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Duvel Moortgat Brewery Toasts to New pH Sensor Technologies

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Beer aficionados everywhere know the unique flavor of the popular Belgian brew, Duvel. Achieving that distinctive taste, however, requires complex processing that is a pH measurement challenge. How Duvel Brewer, Moortgat, confronted that challenge using new long-life sensor technologies has lessons for many other food and beverage manufacturers.

pH in brewing

pH measurement plays an important role in a number of areas of the brewing process. Mash pH impacts enzyme activity and 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. And, quite significantly, pH measurements may be utilized for phase interface detection between brewing stages and clean-in-place processes or water.

In the Moortgat brewing process, the wort is rapidly boiled to 90ºC (194ºF), and then the process is "pushed" by water. Normally, conductivity will be a critical control point to determine when the wort has been transferred to the next process and if excess water is being sent through to the whirlpool. Tighter control parameters are required to optimize the process. Too much water being sent to the fermentors will require additional steps to meet high quality standards. However, for one of the Moortgat brews, there is little differentiation between the conductivity values of the wort and push water, but there is a significant difference between pH values. Thus pH control is used to maintain a distinct separation between the two phases to ensure that excess water does not affect beer quality. The result, however, is that the pH sensor is subjected to intense thermal shock often causing junction cracks to the sensor, which is a critical failure. In addition, the pH sensors with small reference junctions can become coated, which causes sluggish responses and 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, their pH sensors were failing every three days and their engineers had stopped trusting the pH measurement entirely. They considered the use of conductivity sensors, which are far less susceptible to heat and fouling, but the idea was quickly discarded since conductivity measurements were not sensitive enough to determine the difference between the conductivity of the wort and the rinse water in certain Moortgat brands. The Moortgat technicians began doing the phase separation by manual control, meaning a technician would manually oversee 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."

Help from new technologies

It was then that Moortgat technicians turned their attention to new long-life pH sensor technologies that have been increasingly commented upon in the technical press over the last two years. When they began the trial, the technicians were more than skeptical since their longest-life sensor to that time had lasted less than one week. Moortgat installed the new technology sensor and the technicians were amazed when it performed without attention for over three months. When it stopped working, they immediately called their supplier to get a replacement and were told that, like an increasing number of modern sensors, the long-life sensor was refillable. They inserted some gel electrolyte they had on hand and their long-life sensor lived up to its name continuing to measure accurately once again.

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.

pH operational principles

It's not surprising that 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 potential (voltage) proportional to the pH of the solution. Non-glass sensors are available, but they generally are inaccurate at extreme temperature and have limited life if exposed to clean-in-place solutions. Unlike some food and beverage processes, brewing is 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 aging 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 designs

New long-life designs do not alter the fundamental measurement technique of pH sensors. They simply improve each of the vulnerable elements. Scientists have done 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 optimize 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 155oC. 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 temperature exposure. 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 minimize 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 minimize poisoning or the depletion of the primary reference cell maximizing the overall life of the sensor.

For companies like Moortgat, with challenging process environments and an absolute requirement for accurate pH measurements, these dramatic changes to pH design are a dream come true. As Jo Van Roy, technical service maintenance, Moortgat Brewery stated, "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."

For more information, see www.emersonprocess.com [1]

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[1] http://www.emersonprocess.com