Maximizing Optical Sensor Life in Brewing Processes

Introduction

This application note describes a solution to increase the lifetime of luminescent dissolved oxygen (LDO) spots in-line when cleaning-in-place (CIP) is used with strong oxidants, bleaching agents, or harsh conditions. It is possible to maximize the life of the sensor by taking care of the LDO spot during a non-production process phase.

Note: This application note concerns both high and low level spots. However, high level spots are subject to degrading more quickly due to high oxidant and oxygen concentrations and higher CIP frequency.

How Does the LDO Sensor Work?

The LDO spot is based on its capacity to have its luminescent molecules excited by light. To react to this status, the dye will re-emit light (see Figure 1a).

Measurement is based on the light emission characteristics of the luminescent reaction. In the presence of oxygen, the luminescence is quantitatively reduced or quenched. Dissolved oxygen (DO) concentration is inversely proportional to the luminescent lifetime of the light emitted by the photo luminescence process (see figure 1b).

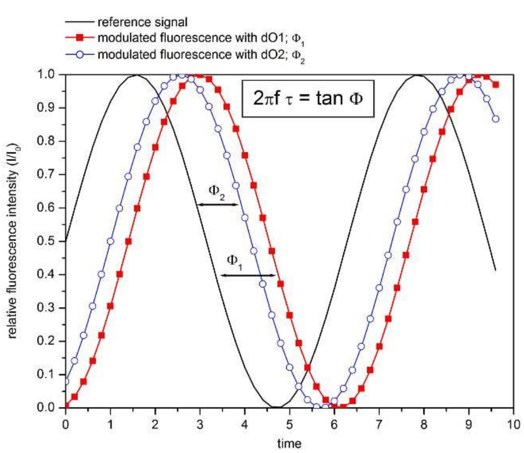


Figure 1a: Luminescence phenomenon *- The luminescent oxygen sensitive spot is comprised of thousands of luminescent indicator molecules. Each of those molecules play a key role in the signal intensity. It is crucial to preserve them to avoid signal and therefore measurement loss.*

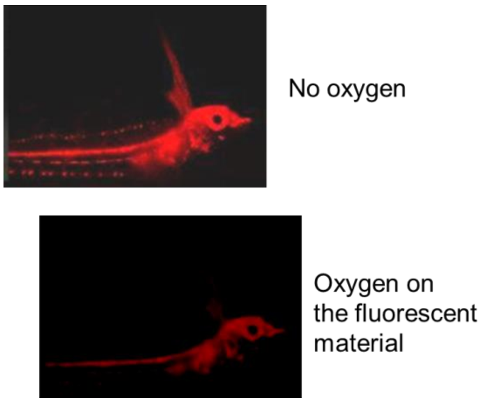


Figure 1b

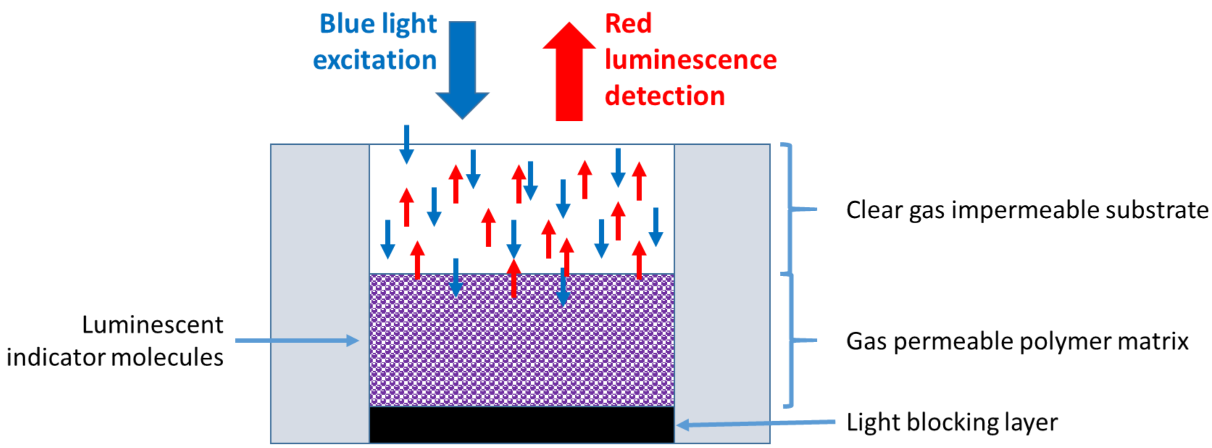


Figure 2: Schematic of new LDO spot

Elements Causing LDO Spot Lifetime Reduction

Light

Light is breaking down the luminescent molecule bounds, reducing the number of available molecules and therefore reducing the LDO sensor measurement capacity. The more the dye is in contact with light, the shorter the lifetime of the LDO spot is.

Temperature

Temperature increases the sensitivity of the luminescent layer to the effect of the light. The higher the temperature, the lower the dye resistance to attack.

Oxygen

Oxygen is the primary element to detect. But, oxygen is also a strong oxidant. Light and oxygen combine to bleach the dye and reduce the measuring efficiency. Two main impacts of oxygen on the LDO sensor can be defined:

- The more oxygen measured, the more the LDO spot is attacked
- The higher the oxygen concentration, the higher the oxygen impact on the spot lifetime.

Other Strong Oxidizing Agent (CIP process)

Between each batch of beer production, breweries are using strong oxidizing products to avoid any unwanted biological growth in the installation. A non-exhaustive list of strong oxidant used for cleaning is shown on:

- Ozone (O_3)
- Peroxyacetic acid (PAA)
- Chlorine dioxide (ClO_2)
- Chlorine (Cl_2)
- Bromine (Br_2)

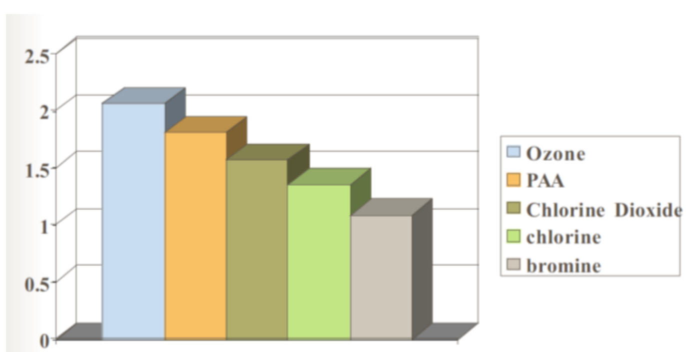


Figure 3: Oxidation potential of different oxidants (in eV)

Other elements used as CIP product in addition to the above chemicals include a UV lamp. UV is very efficient for disinfection purposes, but it only impacts the liquid directly around it.

Key applications of concern:

- Wort production in brewery: CIP is generally stronger and more frequent (daily or multi-weekly CIP) than in bright beer
- Beer production in brewery: daily CIP
- Borderline applications using strong oxidant with UV lamp; ozone to clean lines

Note: This phenomenon of bleaching is application dependent, not spot dependent. In the presence of strong oxidant, the lifetime of the spot is reduced due to the degradation of the pink face to a green coloration. LDO spots are organic compounds which are attacked by strong oxidant, and this degradation process is sped up during the measurement phase. This phenomenon cannot be avoided, but could be limited by different actions during contact with strong oxidant.

Symptoms of the Bleaching Phenomenon

What are the classical impacts on measurement in the presence of a strong oxidant?

- Drift of the measurement into a standard (nitrogen or air)
- Increase the calibration frequency: up to one time per week
- Reduction of spot lifetime (down to a few months)

What are the Visual Symptoms of Spot Degradation by Strong Oxidant?

A spot discoloration located in the center of the spot can be observed in the internal pink face of the cap. This discoloration (pink to green) is caused by the frequent exposure of the spot with a strong oxidant agent (during cleaning) or accidental situations such as over pressure, over temperature, or over concentration (see Figure 4). This phenomenon is application dependent rather than spot dependent. Intensity of this discoloration depends on the level of aging and is specific to the cleaning process (i.e. nature of oxidant, concentration, and frequency of use) (see Figure 5).

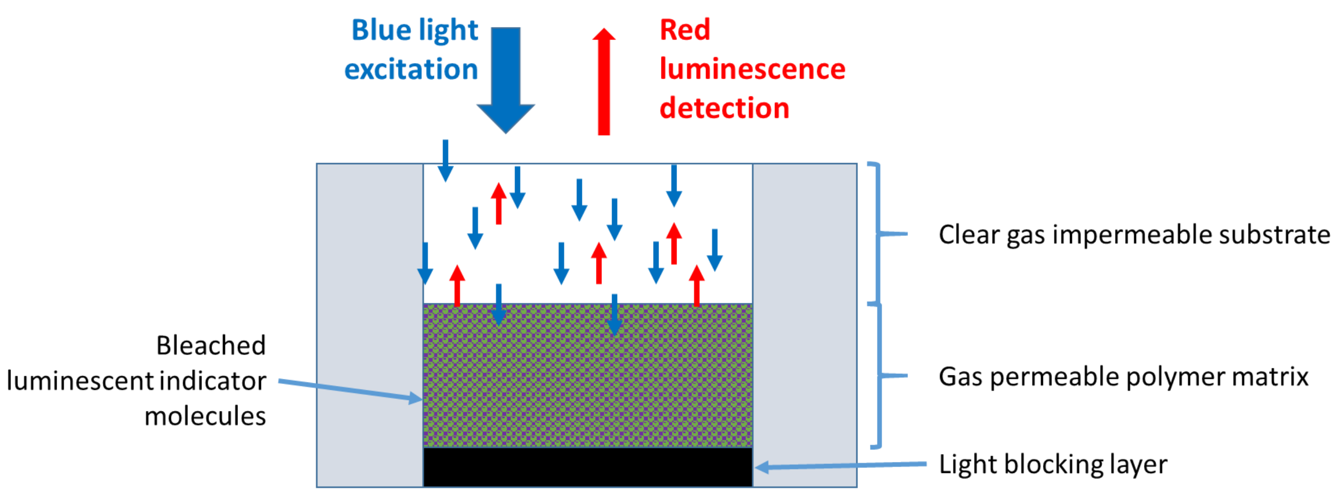


Figure 4: Schematic of bleached LDO spot

Visual aspect of the spot from inside

Figure 5: Green coloration of spots

Hach Solutions

Products concerned

Brand	Systems	Instruments	Sensors	Others
Orbisphere	LDO	410M, 410K, 510K software 3.08 or higher	M1100-L, K1100-L, K1200-L and M1100-H	M1100-L, K1100-L, K1200-L, M1100-H, K1100-H, K1200-H membranes

System Installation

Validate that the LDO sensor is installed as far as possible from the CIP injection point and/or UV lamp location; the farther from that injection point, the better. **Recommendation:** minimum distance 10m (32 feet).

Light

Hach® developed a sensor that offers the following benefits:

- Low drift spot
- Optimized electronics and software
- Optimized light emission/ reception

As such, Hach reduced impact of light on the spot with a high level of accuracy. (*Note: these are competitive differences to other sensors on the market*.)

Temperature: Hach Thermal Cut-off

To protect the sensor spot, the thermal cut-off function allows users to set a sample's high temperature limit. If exceeded (during a CIP cycle for example) the electrical signal to the sensor is cut-off; the measurement session is suspended, and the system displays a "HOT" alarm message. The system resumes when the temperature drops to 90% of the specified cut-off temperature. *(Note: The thermal cut-off value should be set to no more than 5°C (41°F) above the sample temperature.*

Oxygen

Hach uses two different LDO spots to adapt its sensor to the level of oxygen and protect the luminescent molecules from oxygen attack:

- M1100-L for low range of measurement
    - 0-2000ppb DO_2
    - Application in bright beer and final product
    - Automatic measurement hold if oxygen concentration is > 2ppm DO_2
- M1100-H for high range of measurement
    - 0-40ppm DO_2
    - Application in wort application.

Other Strong oxidizing agent (CIP process) + UV lamp disinfection

Hach developed software that signals the Orbisphere 410 or 510 system when the customer's process is not in beer production phase. Anytime the sensor is not in contact with beer (i.e. rinsing phase, CIP, process hold), it will automatically deactivate. This minimizes the impact of the strong oxidizing element on the LDO spot. When the 410/510 system receives information that the line is producing beer, the sensor is activated and functions as usual.

Impact of the Hach solutions

- The spot active lifetime more than doubled—from around four months to a minimum of nine months
- Calibration frequency reduced down to one calibration every three months as soon the critical transition phase is passed
- Maintenance plan clear and transparent for the customer and Hach service team.

In presence of strong oxidant without any protection, dramatic degradation of spot is observed down to "stabilization phase." The drift down to this status can be fast or slow and can take place over several weeks. During this time, calibrations frequency is increased up to once a week to compensate the drift.

When the last status of spot is reached, spot has been drastically attacked. In case of high level spot, signal amplitude in air—initially between 0.8 and 0.9V—can be decreased down to less than 0.200V. In such conditions, calibration frequency is about once a week, and the lifetime of the spot can be less than two months (see the red curve in Figure 6).

Thanks to the actions described above during CIP phases, three phases are identified:

- Stable behavior of the spot in line
- Transition phases over two to four weeks
- Stabilization of the behavior. With such a configuration, no calibration is required during the first phase, only during the transition phase and then time to time at the second plateau (see the green curve in Figure 6).

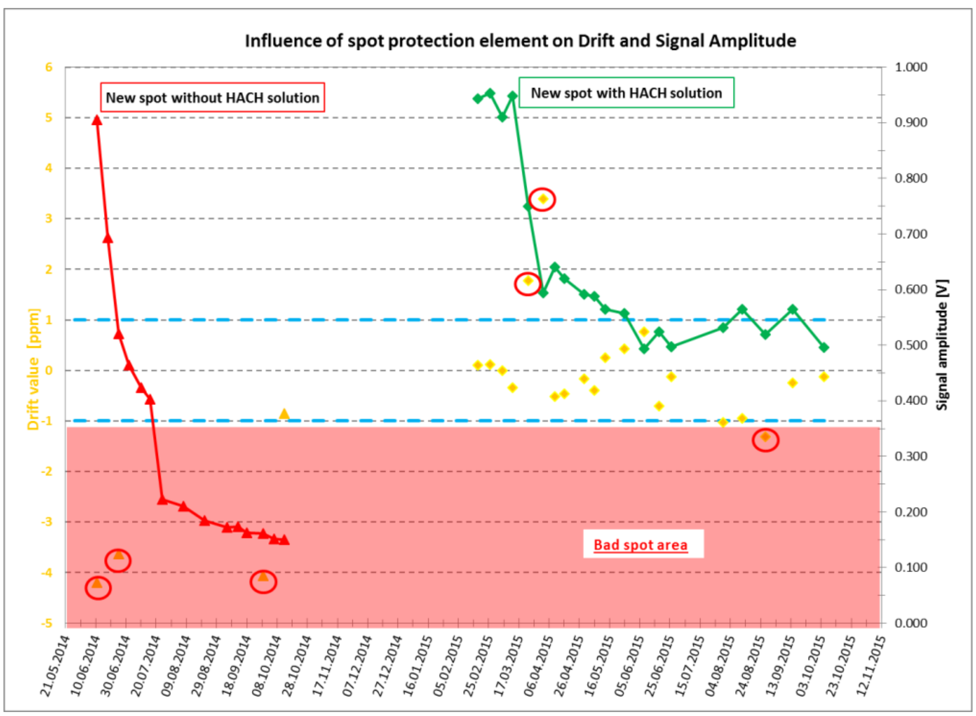


Figure 5: Impact of Hach solution on high level spot lifecycles:
(a) Red curve: signal amplitude variation in V in absence of protection
(b) Green curve: signal amplitude variation in V with recommended actions
(c) Yellow points: Drift of oxygen concentration in ppm

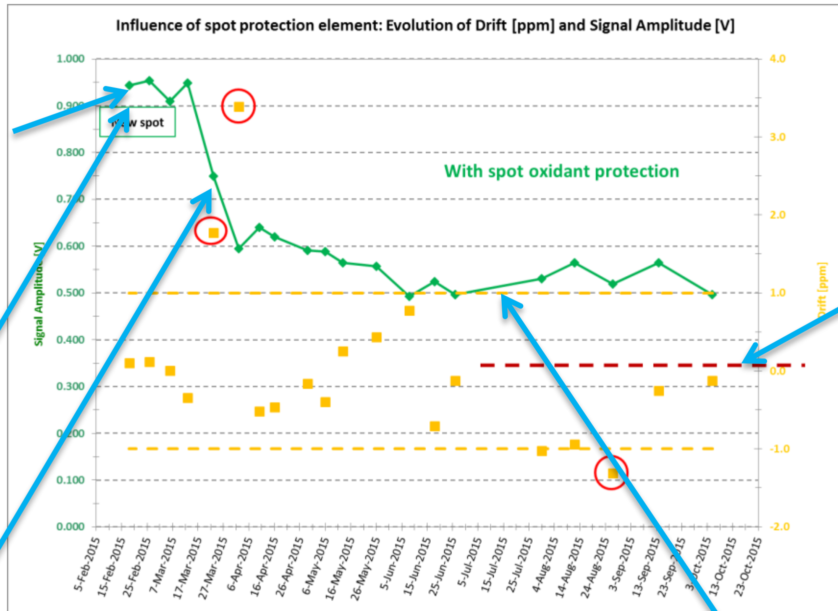
Maintenance plan: Frequency calibration management

Spot life cycle will present 5 phases directly linked to signal amplitude evolution as shown in Figure 7.

Phase 1:
Installation of new spot

- Two points calibration
- Record amplitude in air (Amp0)

Phase 2:
Initial stable phase
Weekly check of amplitude. If new amplitude differs for more than 0.1V from Amp0, Phase 3 is starting.



Phase 5:
End of the spot lifecycle
When fluorescence amplitude in air < 0.350V (value specific to high level spots)

Figure 6: Key spot lifecycle phases with SW 3.08 dry relay function

Phase 3: Weekly check of the amplitude in the air. Perform a 1 point calibration if amplitude differs for more than 0.1V from previous one. When the amplitude drift stabilizes, Phase 4 is started.

Phase 4:
New stabilization phase
One point calibration every three months

The duration of the different phases dramatically depends on the CIP as well as standby/rinsing conditions and frequency. Adjustment of maintenance plan is required to perfectly fit with local situation.

High Level spots are usually the most exposed to daily harsh and concentrate strong oxidant based CIP. An example maintenance plan corresponding to such a situation is detailed on Table 1.

Table 1: Example of maintenance plan for harsh CIP conditions for High Level spots

Phase	Description	Duration (indicative)	Actions
1	New spot installation		Two points calibration + record of initial amplitude (Classical range: 0.8V – 0.9V)
2	Initial stable phase	~1 month	Weekly check of concentration (comparison with portable) or drift in air. Amplitude should stays in the above range: 0.8V – 0.9V)
3	Transition phase with signal drift	Few weeks	Weekly check + 1 point calibration if required
4	New stabilisation phase	6 to 9 months	Check every three months and one point calibration if required (Classical range: 0.4V – 0.5V)
5	End of spot lifecycle		End of the spot life cycle when fluorescence amplitude in air < 0.350V

For low level spots, in-line with less frequent strong oxidant-based CIP, can be sufficient to maintain typical maintenance described in the manual and summarized in Table 2.

Table 2: Example of maintenance plan for less frequent or smoother CIP conditions (even with strong oxidant for Low Level spots)

Phase	Description	Duration (indicative)	Actions
1	New spot installation		One point calibration in nitrogen
2	Intermediate maintenance	6 months	One point calibration in nitrogen
3	End of spot lifecycle	12 months	Spot replacement

What are the Good Practices to Protect Spot?

- Understand the production process but also the CIP process.
- Ask questions about:
  - Use of chemicals, including strong oxidants
  - Oxidants concentration
  - CIP cycle frequency and duration
  - Rinsing water composition (some can contain strong oxidants like chlorine and stay in lines for days)
  - Presence of UV lamps for disinfection, distance to the sensor position
  - Maximum delay between two measurements.

Proactive protection:

- Thermal cut-off activation: Temperature has to be adapted to process, CIP and rinsing water to make sure that there is no sensor activation in presence of oxidant.
- Stop of measurement during CIP with SW 3.08 dry relay function or higher
- Increase measuring interval above the 2 seconds interval by default up to 30 seconds when applicable
- To be applied anytime:
  - When a new probe M/K1100-L or H is installed within a process using frequently a strong oxidant during cleaning in place (CIP)
  - When the CIP is modified and when strong oxidant is introduced
  - When the CIP is modified to increase the frequency of CIP
  - When the CIP is modified to increase the concentration of strong oxidant
  - When a probe already installed face recurrent problem of drift of signal in reference gas; increase of calibration frequency; significant reduction of life time of spot in line, and recurrence of significant green coloration of spot.

DOC043.53.30359.July16

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