Application Note

TruDO

TruDO Sensor Troubleshooting Guide

This application note first discusses general limitations of polarographic dissolved oxygen (DO) sensors. Guidelines for troubleshooting common errors encountered when operating TruDO sensors are then given. Such common errors include no output current, “zero” current being too high, slow response times, and calibration currents in air being too high or too low.

Limitations of Traditional Dissolved Oxygen (DO) sensors

Recall that TruDO sensors are Clark cell sensors constructed using Ag/AgCl and platinum electrodes and using KCl electrolyte, so that the detailed oxygen reduction reaction at each electrode is:

Cathode (Reduction): $O_2+2H_20 + 4e^- \rightarrow 4OH^-$ (1)

Anode (Oxidation): $4Ag+4Cl - 4e^- \rightarrow AgCl$

The overall reaction that occurs is shown in equation 2:

Overall: $4Ag + O_2 +2H_20 +4Cl^- \rightarrow 4AgCl +4OH$ (2)

From equation 1, it can be seen that every time oxygen is reduced, 4 electrons are generated and the cathode is “depolarized”. These electrons produce a current that is related to the partial pressure of the dissolved oxygen. The current is measured using a transmitter that then reports the oxygen value either in % saturation or ppm units.

As with any other type of electrochemical sensor, polarographic dissolved oxygen sensors are not completely trouble-free. As the sensor ages, it may begin to drift or produce more noise in its reading. Such degradation in sensor performance can be caused by a wide range of factors, the common of which are listed below.

1 Anode isolation

The net result of the electro-chemical reaction in a DO sensor is silver chloride (AgCl). This AgCl product slowly coats the anode. Once the anode is completely coated with AgCl, the reaction stops, because there is no more silver available to carry out the reaction, and the DO sensor can no longer respond to oxygen.

The sensor can be reactivated by cleaning the anode to remove the AgCl deposit. This process requires some care, and can be a time-consuming procedure. TruDO sensors allow the user to completely replace the electrode assembly (see application note: “TruDO Sensor Field Service”), which makes reactivation both simple and fast. Finesse also offers fast turn-around sensor services, including probe rebuilding, calibration, and certification, for TruDO sensors (see www.finesse-inc.com/services).

2 Zero Shift

The electrochemical reaction also produces OH- ions which change the pH value of the electrolyte, and move it into the alkaline range. This change in pH causes a shift in the sensor zero point over time. Eventually, the shift becomes so significant that the electrolyte solution in the sensor must be changed.

TruDO sensors allow the user to easily add electrolyte solution (see application note: “TruDO Sensor Field Service”), which makes reactivation very simple and fast. Finesse also offers fast turn-around sensor services, including probe rebuilding, calibration, and certification, for TruDO sensors (see www.finesse-inc.com/services).

3 Depletion of Chloride

The net reaction also consumes chloride ions (Cl^-). Over time, the chloride ions will be fully consumed and this results in the deterioration of the electrolyte. Eventually, the chloride ion depletion becomes so severe that the electrolyte solution in the sensor must be changed.

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4 Polarization Time

Polarographic DO sensors require approximately 675 mV to be applied to the sensor, in order to initiate the electrochemical reaction and produce a measurement. When the sensor is disconnected from the transmitter or polarizer, the voltage supply is cut off, and the sensor will depolarize.

After the sensor and voltage source are reconnected, the user must wait for the probe to become polarized or, more precisely, for the current loop to become stabilized. For TruDO sensors, this waiting period is approximately 30 minutes. Any measurement taken before this polarization period has elapsed will be result in incorrect (higher in value) oxygen readings.

5 Membrane mediated effects

Typical DO sensor membranes are generally made from Teflon and often suffer from "cold flow" deformation as a result of the stress caused by being mounted to a rigid stainless steel shaft. The change in tension changes the effective thickness of the membrane. Because the DO output current is an inverse function of the thickness of the membrane, any "stretching" (or "thinning") of the membrane will produce an effective increase (or upward drift) in the DO reading. Conversely, membrane clogging will create a downward drift in the DO reading. Furthermore, if the sensor is sterilized numerous times (e.g., autoclaved), the membrane can undergo significant physical deformation, sometimes even to the point of rupture or failure.

TruDO sensors have a thicker, steel-mesh-reinforced membrane, which is more robust and reliable than other DO sensors. Please refer to the application note: entitled "TruDO Sensor Reliability" for more details. Therefore, TruDO sensors show greater immunity to drift and have longer operating lifetimes. However, as no sensor lasts forever, TruDO sensors are designed so that the membrane is easily field replaceable by the user (see application note: "TruDO Sensor Field Service"). Finesse offers fast turn-around sensor services, including probe rebuilding, calibration, and certification, for TruDO sensors (see www.finesse-inc.com/services).

6 Environmental effects

Changes in the flow rate of liquid across the DO sensor membrane, such as those produced by agitation and/or stirring in a bioprocess vessel, can cause variations in the output reading. Additional effects on the sensor reading can be caused by vibrations.

Troubleshooting

Setting up the transmitter (other than a TruTransmitter):

- Program the transmitter so that the absolute current output of the TruDO sensor is displayed. Messages such as "calibration not possible" are difficult to interpret if the actual sensor output current is unknown.
- Most transmitters assume that the calibration was performed in air or in air saturated with water. Therefore, be sure to perform the calibration in air that is correctly saturated with water.
- Most transmitters accept only a limited range for the TruDO output currents in air. For non-Finesse transmitters, please verify that the TruDO sensor output is compatible with the transmitter's operating input range. Finesse can provide a list of transmitters that are compatible with our TruDO sensors.
- In the user manual for most transmitters, a wiring table with color codes is provided for specific DO sensors. If your TruDO sensor differs from the DO sensors described in the manual, be aware that the color code may no longer be valid. Please contact your local Finesse representative for technical assistance.

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No current output (at all!):

- Wiring of the sensor to the transmitter is incorrect. First check the anode and cathode connections. Some transmitters can also handle three-electrode oxygen sensors: in this case a jumper must be inserted between the "reference electrode" and "anode" connectors.
- Faulty sensor connector: Check to see if sensor connector pins are covered with liquid and/or dirt (if they are, replace the sensor). If the connector appears to be clean, first try a new cable. If the new cable doesn't help, try a different sensor altogether.
- Faulty cable: Check the cable for any open contacts with a voltmeter set to the "diode" setting. There may be a problem in the cable wiring or the cable connector.
- Membrane body is not filled with sufficient electrolyte (1.5 ml): Unscrew the membrane cap and check the electrolyte level. If there is less than 1.5 ml of electrolyte, refill the electrolyte level.

"Zero" current is too high (out of range) – high probability reasons:

- Cable problem: Disconnect the sensor from the cable to make sure that the transmitter reading goes to zero.
- Connector head: Visually inspect the connector pins to see if they are covered with liquid and/or dirt. If they are clean, connect the sensor and transmitter using a different cable to see if the cable is the root cause. If it is not, try connecting a different sensor to see if the sensor is the root cause.
- Membrane is broken or the mechanical tension on membrane has become to low. Unscrew the membrane cap and exchange the electrolyte solution (see app note: "TruDO Sensor Field Service"). Clean the glass body of the electrode with hot water, dry with a Kimwipe, rinse with electrolyte, and dry again. Replace the membrane cap. Check that the resistance between the anode and cathode is low.
- Liquid inside the sensor connector head. Inspect the female jack of the cable and the male jack of the sensor connector to see if there are any liquid droplets on either. If there is liquid, dry the cable and connector. Note that it is very difficult to dry (restore) a VP female connector; however, attempt to clean the inside with a swab and rubbing alcohol. Once the connectors are dry, reconnect the probe and cable, and first check that the anode to cathode resistance is low using an ohmmeter. Then, check that the sensor responds to nitrogen. Finally, check that the current goes to zero if the sensor is disconnected from the transmitter.
- Polarization time too short. Apply the polarizer and wait at least 15 minutes.
- The test medium is not completely oxygen free. Use oxygen-free nitrogen.

"Zero" current is too high (out of range) – lower probability reasons:

- Anode is contaminated with cyanide, sulfide or iodide (the polarogram is shifted to more negative values). With the sensor exposed to air, check to see if the sensor output current is higher than expected for air.
- Sample media contains gaseous species that can be reduced or oxidized at the cathode. One indicator of this problem is a positive "zero" current reading.

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Response time is too slow:

- For measurements in liquid media: an air bubble is sitting in front of the membrane. In this case the sensor output current will produce a constant reading that is close to the value in air. Change the position of the sensor in the process and find a location for the membrane tip such that air bubbles cannot become trapped. Recall that the response of the sensor is slower when measuring in an unstirred solution, because the rate of oxygen diffusion is slower in liquids. Note that the time response specification stated in the TruDO datasheet is only valid for measurements in the gas phase (i.e., calibration).
- For measurements in the gas phase: a droplet of water is sitting on the top of the sensor: In this case, the sensor response to nitrogen is slow. Dry the sensor with a soft paper towel (e.g., Kimwipe).Process temperature is too low: The response of TruDO sensor slows down with decreasing temperature. The response time specifications are valid only for process temperatures around 25°C.
- Media contains a lot of carbon dioxide. May require a different DO sensor.
- Membrane is broken or the mechanical tension on the membrane has become too low. Replace the membrane cap (see app note: “TruDO Sensor Field Service”).
- Membrane is covered with dirt or is biofouled: The “dirty” layer may contain living organisms that consume oxygen, so that the sensor response time is artificially slowed. First, try to wipe off the “dirt” layer with a wetted soft towel (e.g., Kimwipe). If the “dirt” layer cannot be removed after being wiped several times because of excessive contamination, replace the membrane cap with a new one (see app note: “TruDO Sensor Field Service”).

Current in air is too high – high probability reasons:

- Liquid inside the sensor connector head. Inspect the female jack of the cable and the male jack of the sensor connector to see if there are any liquid droplets on either. If there is liquid, dry the cable and connector. Note that it is very difficult to dry (restore) a VP female connector; however, one can attempt to clean the inside with a swab and rubbing alcohol. Once the connectors are dry, reconnect the probe and cable, and using a voltmeter check that the anode to cathode resistance is low. Then, check that the sensor responds to nitrogen. Finally, check that the current goes to zero if the sensor is disconnected from the transmitter.
- Short circuit between the anode and cathode at the cable or transmitter: Disconnect the cable from the transmitter and check that the current display shows “zero”. If it is “zero”, the transmitter is fine. Reconnect the probe and cable to reproduce the high reading. Then, disconnect the cable from the probe. The transmitter display should again read “zero”. If it does, try a different sensor. If it does not, the cable is faulty and should be replaced.
- Cathode glass body is broken. Replace the sensor.
- Membrane is broken or the mechanical tension on membrane has become too low. Replace the membrane cap (see app note: “TruDO Sensor Field Service”).
- Membrane is damaged in the inside: In this case, the cathode and the steel mesh are in contact, producing a short circuit. Check the anode to cathode resistance using an ohmmeter. If the resistance is zero, replace both the electrolyte solution and the membrane cap (see app note: “TruDO Sensor Field Service”).

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Output current in air is too high – low probability reasons for bioprocess applications:

- Anode has become contaminated by cyanide, sulfide or iodide (sensor response has been shifted to more negative values). Check if sensor responds to nitrogen. If the sensor does not respond, please return the sensor to Finesse for maintenance.
- A short circuit has been created between the anode and the stainless steel shaft: Unscrew the membrane cap. Check that the helix of the anode is sitting firmly around the glass body of the internal electrode assembly. Do not apply any mechanical force to the electrode during this process. If the anode is attached, please return sensor to Finesse for maintenance. If the anode is no longer attached, maintenance is not possible.

Output current in air is too low:

- Membrane broken and/or electrolyte contaminated: Unscrew the membrane cap and check that electrolyte is not contaminated (it should look clear and transparent, with no precipitation). If it is, exchange it (see app note: “TruDO Sensor Field Service”). If the electrolyte appears fine, check the membrane by holding it up to a bright light and examining it from the inside of the cap. If the membrane appears non-uniform or has holes or micro-tears, replace it.
- Membrane is covered with dirt or is biofouled: The “dirty” layer may contain living organisms that consume oxygen, so that the sensor reading is artificially low. First, try to wipe off the “dirt” layer with a wetted soft towel (e.g., Kimwipe). If the “dirt” layer cannot be removed after being wiped several times because of excessive contamination, exchange the membrane cap for a new one (see app note: “TruDO Sensor Field Service”).
- Cathode has lost all activity: This problem can arise if the membrane ruptures and the sample media has penetrated through the membrane to the cathode. First, check the cathode to see if there are any deposits on the tip of the glass body. If the glass body is contaminated, polish the cathode (see app note: “TruDO Sensor Field Service”).
- Polarization potential is incorrect: First make sure that a voltage is being applied. Then, using a voltmeter, check that the polarity (plus “+” and minus “-“ sign) and magnitude of the applied voltage are correct.

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