White Paper

Discover how our latest digital pH/ORP sensor surpasses legacy analog technology

EMERSON™

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In this White Paper

This white paper takes a close look at the new Rosemount 396A Digital Anti-Coating pH/ORP Sensor and aims to show that the new digital sensor outperforms respective legacy sensors across critical performance indicators, including accuracy, resistance to poisoning, and long-term reliability. Through data collected in both lab environments and field applications, here is a clear case for why the new digital pH sensor surpasses its legacy analog counterparts in challenging liquid analysis applications.

As demands in liquid analysis continue to rise, the tools used to monitor and control processes must evolve to keep pace. This progression is driven not only by the need for greater precision and data integration but also by the growing demand to future-proof sensing technology. Traditional analog sensors, while long trusted for their simplicity and robustness, are increasingly challenged by the need for improved reliability, real-time diagnostics, and seamless installation and integration.

System Overview

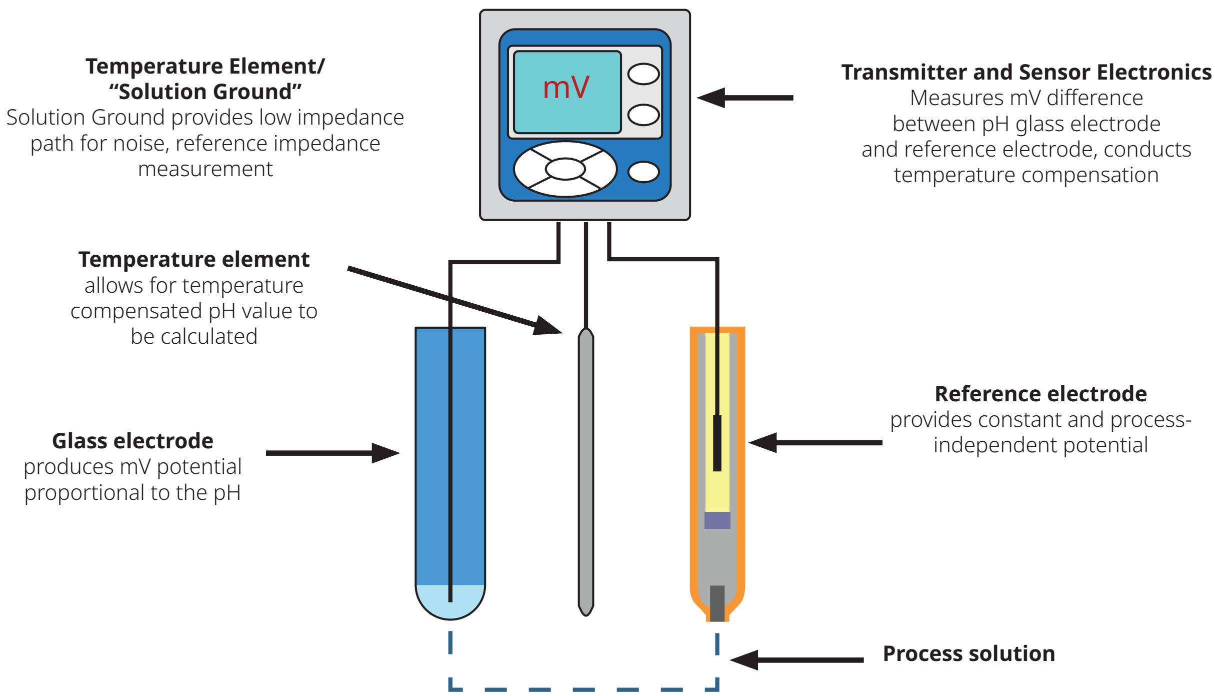


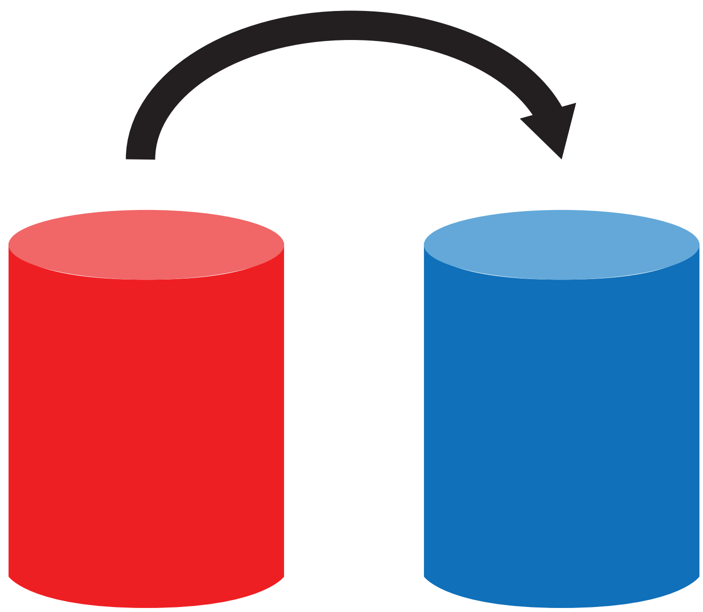
Figure 1. *Graphic showing components of a typical pH measurement system*

pH is a measure of the acidity or alkalinity of a solution or mixture. The acidity or alkalinity is determined by the relative number of hydrogen ions (H+) or hydroxyl ions (OH-) present.

Measurement can be influenced by:

- Temperature
- Conductivity
- Pressure
- Flow
- Electrical interference

The measurement of pH will change over time as the reference and glass electrode age. It is recommended to periodically calibrate sensors to ensure accurate measurements. When calibration occurs, a slope and offset will be output. Slope is temperature dependent—the theoretical slope at 25 C is 59.2 mV/pH. Offset will accrue over time—an initial offset should be close to 0 mV.



pH 4
Example: 175 mV

pH 10
Example: -168 mV

Slope

$$\frac{(175\ \text{mV} - (-168\ \text{mV}))}{10\ \text{pH} - 4\ \text{pH}} = \frac{343\ \text{mV}}{6\ \text{pH}} = 57.2\ \text{mV/pH}$$

Figure 2. *Graphic illustrating calibration and method of slope calculation*

The 396A solution ground is a titanium sleeve which sits near the end of the glass pH or ORP electrode. 396A utilizes the 3900 glass electrode assembly, which shares the same pH sensitive bulb formulation and is well regarded in the field. Additional testing to evaluate the performance of this glass at the elevated pressure rating of the 396A was done with successful results.

Figure 3. *Glass and solution ground subassembly*

The glass electrode and solution ground are inserted into a sled, where an RTD is added, reused from legacy 396P. A potting mechanism is added to provide thermal conductivity and glass electrode cushioning.

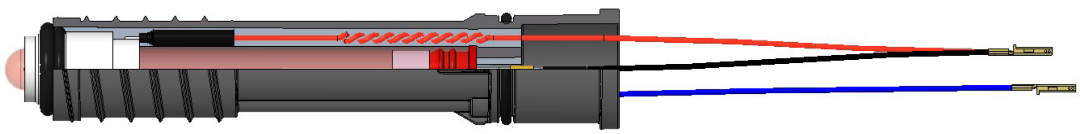


Figure 4. *Sled assembly with RTD*

A dipped wire and seal are reused from legacy 396P to provide a reference signal.

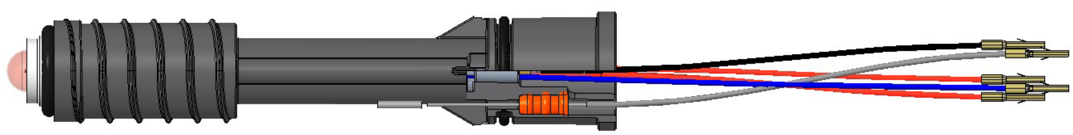


Figure 5. *Full sled assembly*

A junction is established through the front wall of the body. K+ and Cl- ions travel from the gel along the helical pathway and through the wall along the long glass fibers to the process, which completes the reference circuit.

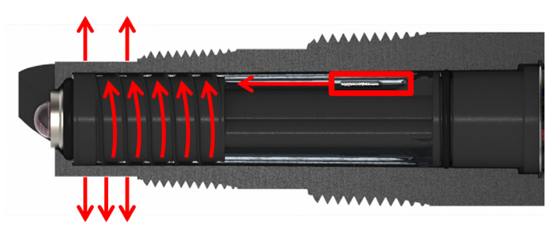


Figure 6. *Ion flow path*

There are two termination styles available: integral cable or M12 connector. Integral sensors have an M12 cable pre-installed on the sensor side. It has internal sealing components and a strain relief feature boot (figure 7). M12 sensors allow for quick-connect option with an M12 cable (in Figure 8).

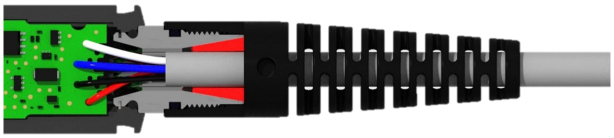


Figure 7. *Integral cable sealing components and strain relief boot*

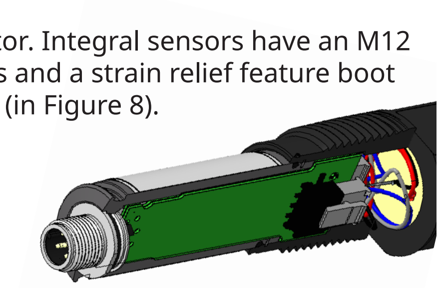


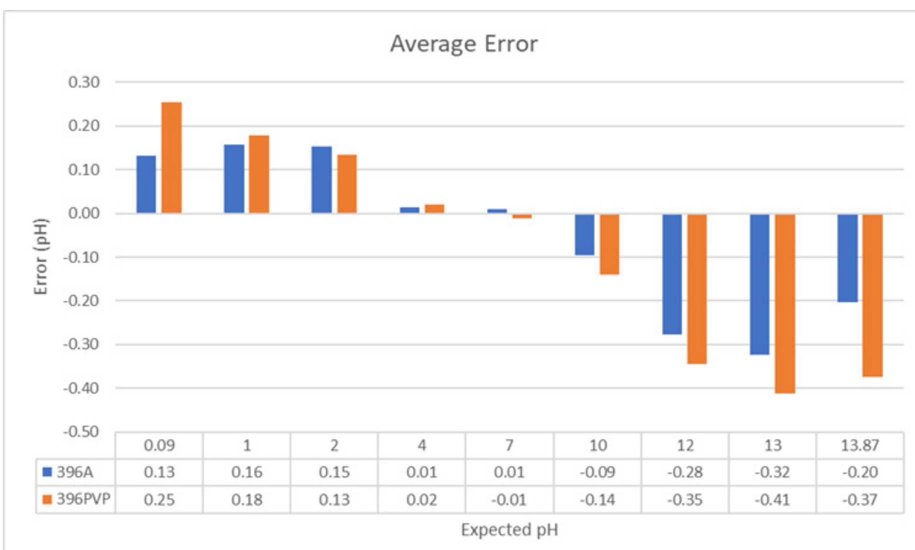
Figure 8. *M12 board retention*

Performance Verification

Overall, the Rosemount 396A Digital pH Sensor has outperformed the legacy Rosemount 396P/PVP pH Sensor with respect to accuracy, linearity, repeatability, resistance to poisoning, and pressure and temperature testing. Results from the experiments described below have shown the same or better performance throughout 0 pH - 14 pH range.

Accuracy Test

Accuracy testing was conducted with two-point buffer calibrations between pH 4 and 7. The test occurred at 25° C with atmospheric pressure and ambient humidity and without flow or stirring. Standard pH buffers were used. Three rounds of testing were conducted. The difference from the expected pH value was compared to the actual measured pH value as an average of the three rounds of testing. A sensor-type average was taken to show the results.

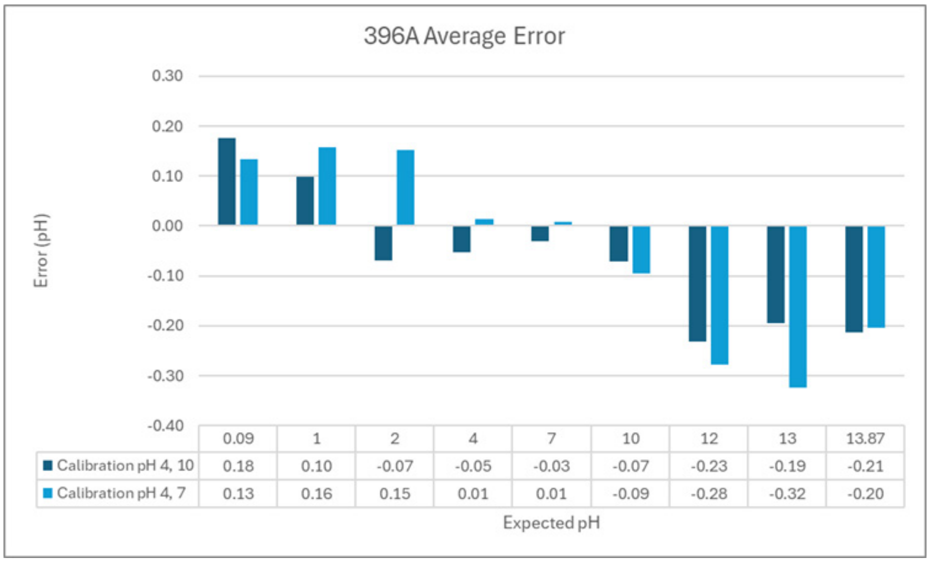


	0.09	1	2	4	7	10	12	13	13.87
396A	0.13	0.16	0.15	0.01	0.01	-0.09	-0.28	-0.32	-0.20
396PVP	0.25	0.18	0.13	0.02	-0.01	-0.14	-0.35	-0.41	-0.37

Figure 9. *Error of 396A and 396PVP compared to the expected pH in different buffers*

Test results show that the accuracy of the Rosemount 396A is about the same or better than the legacy Rosemount 396. As the process pH moves towards the extremes away from the standardization pH points, the measurement error increases. This is partially a result of calibrating in pH 4 and 7, which is recommended in some cases, rather than in pH 4 and 10, because of the instability of pH 10 relative to pH 7.

Figure 10 shows error with calibration in pH 4 and 10 and in pH 4 and 7 for 396A alone. The different calibration solutions used results in somewhat different error at each expected pH. The error in pH 1, 2, 10, 12, 13, and 13.87 improved or stayed about the same, while the error in pH 0.09, 4, and 7 became somewhat worse but not by a significant margin.

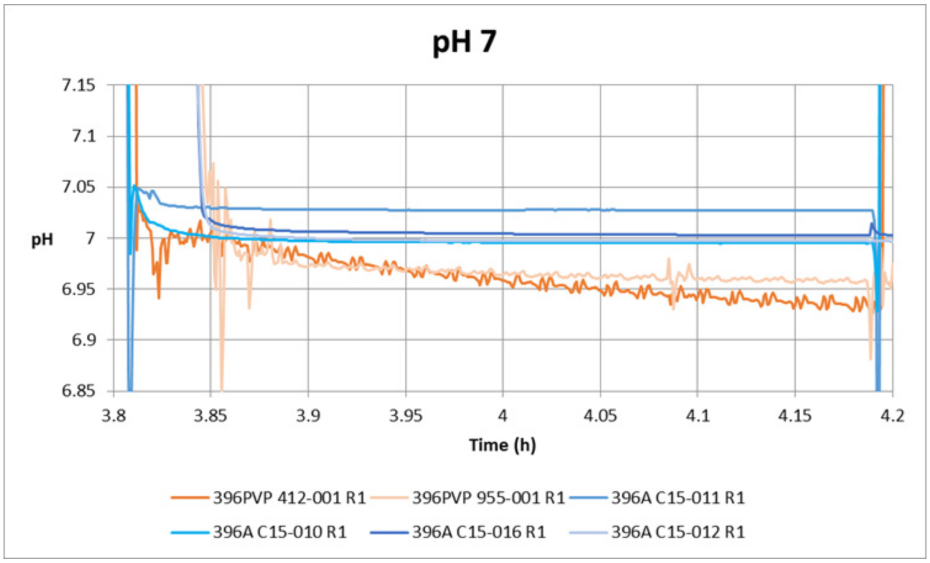


	0.09	1	2	4	7	10	12	13	13.87
Calibration pH 4, 10	0.18	0.10	-0.07	-0.05	-0.03	-0.07	-0.23	-0.19	-0.21
Calibration pH 4, 7	0.13	0.16	0.15	0.01	0.01	-0.09	-0.28	-0.32	-0.20

Figure 10. *Average error for 396A sensors tested to expected pH for calibration in pH 4/10 and pH 4/7*

As pH sensor accuracy depends on calibration, customers should be advised to ensure the calibrating pH buffers cover the expected process pH (e.g., if expected process pH is pH 10, calibrate pH sensor with pH 8 and pH 12 buffers).

Digital sensors have a shorter analog measurement path so the measurement should be less susceptible to interference. Figure 11 shows 396A and 396PVP in pH 7 buffer after being in pH 10 buffer and transferring to pH 4 buffer afterwards. The 396A sensors show better measurement stability for noise and drift which could point to the value of the digital signal compared to the analog, which can be more susceptible to interference from the surroundings.



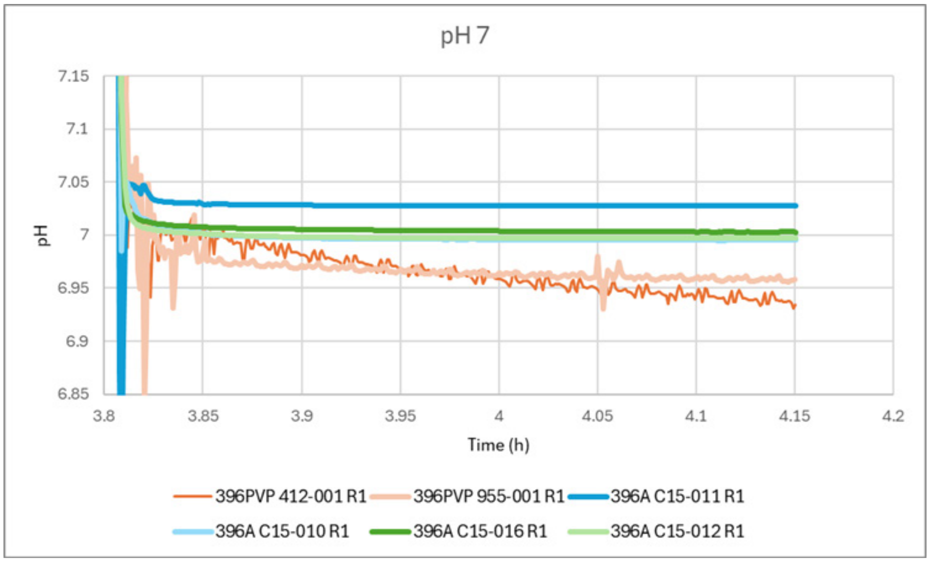


Figure 11. *pH measurement in pH 7 for about 20 minutes in buffer for 396As and 396PVPs for round 1 of testing going from pH 10 to 7 s*

Poisoning Test

396As and legacy 396s were exposed to 0.22 M sodium sulfide with 0.4 M NaOH for around 29 days total (approximately 5 days at room temperature, 9 days at 35C, and 15 days at 45C). The reference potential in about 0.3 M KCl was measured before and after poisoning and then compared, with results shown in Figure 12. The 396As were close together in potential and saw minimal change. One legacy 396 changed only a small amount as well but another had a large change in reference potential, indicating drastic poisoning.

Reference potential definition:

The voltage output of the reference electrode half of the pH sensor compared to a reference sensor that is unexposed to any potentially degrading test conditions and that is known to have a stable potential in a variety of conditions, such as over different ionic strengths. This measurement does not include the pH-sensitive glass electrode.

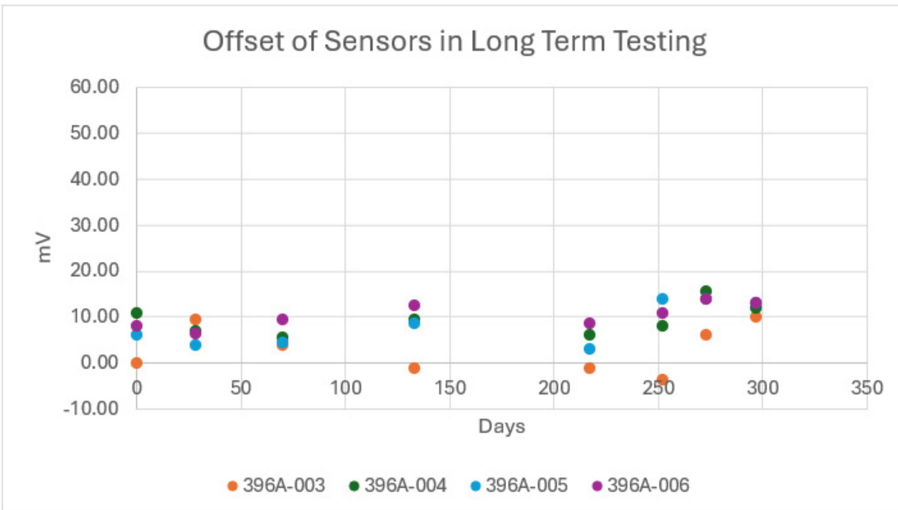
Difference in Reference Potential (mV)					
396A 1	*396A 2*	*396A 3*	*396A 4*	*396PVP 005*	*396PVP 001*
-6	*-8*	*-9*	*-8*	*-6*	*-786*

Figure 12. *Difference in reference potential between before and after poisoning. The reference potential was collected at a KCl concentration of about 0.3 M in water compared to an unexposed reference electrode.*

The 396A sensors show a close retention of reference potential after exposure to sodium sulfide and sodium hydroxide over a period of about 4 weeks at temperatures of 25-45C. One legacy 396 unit was able to retain a good reference potential after exposure, but another shifted drastically which shows a greater susceptibility to poisoning in some cases as well as inconsistency in performance between different legacy 396 units.’

Long Term P&T Test

As a part of extended testing, 396A units were put into a flow system which cycles tap water at controlled pressures for long term testing to assess lifespan and functionality over time. The flow system set to 75 psi and the temperature of the flow was measured at about 42C. Sensors were removed and calibrated periodically to assess slope and offset. The test ran for 42 weeks. Figure 13 is the offset and slope data for 4 different sensors that were included in this test. Note that the transmitter will alarm if the offset reaches 60 mV or if the slope reaches 45 mV/pH.



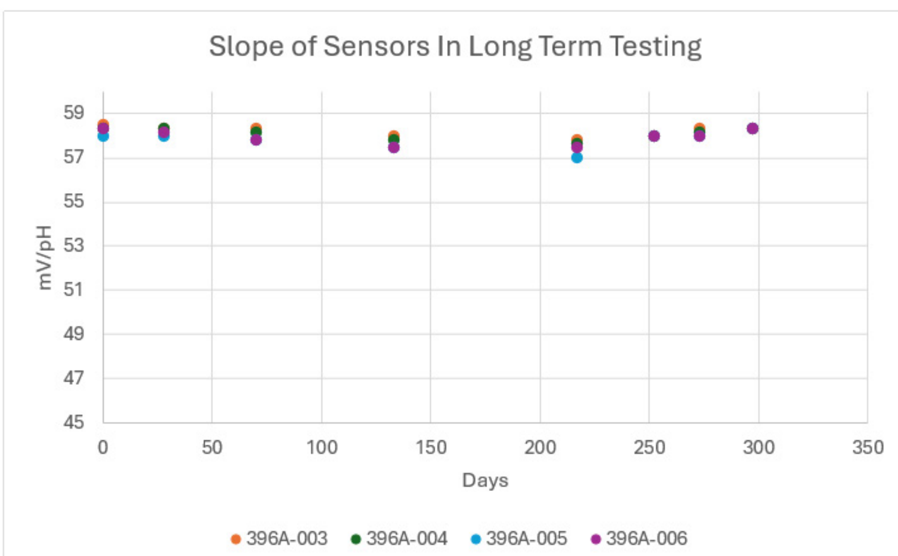


Figure 13. *Slope and offset measured periodically during long term testing*

The offset and slope of the sensors were well within acceptable ranges throughout the 42 week run shown above, indicating that the glass and reference system were not impacted by operating at these conditions for an extended amount of time. As mentioned, 1058 transmitter will alarm when the slope reaches -45 mV/pH as well as when the offset reaches 60 mV – these sensors are not near these values after 42 weeks, indicating that their lifetimes in similar conditions should extend well past that point unless they experience a failure mode outside of glass aging or reference system depletion.

Pressure and Temperature Cycle Test

As a part of verification testing, sensors are exposed to extreme rated pressures and temperature to evaluate the effects on performance and process sealing. This test uses our flow system, which can control the temperature and pressure of flowing tap water within the limits of the steam curve and liquid range of water. The standard test begins with a pre-buffer check, which assesses span, offset, glass impedance, temperature, and reference impedance of sensors before testing. Then, the sensors are inserted into the flow system with 1” NPT threads, and exposed to 72 hours at the maximum process pressure, 150 psi, and 110% of the maximum process temperature, 110 C. Then, the system is cooled down, and the sensors are run at the maximum process temperature, 150 psi, and the minimum process temperature, or as close to 0 C as the system can handle. Afterwards, a post-buffer check is run to assess the same attributes and compare the sensor performance before and after testing. In order to pass, sensors must read within 95% of pre-test span, as well as read reasonable values for all attributes (pH, reference impedance, glass impedance, and temperature). Figure 14 shows the data traces of 396A in P&T Cycle Testing.

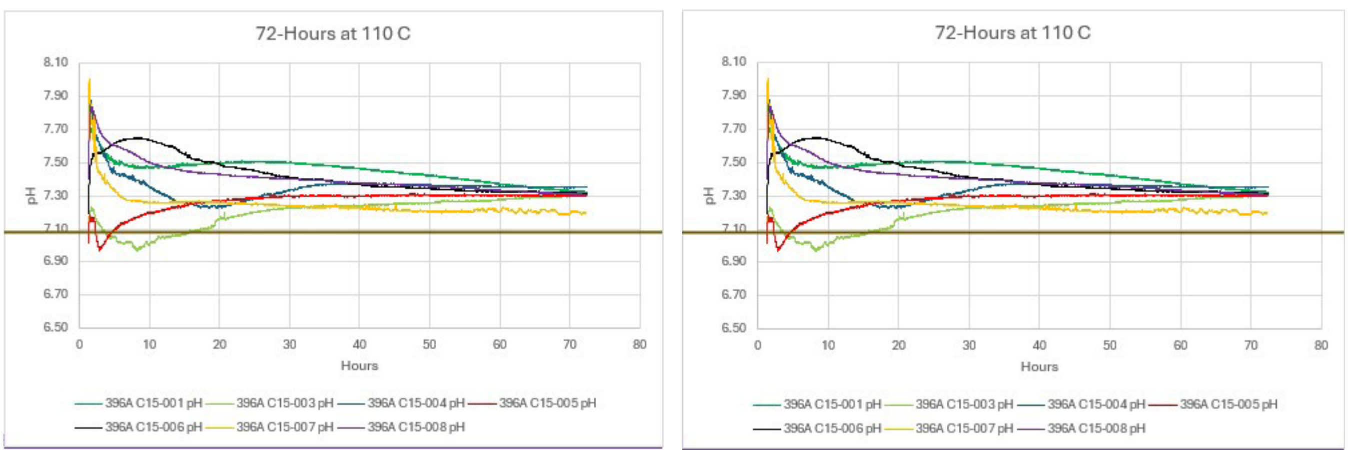


Figure 14. *pH measurement evaluated in pressurized flow system at temperature extremes*

8 sensors were run through P&T Cycle Testing as a part of verification testing. With the exception of one sensor that had cracked glass, all sensors passed this testing, indicating that the sensors are able to perform at the most extreme rated conditions and can survive these conditions without significant degradation to the sensing capability.

Overpressure Test

As a safety test and an assessment of robustness, our sensors undergo overpressure testing in flow at extreme temperature conditions, in addition to IEC 61010 approvals testing. The sensors are not required to maintain functionality, but are expected not to have external leaking, permanent deformation, or bursts. This test is done in the flow system described in section 3.4, and follows the procedure shown in Figure 15.

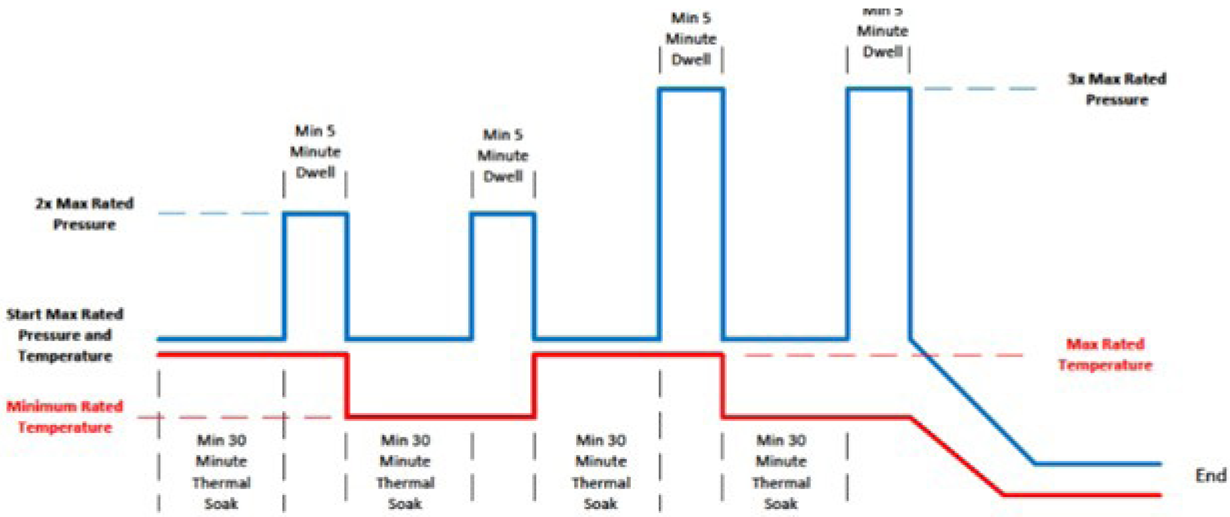


Figure 15. *Temperature and pressure profile used in the overpressure test*

In the case of 396A, two times the maximum pressure is 300 psi, and three times the maximum pressure is 450 psi. The minimum rated temperature is 0° C, and the flow loop is run as close as possible to 0° C. The maximum temperature is 100° C. Fifteen sensors were run through this test, and none experienced any failure as outlined in the criteria above. Six of the 15 sensors tested were still fully functional after the test. The results indicate that the sensor design is robust and safe.

Field Trial Feedback

The 396A has been tested in multiple field trials. In one case, a 396A was used in wastewater treatment application for coal and gypsum pile drainage against a 396RVP redundant loop. This application has heavy dissolved iron coating, and analog sensors typically fail due to high offset in about three months. Sensors experience a pH range from 3 to 10, atmospheric pressure, and process/ambient temperatures from 50 F to 90 F. The customer found that the 396A was more responsive to changes in pH and stabilized more quickly than the 396RVP. Additionally, the 396A was observed to be easier to clean. Legacy 396RVP redundant loop saw failure due to offset after 2 months and 24 days. As of 4 months and 6 days, 396A was still functional. Lifespan to be updated with findings as field trial continues.

A second field trial was conducted in a mud slurry application for refining chromium. The pH is measured in order to assess the success of sodium chromate neuralization. This application experiences a pH range from 10 to 12 then drops to 8.5 after neuralization. They see atmospheric pressure and temperatures at approximately 120 F. Sensors typically fail due to high offset or poor slope in 1-2 weeks. 396A and 1058 loop was installed against a redundant loop of 396VP and a 54E. After 8 days of installation, the customer observed that 396A is continuing to react quickly to process and calibration changes. Typically, the customer would have started to see a sluggish response within a week. Field trial is in progress, and lifespan analysis and other observations will be shared when updated.

Digital Advantages

Digital sensors have several advantages over their legacy analog counterparts.

1. Rosemount digital sensors come with M12 connectors, allowing the sensor to be quickly connected via ports on the transmitter. No manual wiring is needed.
2. Calibration logs are stored in the digital sensor board itself, allowing sensors to be calibrated on the bench before being installed out in the field.
3. Digital sensors offer predictive sensor health indicators, built-in troubleshooting tips, and store detailed event logs to aid failure analysis.
4. With the digital cable, the sensors are more robust against ground loops, vibration, and EMI.
5. Rosemount digital pH sensors are IP67/IP68 rated to protect against dust and water ingress.
6. The new digital platform offers interoperability with one transmitter (Rosemount 1058) that supports all Rosemount digital sensors.
7. Sensor labels are now adhered to the backend of the sensor board housing and feature QR codes for easy sensor identification and reordering.

Conclusion

This comparative evaluation clearly demonstrates that the Rosemount 396A Digital Anti-Coating pH/ORP Sensor delivers significant advantages over its traditional analog counterparts. Through accuracy testing, long-term pressure and temperature runs, poisoning resistance assessments, and customer field trials, the Digital 396A outperformed analog sensors, maintaining improved performance and reliability in challenging environments.

For Rosemount 396A ordering information, please reference the 396A Product Data Sheet.

For more information related to the Rosemount Liquid Digital Platform, please visit the Liquid Digital Campaign Page

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