles, PET bottles, and cans a Varivent sensor was mounted into a DN 80 (NPS 3) pipe upstream of the valve. Figure 5 shows a LiquiSonic measuring point at the filler. During the filling the sensor measures continuously and precisely the Plato or Brix concentration of 30 products, even in low flows. If there is a product change, the controller switches to the product-specific data set. Additionally, by activating the flow/stop detection, the sensor continues the correct measurement during breaks of the filler.

Resource Efficiency and Quality Assurance

Using the inline measuring technology, the process is monitored permanently in real time, so that the final product is bottled only in the predefined concentration range. If the measuring result is not within the tolerance range, a signal is sent immediately. This eliminates the filling of failed production batches, cleaning agents, or other undesirable substances. Only perfect and best-tasting drinks will be passed to the consumer. Furthermore, the Plato- and Brix-oriented control of the filler leads to savings of valuable resources by separating forerunnings and last runnings from the final product. In case of product type changes, the measuring technology switches automatically to the corresponding data set. “For us, the investment in the measuring technology has paid off definitely,” said Siegfried Hanisch. “Thanks to the analyzers, we can record and control accurately the process parameters of our product portfolio including a large variety of types. Consequently, our production facilities run at optimum utilization, and we increase the efficiency and reduce costs.”

Also, in regard to quality assurance Oettinger Brewery is satisfied. With a measuring accuracy of ±0.05°P or ±0.05°Brix, the inline measurement is acceptable. “In the past we have periodically taken samples and analyzed them in the laboratory,” pointed out Uwe Berkhausen. “Only for the time of sampling we obtained data on the production course. With the inline measuring technology, however, we capture production data every second in real time. Thus, we always have the present state of knowledge, and with the smallest deviations from the guideline we can immediately intervene in the process.” According to ISO9000 and HACCP, all data is documented and stored in the controller of the analyzer.

In breweries additional measuring points can include the wort cooler and the filter. At the wort cooler, the sensor monitors the original gravity before pitching the yeast. During fil-

Table 2. Deviations of the process measuring value during a filling break with activated flow/stop detection

Time	Original gravity in °P	Temperature in °F
12:01	12.70	41.45
12:10	12.70	43.56
12:20	12.69	44.49
12:32	12.69	46.76
12:40	12.72	40.93

Figure 3. To avoid deposits on the sensor in the wort boiler the sensor features a cleaning adapter.

Figure 4. The cleaning adapter frees the measuring sensor component from possible deposits in the wort boiler.

Table 1. Statistical analysis of the process and laboratory measuring values for original gravity concentration in °Plato of different beer types

Beer type	Mean value	Standard deviation	Confidence interval
Beer type 1			
Inline LiquiSonic analyzer	12.7080	0.0130	12.6918; 12.7242
Laboratory device	12.7280	0.0130	12.7118; 12.7442
Beer type 2			
Inline LiquiSonic analyzer	12.6933	0.0115	12.6647; 12.7220
Laboratory device	12.7000	0.0100	12.6752; 12.7248
Beer type 3			
Inline LiquiSonic analyzer	12.0400	0.1212	11.7390; 12.3410
Laboratory device	11.9567	0.0416	11.8533; 12.0600
Beer type 4			
Inline LiquiSonic analyzer	12.4800	0.0100	12.4552; 12.5048
Laboratory device	12.5067	0.0058	12.4924; 12.5210

tration, the measuring technology separates the forerunnings and last runnings and helps to meter exactly the pre- and post-beer in the unfiltrate. By monitoring of start-up processes, costly hectoliters of wort can be saved.

Highly Hygienic and Online Processing

To meet the strict hygiene requirements of the food industry, the sensors are made of stainless steel DIN 1.4571 (SS 316Ti). Some types are also 3-A certified. Because of the aseptic design and sophisticated construction that requires neither gaskets nor moving parts, the sensors are robust against deposits and operate maintenance-free, drift-free, and long-term stable. Furthermore, two Pt1000 temperature probes are integrated into the sensor, so both the concentration and the temperature are displayed on the controller.

For the sensor installation no bypass is required. There are various types of process connections available, for example Varivent or Clamp. Figure 6 shows a LiquiSonic sensor installed in a Varivent inline housing. The sensor electronics are protected in a stainless steel housing with an IP68 (NEMA 6P) degree of protection. If there are vibrations of the piping system or temperatures over 120°F in the piping environment, the electronic housing can be mounted apart from the sensor to ensure the stable processing of the measuring data.

The data are displayed and stored in the controller. One controller can handle up to four sensors, reducing the investment costs of having more measuring points. As shown in Figure 7, Oettinger Brewery mounted each controller in a LiquiSonic wall housing made of stainless steel and with an IP66 (NEMA 4X) degree of protection. For process automation, the controller is connected to the process control system via Profibus DP.

Figure 5. The LiquiSonic Varivent sensor is installed directly in the pipe of the filler at Oettinger Brewery and measures precisely the Plato or Brix concentration.

"Operating the controller is easy, and no complex manual study was necessary," said Siegfried Hanisch.

To analyze the measuring data and to have remote access to the controller, Oettinger Brewery uses SonicWork software from SensoTech. Integrating the controller in the network, the production data of bottling can be viewed on a personal computer. From there the engineers at Oettinger Brewery can operate the controller via SonicWork or alternatively via a safe Internet connection. "The remote access options make working with the measuring instruments convenient," said Uwe Berkhausen. "The network and web server feature improve the integration of the measuring technology in our processes. For example, controller settings can be made from the laboratory, eliminating the need for long distance travel to install set point changes. This saves time and allows for quick response."

In addition to the remote access, the software includes analyzing records, visualizing process trends and creating data sheets for documentation and diagnostics. If the production process has changed for a particular product, a new product data set can be loaded on the controller via SonicWork. Furthermore, firmware updates can be transferred to the controller. Both guarantee maximum flexibility and easy handling.

Figure 6. The sensor installation requires no bypass and is possible for any facility.

Figure 7. The LiquiSonic controller displays, saves, and transfers the Plato and Brix concentration values to the process control system.