Optical DO Sensors Improve Fermentation Management

Problem

As annual beer production goes up, a major brewer found it increasingly difficult to find appropriate time slots for maintenance interventions, especially in the recalibration of EC dissolved oxygen sensors in the wort lines.

Solution

Hach®'s high-range LDO in-line sensor was installed in a wort line. Side-by-side tests were run to compare the results to an EC sensor. Over 12 months, the high-range LDO performed extremely well.

Benefits

The high range in-line DO sensors delivered a dramatic reduction in service and maintenance requirements. The LDO spot itself is changed only once per year and calibrated twice rather than 12 times per year.

Background

A major brewer was looking to increase brewing production by approximately 2 million hectoliters per year (around 1.7 million barrels) from 3.5m to 5.5m hectolitres. The brewery, which operates 24 hours/day, is an important production site within its brewing network, and the investment has enabled them to continue to meet strong customer demand for its brands.

Wort Management

Pure oxygen or air is injected into the wort lines to aid fermentation. This is not to encourage yeast respiration; after pitching, yeast absorbs oxygen rapidly and uses it in membrane biosynthesis. The oxygen enables the yeast cells to grow much faster and to reach a higher cell density. However, by controlling the DO levels, at 20 ppm for a lager for example, the speed of fermentation proceeds at the correct rate. If fermentation takes too long, production is delayed, and if it is too short, the flavor would be affected.

Figure 1: Wort fermentation

Wort Measurement

Control is obviously required when adding oxygen or air to the wort. Too much oxygen results in an undesired rapid and over-vigorous fermentation. This affects flavor and results in excessive yeast growth. Overproduction of yeast is costly to the brewer because excessive beer losses in spent yeast are obviously undesirable.

Conversely, a lack of oxygen in the initial stages results in poor fermentation and could lead to an increased level of acetyl coenzyme A in the yeast cells. This in turn can produce higher levels of esters in beer and other undesirable off-flavors.

Impact of Insufficient Wort Oxygenation

- Stalled fermentation
- Poor fermentation
- Acetyl coenzyme A buildup
- Yeast cell wall synthesis starts with acetyl coenzyme A
- O_2 is required for proper lipid development
- Low O_2 leads to elevated ester formation
- Increased H_2S

Impact of Wort Over-Oxygenation

- Hot fermentation
- Excessive yeast growth
- Yeast starvation from lack of available nutrients
- Undesirable flavor development

Oxygenation Objectives

Beer off-flavors can originate in fermentation

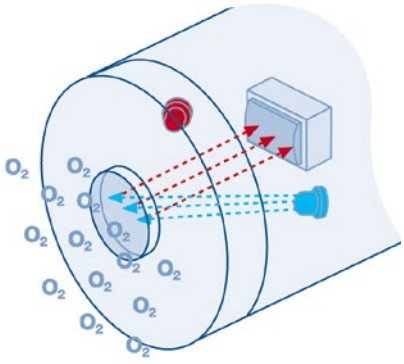
- Achieve optimum oxygenation level for yeast health
- Use as little gas as possible (O_2 or air)
- Keep the gas in solution
- Minimize foaming
- Validate measurement points

Solution and Improvements

The main objective in moving from EC to optical DO sensors was to reduce both the frequency of recalibration and the time taken to undertake this work. In order to work on the sensors, it was necessary to stop production, and since most of the lines are pressurized, a number of procedures were needed in order to obtain the necessary authorization. They generally looked for gaps in production to conduct this work because delays in production would be very costly.

Hach Optical DO Technology

The sensor's 'spot' is coated with a luminescent material, called luminophore, which is excited by blue light from an internal LED. As the luminescent material relaxes it emits red light, and this luminescence is proportional to the dissolved oxygen present. The luminescence is measured both in terms of its maximum intensity and its decay time. An internal red LED provides a reference measurement before every reading to ensure that the sensor's accuracy is maintained.



By modulating the excitation, the decay time is transformed into a phase-shift of the modulated fluorescence signal, which is independent of fluorescent intensity. Crucially, in contrast with EC sensors, this means that the accuracy of the sensor is not affected by aging.

So, while an EC sensor requires frequent service and recalibration, typically every one to three months, the LDO simply requires a six month calibration that takes just a few minutes and only one spot change per annum. The LDO also has a faster response time than EC sensors, which can be a vitally important factor in minimizing any potential delays in production.

Figure 2: Hach 410 Controllers – typical installation

Figure 3: Hach M1100-H LDO Sensor – typical installation

High- and Low-Range DO Measurements

DO in bright beer is measured in parts per billion, typically up to 100 ppb, which is well within the capability of Hach's low-range LDO, the M1100-L. Portable versions of the LDO technology (Orbisphere 3100) are also used to supplement online measurements. A high-range LDO sensor is also available; the M1100-H sensor which has a range of 0-40 ppm and is therefore ideal for wort applications.

The brewery has employed in-line low-range LDO sensors for a number of years, so the QA and QC staff already had confidence in optical technology. A new high-range LDO sensor was installed in 2014, and no problems were encountered and the sensor performed extremely well. The line was also monitored with an EC sensor, so we were able to check the long-term performance of the sensor.

Results

Over a 12 month period, the brewery completed approximately 1,344 brews with a weekly process clean. However, the annual production on this line has since been increased to 2,200 brews. The performance of the high-range LDO met with their requirements, and as a result recently purchased two further high-range LDO sensors.

Conclusion

The brewery is acutely aware of the efficiency and stability improvements that the LDO sensors offer. The EC sensors require recalibration 12 times per year for every line, so they represent a greater administrative and operational burden. As production levels have increased, it has become more difficult to find appropriate time slots for interventions.

In contrast, the sensor spot in the low-range LDO sensors is changed and calibrated once per year, and the brewery plans to do the same with the high-range, except at a 6 month interval. The annual planned plant shut down for maintenance is normally during the period of lowest demand in January, so this is the ideal time to change and recalibrate LDO sensors.

Figure 4: Portable Orbisphere 3100 used for on-line verification

Fig 5: High-range LDO sensor ideal for fermentation management

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