Low-Oxygen Brew Process Ensures High Quality

Krombacher Brewery relies on Optical Dissolved Oxygen Sensors by Hamilton Bonaduz AG

With total output of 6.4 million hl per year, of which 5.5 million hl alone are bottled at the Krombach facility, Krombacher Brewery, founded in 1803, is one of the largest private breweries in Germany. The company's success is not least due to the high quality of the products that are produced and bottled here every day. Taste, turbidity and shelf life of the beer play an important role in this process – for all these factors the dissolved oxygen content of the product is key. Based on this background, continuous measurement of the dissolved oxygen content is very important – and the sensors of the Swiss company Hamilton Bonaduz AG provide a significant contribution.

The Krombacher Brewery had for quite some time been in contact with Hamilton Bonaduz AG, because the latter supplies, amongst others, solutions for the pH measurement. In 2010, the market began to focus more intensely on optical dissolved oxygen sensors for breweries. This measurement principle promised advantages over amperometric measurements, which had been used until then. The new sensors were expected to end the stop-of-flow effect, ensure faster and consistent response times, longer service intervals, as well as easier and time-saving maintenance. Krombacher Brewery initially tested various products in order to gain an overview over sensor functionality. All products had a very short response

time. However, errors occurred during testing. Detachments of the luminophore from the sensor cap, leakage and even similarities to the stop-of-flow effect of amperometric sensors were only some of these. One problem with all tested sensors was a leap in the absolute oxygen measurement after the CIP cycle. Since at the time of the planned new acquisition there was no product that met all of Krombacher's requirements, Hamilton rose to the challenge of providing an adequate solution. The company picked up these problems and explored optimizing the measurement principle in close cooperation with the responsible persons at the brewery. Over several months of testing, three Hamilton optical sensors were tested concurrently with the amperometric oxygen measurement used until then. These sensor were continuously further developed. In the process, the stop-of-flow effect was corrected, as well. That effect occurs during opening and closing of valves and the resulting pressure hammer. Amperometric sensors transfer the pressure hammer to the electrolyte. This causes disruptions to the measurement of oxygen content. In contradiction the pressure hammer has no effect on optical oxygen sensors, because there is no liquid within the sensor cap. Optics and electronics are furthermore protected by a sapphire glass. The configuration values of the sensor, which is made from stainless steel, can be set in %-sat, %-vol, µg/l, mg/l, ppb, ppm with regard to the dissolved oxygen, and in °C with regard to temperature. Measurements only deviate <1% per week at room temperature and under constant conditions. The measurement range of the VisiFerm DO B is between 4 ppb (parts per billion) and 25 ppm (parts per million) for dissolved oxygen, as well as 0.1 to 600 mbar for the partial pressure of oxygen (pO_2). The operating temperature ranges from -10°C to 140°C, whereby no measurements are provided above 85°C (e.g., CIP) in order to increase the shelf life of the sensor cap. In addition, the solution not only promises very quick response times of less than 30 seconds (t_{98}), accuracy and low maintenance effort, but during the CIP cycle it also compensates for the shift in measurements. This shift occurs because the heat briefly makes the oxygen-sensitive molecules more mobile leading to a slightly decreased phase angle. For low oxygen concentrations, this results in a seemingly higher oxygen content, which is corrected by the CIP mode. Since the shift in measurements depends on the different CIP methods, the necessary correction can be set by using the Hamilton Device Manager, a software that can be downloaded free of charge from the Hamilton website. A detachment of the luminophore layer

was corrected by Hamilton by optimizing the glueing process during the production of the sensors.

State-of-the-Art Technology Offers Many Advantages

The sensors are based on the luminescence measurement principle. The oxygen-sensitive luminophore in the sensor cap is agitated by blue light and reflects part of the absorbed energy in the form of red luminescent light. The intensity depends on the existing oxygen content. The measurement is based on the shift in the phase angle between the agitation and emission lights, which indicates the dissolved oxygen content. This detection process ensures a very good measurement performance and withstands the occasionally rough process conditions during beer production. Pressure hammers for example during opening and closing of valves do not harm the measurement. For a few milliseconds, the sensor cap resists pressure hammers of up to 80 bar.

A total of 37 in-line sensors have been shipped so far and are used gradually in CO_2 recovery, separator, filtration and bottling areas. The sensors are also used in a system for producing de-aerated, low-oxygen water. An example for the advantage of the new solutions is the behavior during bottling, in particular. Here the oxygen content is one of the important monitored parameters. If it is not below a defined level, bottling will be stopped. Fast response behavior is therefore necessary to avoid standstills and to reduce discharge quantities caused by incorrect measurements. While amperometric measurements do not ensure this and even slow down over time, optical sensors are definitely meeting these demands. If there is a stop-of-flow in the bottling line due to clogging of a valve, the amperometric sensor is negatively affected and therefore shows an incorrect measurement. Optical oxygen sensors, in contradiction, are impervious to pressure hammers and show a fast response time. "If you consider the fact that these new measurements optimize the accepting of beer, and product feed and output at the bottler, the advantage of optical oxygen measurement with its short response times is underscored again," says Gerd Hoffmann, responsible for the physical and analysis measurement technology at Krombacher. Unnecessary downtimes like with the amperometric technology, no longer occur. This leads to time savings, because the next bottling procedure can start immediately thereafter.

Even if the product is changed after a CIP cycle, VisiFerm DO B is ready for measuring below the defined level up to 5 minutes faster than amperometric sensors. This means that the product to be bottled can be checked for its oxygen content faster. Unlike the amperometric technology, whose response times can only be kept at a consistent level with a high maintenance effort, the optical sensors' response times remain consistent. The maintenance effort here is very low, because all that has to be changed are the sensor caps, which can be performed easily and independently.

Control in Real Time During the Entire Process

Handling the VisiFerm DO B sensors is also straightforward. The sensor will be pre-calibrated by the technical maintenance staff and the corresponding parameters will be stored in the sensor head. Zero-point calibration is performed in an oxygen-free gas and high-point calibration can be done with air. Thereafter, the sensor can be changed by the brewer or system operator him- or herself, without the need for help of the technical maintenance staff. If the cap must be changed during a running process, retractable housings allow for implementation of maintenance procedures. "Such a high degree of flexibility during use is a decisive benefit in favor of using this technology," Gerd Hoffmann knows. "The communications connection does not require any special preparations. At our company, the sensors are connected to the process control system; all values are therefore visualized in the system at any time. VisiFerm DO B also contributes to this, because it ensures direct communication via an analog 4-20 mA standard signal," adds the brewery's master electrician Torsten Friedrich, responsible for automation technology and others. If a deviating value is detected during inline measurement, cross-checks are done before further steps are initiated.

For the Krombacher people the fact that the oxygen sensor does not require an additional transmitter was also important. "Transmitters and associated equipment

cause high costs. In addition, the special cables that connect the transmitter and the sensors are very interference prone. It was therefore obvious to us that we must use a product that completely eliminates these factors," Friedrich says.

In order to keep an eye on important values at all times, the VisiFerm DO B sensors were installed at different process steps - from the fermentation tank to the bottling line. Due to the fact that lowest oxygen levels must be ensured here, the first measuring point is at the CO_2-recovery system. The product flows from the brew house via the fermentation cellar to the storage cellar. From there it reaches the filtration units via separators before it flows to the bright beer tank cellar, whereby several measuring points have been integrated on the way. "During production there are several points where oxygen can ingress," brew master Martin Spelz explains and adds that this is also effective for low-DO water used for producing soft drinks and for the cleaning process.

Beverly Allows for Reliable Measurement On Site

When the idea of a portable optical oxygen device was introduced in 2012, Hamilton was again the competent point of contact. This device was intended to be used for quality assurance purposes in the bottling department and for cross-checks during the process. "With respect of the different packaging sizes and the type of product, certain target values for dissolved oxygen must not be exceeded before the products are shipped to the retailers," graduate brew master Frank Zwingelberg, who works in the quality assurance department, explains. A focus during inspection of the final product is the recurrent check of the oxygen content. For this purpose a portable at-line device is necessary, who's optical sensing part has already stood the test of time in the brewing process and therefore provides reliable data. In order to meet these requirements, Hamilton provided the portable device Beverly. Beverly has built-in a VisiFerm DO B sensor - the user therefore gets both an at-line and an in-line sensor at the same time. The solution was customized specifically for the needs of breweries and was developed together with the Krombacher Brewery after many in-depth meetings and detailed requests for requirements. An alternative to the measuring systems used so far, which were getting on in years was created. Calibration can be done by the operator independently with little effort. In addition, the new solution is much more cost-effective, requires lower maintenance and is designated for brewery applications due to its robust construction. "After our re-

quirements had been collected, we first worked with a prototype, developed based on our experience during daily use," Frank Zwingelberg says. Because the bottling department works in a 3-shift system and the unit is therefore accessible to many staff members, it had to have a robust body. Beverly consists of a rubber coated plastic body resistant to mechanical impacts. In addition, all connections of the portable device are arranged in a way that they cannot easily break off. Handling the Beverly is also straightforward: "Operation is intuitive, the device does not require intensive training. It is self-explanatory, has great response behavior into the ppb (parts per billion) range and the measurements are displayed clearly and in real time," Zwingelberg says. Another benefit is the long battery life, so that the unit must only be charged during the weekend and can be operated the rest of the time without any issues. Over time all necessary optimizations were incorporated based on experience, and the last "teething problems" were solved. The result is a reliable robust portable device and everyday life at the Krombacher Brewery cannot be imagined anymore without the daily use of Beverly.