Understanding pH & ORP Sensor Performance

To ensure effective process control and cost management, it is imperative to develop a comprehensive understanding of the behaviour of pH and ORP sensors across various plants and sites. These sensors, which function as consumable electrochemical devices, are susceptible to both poisoning and depletion during operation. Their lifespan is influenced by exposure to chemicals and extreme conditions, necessitating replacement when they reach the end of their useful life. In demanding applications, replacement intervals may be as short as weeks or months, while in less challenging scenarios, they can be extended to months or even years. Moreover, the maintenance and attention required by these sensors can consume considerable human resources.

Irrespective of the specific application, establishing benchmarks for sensor lifespan and performance is crucial to accomplish the following objectives:

- Streamline maintenance activities to minimize the labour-intensive management of sensors, which often constitutes a substantial expense.
- Enhance the longevity and/or performance of sensors.
- Promptly detect any changes within the plant or operation and implement corrective measures.
- Maintain an adequate inventory of replacement sensors.
- Continuously improve the sensor measurement program, encompassing design and instrumentation.

What is the REFERENCE and how is it affected?

The reference electrode is a crucial component of a pH/ORP sensor that maintains a stable potential against which the pH/ORP measurement is compared. When a pH/ORP sensor is exposed to certain chemicals, especially those that are oxidizing or reducing agents, the reference electrode can be depleted or consumed due to chemical reactions. This can lead to a loss of reference potential and affect the accuracy of pH measurements. The depletion of the reference electrode can occur through different mechanisms:

- **Redox Reactions:** Some chemicals used in industrial processes or cleaning solutions can participate in redox reactions with the reference electrode. For example, oxidizing agents can react with the reference electrode's internal electrolyte and oxidize the metal electrode, depleting its active material. Similarly, reducing agents can chemically reduce the metal electrode, also resulting in depletion.

- **Electrolyte Contamination:** Exposure to certain chemicals can contaminate or interfere with the reference electrode's internal electrolyte. This can lead to changes in the chemical composition or properties of the electrolyte, affecting its ability to maintain a stable reference potential. Contamination can occur through chemical reactions, precipitation, or formation of insoluble compounds that block the electrolyte's pathways.

- **Ion Exchange:** Chemical exposure can also induce ion exchange processes at the interface between the reference electrode and the sample solution. This can result in the migration of ions from the reference electrode into the sample solution or vice versa, depleting the concentration of ions necessary for establishing the reference potential.

- Fouling or Coating: Some chemicals can cause fouling or coating of the reference electrode surface. This can create a physical barrier or hinder the ion exchange processes necessary for maintaining the reference potential. Fouling can be caused by deposition of insoluble compounds or substances that adhere to the electrode surface.

When the reference electrode is depleted or compromised due to chemical exposure, the pH sensor may exhibit drift, slow response times, or inaccuracies in pH/ORP measurements. **Regular maintenance, proper cleaning, and calibration procedures can help mitigate these issues.** In some cases, it may be necessary to replace the entire pH/ORP sensor if the depletion is significant or irreversible.

What is the GLASS and how is it affected?

The glass element of a pH sensor is a critical part that determines the pH measurement by responding to changes in hydrogen ion concentration in the solution. During the process, the glass element can be affected in several ways:

- **Chemical Attack:** Depending on the nature of the process, the solution may contain chemicals that can attack the glass membrane of the pH sensor. Strong acids or bases, corrosive substances, or reactive compounds can cause chemical reactions with the glass, leading to erosion, etching, or dissolution of the glass material. This can result in physical damage to the glass membrane, compromising its integrity and affecting the accuracy of pH measurements.

- **Fouling and Coating:** Some processes may involve the presence of substances that can deposit or coat the glass membrane. This can lead to fouling, which creates a barrier between the solution and the glass surface. Fouling can interfere with the diffusion of hydrogen ions across the glass membrane, slowing down the sensor's response time or causing inaccuracies in pH readings.

- **Temperature Effects:** Process temperatures can also impact the glass element of a pH sensor. Extreme temperatures can cause thermal stress, leading to physical expansion or contraction of the glass material. Rapid temperature changes can result in mechanical strain, microcracks, or even breakage of the glass membrane. Additionally, high temperatures may alter the properties of the glass, affecting its sensitivity or response characteristics.

- **Abrasion and Scratching:** In some processes, the flow of the solution may contain particles or solids that can cause abrasion or scratching of the glass membrane. Physical damage to the glass surface can disrupt its uniformity and alter its permeability to hydrogen ions, leading to measurement errors or reduced sensor lifespan.

To minimize the impact on the glass element during the process, it is essential to select pH sensors that are compatible with the specific chemicals, temperatures, and conditions involved. **Regular maintenance, proper cleaning procedures, and appropriate sensor protection can help mitigate the effects of chemical attack, fouling, temperature variations, and physical damage.** It is also important to follow manufacturer guidelines for handling, calibration, and replacement of pH sensors to ensure accurate and reliable pH measurements.

The IMPORTANCE of Historical Data

In the absence of documented sensor experience within a plant, accurately estimating the lifespan and performance of sensors becomes unattainable. Relying solely on theoretical analysis proves insufficient in predicting their behaviour, and extrapolating experiences from one site to another is not reliable. The only dependable approach to gaining insight into sensor lifespan is through the adoption of a scientific method that involves meticulous monitoring and recording of installed sensors' behaviour. Fortunately, Smart Digital Sensors alleviate a significant portion of the effort involved in this process by automatically capturing relevant data, such as service time, critical variables like temperature fluctuations, and recent diagnostic information on sensor performance.

However, this data alone provides only a partial understanding. While sensors themselves are manufactured with high precision and exhibit minimal variations among one another, plant processes demonstrate significant variability. Much of the observed variance in sensor lifespan is directly linked to changes in site operations and plant behaviour. To achieve a comprehensive comprehension of sensor performance, it is crucial to consider plant variables that have an adverse impact on sensor lifespan. The following considerations highlight factors influencing sensor performance:

- **Sensor Placement:** The impact on sensors can vary across different locations within a plant due to the presence of forces and chemicals. Each specific location should be individually assessed, and even the relocation of a sensor within the same area should be duly documented.

- **Plant Stability:** Plant processes may experience periods of instability, particularly during initial stages or after changes in production or processes. These changes can involve variations in raw inputs, chemicals, production throughput, or equipment modifications. As a result, sensors may be exposed to higher levels of chemicals, different contaminants, or abnormal stress.

- **Temperature Effects:** Temperature and thermal shock affect sensors differently. It is essential to determine whether sensors are subjected to significant temperature fluctuations or are operating near their specified limits.

- **Start-up/Shutdown:** Sensor conditions can undergo significant changes during start-up and shutdown phases, potentially leading to substantial deterioration or failure if not managed properly.

- **Maintenance and Care:** This aspect is crucial and largely controllable. Poor sensor performance often results from insufficient or improper maintenance practices. Seeking guidance from representatives on appropriate and timely maintenance procedures is advised. Sensors cannot be installed and forgotten; they require meticulous cleaning with appropriate agents to remove microscopic or visible deposits without damaging the sensing element. Inadequate cleaning can accelerate the poisoning of the sensing element.

- **Human Factors:** Various human elements can impact sensor performance. Changes in personnel or maintenance crews often have an influence. Not all individuals exhibit the same level of care and attention when it comes to calibration, cleaning, or replacement of sensors. Some may prematurely discard sensors instead of cleaning them.

A Systematic Approach

To ensure a comprehensive assessment of sensor performance and enable a systematic approach to improve sensor management, it is essential to gather precise information on the status and behaviour of each sensor. Relying solely on observations of a single-use sensor at a single location lacks statistical significance and fails to account for potential adverse events that may have occurred without our knowledge. Instead, to establish a reliable overview of sensor performance, it is necessary to accumulate the history of at least five consecutive sensors deployed in the same location, with a preferable minimum of ten sensors to obtain an accurate statistical trend. The collection of as much data as possible is paramount, and the following information represents the minimum requirements for documentation and compilation to facilitate a comprehensive understanding of sensor performance in relation to their operational environment, maintenance procedures, and attention they receive.

Recommended Data Table (example)

INFORMATION	RESULT
Location	Area 3400
Process	Neutralisation. Addition of 10% NaOH to neutralise from 4 to 7.
Sensor type and ID	pH TT.01.02-03
Days in Service	180
Calibration Schedule	Weekly
Cleaning Schedule	Every 3 days
Drift Tolerance	0.3 pH units
Cleaning Regime (ie HCL, NaOH, Surfactant, other)	15% HCL soak for 5 min, clean water soak 10 min, conditioning solution soak 15 min
Sensor Failure Mode (Broken Glass, Won't Calibrate, Off scale, other)	Sensor won't calibrate. Slope too low (unresponsive)
Other observations (following plant shut, plant excursion, change of personnel)	Changed ore body 2 weeks ago.

Notes:

- The calibration frequency should be determined in accordance with the Turtle Tough Guideline for establishing calibration frequency.
- Whenever possible, it is crucial to perform cleaning procedures prior to calibration.
- Calibration standards must always be fresh and kept up-to-date.
- Cross verification against laboratory or portable methods should be carefully reviewed by authorized personnel. Inaccurate cross verification methods can result in significant errors and premature rejection of the sensor.
- For further information on establishing sensor health, please consult the Turtle Tough Guideline.
- If desired, the table can be expanded to include additional relevant information, such as the name of the operator.
- If you have any uncertainties, you are encouraged to send your sensors back to Turtle Tough for a complimentary evaluation.

Refining Sensor Performance - An Iterative Process

As a provider of customized sensor solutions, Turtle Tough possesses the expertise to optimize your sensor's performance by fine-tuning its design. However, in order to make well-informed decisions regarding potential modifications to your sensor's configuration, it is crucial for us to have access to the detailed information specified in the aforementioned table. If you are interested in assessing and enhancing your sensor's performance, we are pleased to assist you in this process and explore alternative designs, subject to the following requirements:

- You are capable of providing us with comprehensive and accurate information as outlined above, and have already conducted testing on a minimum of five sensors deployed in the same location.
- You will be required to return those sensors to us or our nearest representative for thorough analysis.
- Please furnish a visual image (photograph) showcasing the precise installation, highlighting how the sensor is positioned in its operational environment.

IMPORTANT!!

It is crucial to understand that this process is iterative and involves experimentation and adjustments. We do not offer guarantees, free samples, or trials. As an equipment vendor, we are providing an alternative sensor configuration in good faith, aiming to better accommodate your specific conditions based on our mutual observations and the data you have provided. Any subsequent recommendations we make are solely based on good faith, and it is your decision whether to act upon those recommendations or not. We do not provide any implied or explicit performance guarantees, and it is important to note that a single-use instance does not establish a statistical trend. It is essential to test multiple sensors before making further changes or modifications.

All information provided by Turtle Tough, including sensor design recommendations, is of a general nature and intended solely as product information. We do not guarantee that our products are suitable for any specific purpose or application. The end user is responsible for evaluating the suitability of our products for their own needs and requirements. We shall not be held liable for any damages, losses, or inconveniences arising from the use of our products or reliance on the provided information. The end user is advised to conduct their own evaluations and tests to determine the suitability and performance of our products in their specific circumstances.

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