Beer aficionados everywhere know the unique flavours popular Belgian brewer Duvel Moortgat delivers - from its Golden Ales to its Trappist Beers. Achieving that distinctive taste, however, does not come without a price.

The Duvel Brewing process is different than other brewers’ processes. Duvel utilises pH control where other Brewers utilise other measurement technologies, and the implementation of pH measurement in Duvel’s Brewery is an application challenge. How Moortgat Duvel confronted these challenges using new long-life sensor technologies have lessons for many food and beverage manufacturers around the world.

**pH in brewing**

pH measurement plays an important role in a number of areas of the brewing process. Mash pH impacts enzyme activity and determines how efficiently the starch is converted to fermentable sugars. In the brew kettle, the wort pH is monitored to determine hop solubility and is controlled to affect body, palate and clarity. pH can also be used in filling applications to ensure beer is being packaged into the final product for consumption without any cleaning chemicals included in the packaging.

In Duvel’s brewing process, pH measurements are utilised for phase interface detection between brewing stages and clean in place (CIP) processes or beer – push water. In Moortgat’s brewery, wort is heated to a rapid boil maintained at 90°C temperature for 90 minutes. After the wort has been cooled, it is “pushed” by beer water to the fermentation vessel. Normally, conductivity is used as a critical control point to determine when the wort has been transferred to the next process and whether excess water is being sent through to the whirlpool. Tighter control parameters are required to optimise the process. Too much water being sent to the fermentation vessels will require additional steps to meet high quality standards.

However, for one of the Moortgat brands, there is little differentiation between the conductivity values of the wort and push water, but there is a significant difference between pH values of the two solutions. Thus pH control is used to maintain a distinct separation between the two phases to ensure that excess water does not affect beer quality. Due to the extreme temperatures of the application as well as exposure to hot caustic solutions, pH sensors exhibit shortened life expectancy. The pH sensor is subjected to intense thermal shock often causing junction cracks to the sensor glass bulb, which is a critical failure. In addition, the pH sensors with small reference junctions can become coated, which causes sluggish responses and high offsets in the pH values. Some applications with sulfide concentrations will severely damage the reference electrode, again creating offsets to pH values.

**Failure every three days**

Moortgat had traditionally experienced both of these problems with their pH sensors. Initially the pH sensors lasted two to four weeks. However, when the brewery increased its capacity by increasing CIP flow rates by 33%, the pH sensors were failing every two to three days. The process engineers stopped trusting the on-line pH measurement. They considered switching to conductivity sensors, which

**pH sensors in brewery: A toast to long-life**

By Dave Anderson, Emerson Process Management, Rosemount Analytical

Courtesy of Duvel Moortgat
are far less susceptible to heat and fouling, but the idea was quickly discarded since conductivity measurements were not sensitive enough to determine the interface detection between the conductivity of the wort and the rinse water in certain Moortgat brands. This led to the Moortgat technicians performing the phase separation by manual control, resulting in some one manually overseeing the phase interface detection by staring through a site glass in the process pipe and then manually closing a valve. As one commentator said, “The technicians were not amused.”

The manually controlled process could not be maintained, so Moortgat’s engineers researched alternative long-life pH sensor technologies. One of the sensors under evaluation was Emerson’s PERpH-X high performance pH sensor. When they began the trial, the technicians were more than skeptical of the PERpH-X capabilities since their longest-life sensor to date had lasted less than one week! Moortgat installed the new technology sensor and the technicians were amazed when it performed without attention for more than three months! When the sensor finally stopped working, they contacted Emerson to obtain a replacement sensor and were pleasantly surprised to discover the sensor was still in working condition – all that was needed was to refill the replacable reference electrolyte. Once the gel electrolyte was replaced, Moortgat had their pH control loop back up automating the process – in less than ten minutes!

Needless to say, the difference for Moortgat is considerable. The brewery no longer needs to replace their pH sensors every three days to a week, reducing equipment costs and installation time. Even more important, their technicians now trust the measurement to control the process accurately, saving hours of personnel time and frustration.

Operational principles

It’s not surprising that the Moortgat technicians were skeptical about the so-called long-life sensor before they tested it. pH measurement, while receiving incremental tweaks in design and improvement over the years, has not changed fundamentally for a century due to the reliable performance of the technique in most circumstances. However, the fundamental design of pH sensors has long rendered them unreliable at extreme temperature and in “dirty” environments.

pH electrodes use a specially formulated pH-sensitive glass that is placed in contact with a solution and develops
a voltage potential proportional to the pH of the solution. Non-glass sensors are available, but those sensors generally are inaccurate at extreme temperatures and have limited life if exposed to clean-in-place solutions. Unlike some food and beverage processes, breweries are able to use glass sensors since there are a number of filtering steps that occur throughout the brewing process. pH measurement is also dependent on a reference electrode that maintains a constant potential at any given temperature and completes the pH measuring circuit. The difference in the potentials of the pH and reference electrodes provides a millivolt signal proportional to pH. Solution pH changes with temperature, and extremes of temperature accelerate the aging of the electrode and may cause the fill solution in the tip of the electrode to freeze or boil. This, in turn, can cause the glass to crack or break. In addition, the ageing of the glass causes sluggish response to pH changes.

Common reference electrodes consist of a silver wire coated with silver chloride in a fill solution of potassium chloride. For accuracy, this fill solution must remain relatively uncontaminated. At the same time, the reference electrode must be in contact with the pH electrode through the process solution. Both of these conditions are easily compromised when the process solution is thick or contains a concentration of ions that form precipitates plugging the liquid junction between the reference and pH sensors and/or poisoning the fill solution.

**Long life design**

New long-life designs do not alter the fundamental measurement technique of pH sensors. They simply improve each of the vulnerable elements. Scientists have performed studies on pH-sensitive glass to determine the aging mechanism after high-temperature exposure. Interestingly, they found that most of the aging occurs in the surface gel layer of the pH-sensitive glass. Armed with this knowledge, scientists were then able to isolate and optimise proprietary designs for temperature-resistant gel surface layers. The results have been pH glass electrodes that provide exceptional resistance to thermal degradation even at temperatures as high as 155°C. This translates into less breakage from thermal stress and shock and, equally important, improved speed of response providing fast, accurate measurements even after months of exposure to extreme temperatures. Manufacturers also add protection with design changes like slotted tip caps that protect the glass bulb from impact. These glass design changes translate to part of the performance improvements Moortgat experienced.

But most pH measurements fail due to issues in the reference electrode. The most common problems, as mentioned earlier, are fouled and poisoned electrolytes and coated or clogged reference junctions. Long-life sensor designers have tackled this problem with a specially-designed porous Teflon liquid junction that has a large surface area that provides a stable contact to the solution and helps resist coating in dirty environments. The large surface area and high porosity also minimise junction potentials allowing accurate measurements. The reference electrolyte used in these long-life sensors is a chemically inert viscous gel that can stand up to the harshest chemicals and is unaffected by thermal or pressure cycling. The internal reference junction is a small diameter, low porosity ceramic designed to minimise poisoning or the depletion of the primary reference cell maximising the overall life of the sensor.

To further extend life, these new sensor designs allow for easy replacing of a clogged reference junction and recharging of the electrolyte that will rejuvenate most failed sensors. Interestingly, specialised electrolytes are made available to optimise performance in certain types of applications such as bio-film resistant, oil resistant, scaling resistant, etc. The piece de resistance in these long life designs is the use of chemically and thermally resistant housing materials such as Ryton and titanium.

For companies like Moortgat, with challenging process environments and an absolute requirement for accurate pH measurements, these dramatic changes to pH design are a godsend. As Jo Van Roy, technical service maintenance, Moortgat Brewery, said, “Extending the reliable operation of our pH measurement from a few questionable days to months of virtually unattended operation has made more than a financial change for Moortgat. It helps us assure the quality and integrity of the unique Duvel experience.”

**Behind the byline:**

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