White Paper

Honeywell

Building a Better Ammonia Sensor

A new and improved approach to ammonia gas detection

Building a Better Ammonia Sensor

One of the most common industrial chemicals, ammonia (NH_3) is widely used as a refrigeration gas for cold storage facilities, blast freezers, and other areas in food and beverage plants. As a refrigerant, ammonia offers several advantages. The gas is abundant and extremely efficient in refrigeration systems, requiring less energy per BTU. In addition, its low infrared (IR) absorption profile translates into zero global warming potential.

As a result, ammonia is the preferred, low-cost, environmentally friendly refrigerant for industrial food processes, cold storage and pharmaceutical applications.

However, because ammonia is highly corrosive, it poses a serious health risk. In the U.S., for example, exposure limits from the Occupational Safety and Health Administration range from 25 to 50 parts per million (ppm). In addition, ammonia gas leaks create significant operational risk through their potential for explosions, fire and food spoilage.

Ammonia's low IR absorption profile makes it difficult for conventional, low-cost IR detectors to accurately read and detect low-ppm gas levels. In addition, sensors often face significant challenges in cold storage and food processing applications.

Ammonia sensors fall into two broad categories: solid-state and electrochemical. Solid-state sensors are prone to false alarms in difficult conditions. Electrochemical sensors are the most effective way to monitor low-level NH_3.

Unfortunately, current electrochemical sensors rely on liquid electrolytes that can rapidly evaporate. Some standard electrolytes are aqueous and, therefore, evaporate very quickly in extreme environments. Others are petroleum-based and, even though they last longer, can be continually stressed in refrigerated environments by sharp changes in temperature and humidity.

"The EC-FX is designed specifically for the engine rooms, processing areas, and blast freezers that make up the challenging applications found in most cold storage facilities."

Challenging Applications

The most common challenges in ammonia sensing include:

- **Refrigerated storage and blast freezers.** In conventional freezers, chillers, spiral freezers and other cold-storage areas, electrolytes must contend with extremely low temperatures along with changes in humidity, due to doors opening and closing, along with periodic, high-pressure washings. In blast freezers, similarly, sensors face rapid reductions in temperature, along with changes in humidity during hot-water washdowns, which can reduce the life of some sensors and challenge their accuracy.

  In addition, as the electrolyte dissipates, the sensor's gain — or level of sensitivity — must be increased. However, the elevated gain can also increase the propensity for false alarms, particularly during sudden humidity changes.

- **Engine rooms.** These areas — usually hot, dry and with high levels of background ammonia — present a different challenge. Engine rooms can quickly deplete the electrolytes in standard ammonia sensors, shortening their lifespans and impacting their accuracy.

Next-Generation Ammonia Detection

Responding to the need for a resilient, long-lasting ammonia sensor, Honeywell Analytics has engineered a new sensor — called the EC-FX — for use in our new EC-FX-NH3 transmitter, which is an evolution of our Manning EC-F9-NH3. This technological breakthrough uses a proprietary, non-evaporative electrolyte to offer numerous advantages over the standard formulation:

- **Longer lifespan and lower costs.** The sensor's thicker, higher-viscosity electrolyte lasts two to three years in engine rooms and up to four years in refrigerated areas. That's up to 18 months longer than most other ammonia sensors.
- **Responsiveness.** The new sensor reacts quickly to ammonia gas in both hot and cold environments, without false alarms.
- **Accuracy and stability.** The sensor maintains sensitivity, accuracy and a more consistent linear response — even after exposure to NH_3 gas and extreme fluctuations in temperature and humidity.

Rigorous Testing

> "The EC-FX should define quality and reliability for the industrial refrigeration industry."

Rigorous Testing

The above findings are based on a series of tests that compared the new, non-evaporative electrolyte to the industry standard. In October 2013, Honeywell Analytics tested both electrolytes in coordination with the Ammonia Safety & Training Institute at Fort Ord, in Northern California. We compared the performance of EC-F9 transmitters featuring the new electrolyte with the performance of gas detectors containing sensors that are traditionally used to monitor ammonia gas.

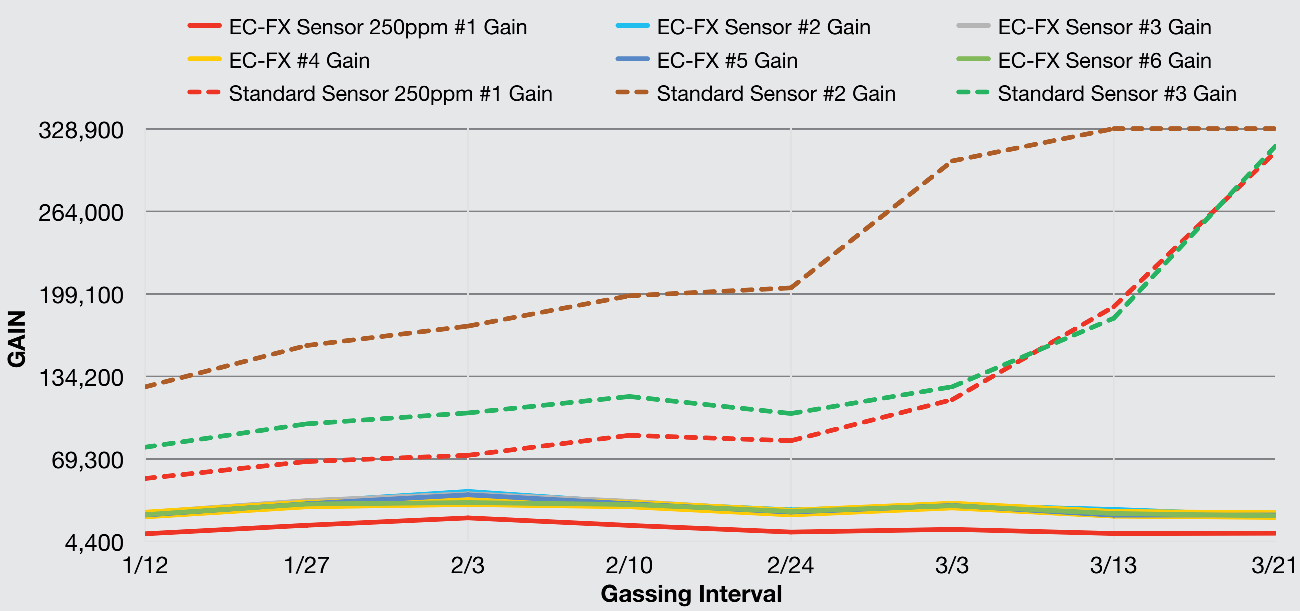
We spanned two of each sensor type to 100 ppm (NH_3 mixed with air) and one of each to 250 ppm. We then placed both types on the floor and on a shelf in a closed concrete room (30 by 30 feet) and exposed the sensors to approximately 15 pounds of NH_3, raising gas concentrations above 70,000 ppm.

During the test, the standard sensors degraded, and some of the detectors stopped reporting gas, having used up their entire electrolyte reservoir. By contrast, all the new EC-FX sensors, with the non-evaporative electrolyte, continued to accurately report ammonia.

Gas exposure reduced sensitivity in the standard sensors, significantly increasing their gain. However, the sensors with the non-evaporative electrolyte showed only modest increases in gain, making them less susceptible to false alarms.

After the test, when the sensors were brought back to the lab, the electrolytes in the standard sensors had almost completely dissipated, making them difficult to calibrate.

Figure 1 **EC-FX vs. Standard Sensor Gain Trends**



However, the reformulated sensors continued to function well, with only minimal degradation. In the real world, the standard sensors would need to be replaced, while the EC-FX sensors would simply have to be recalibrated and returned to the transmitter.

Subsequent tests showed conclusively that the electrolyte in the standard sensors was consumed and the electrodes oxidized when exposed to large amounts of ammonia. However, in the non-evaporative sensors, the electrolyte handled more iterative reactions to generate free electrons. This steady signal alleviated the need to increase gain. ***See Figure 1.***

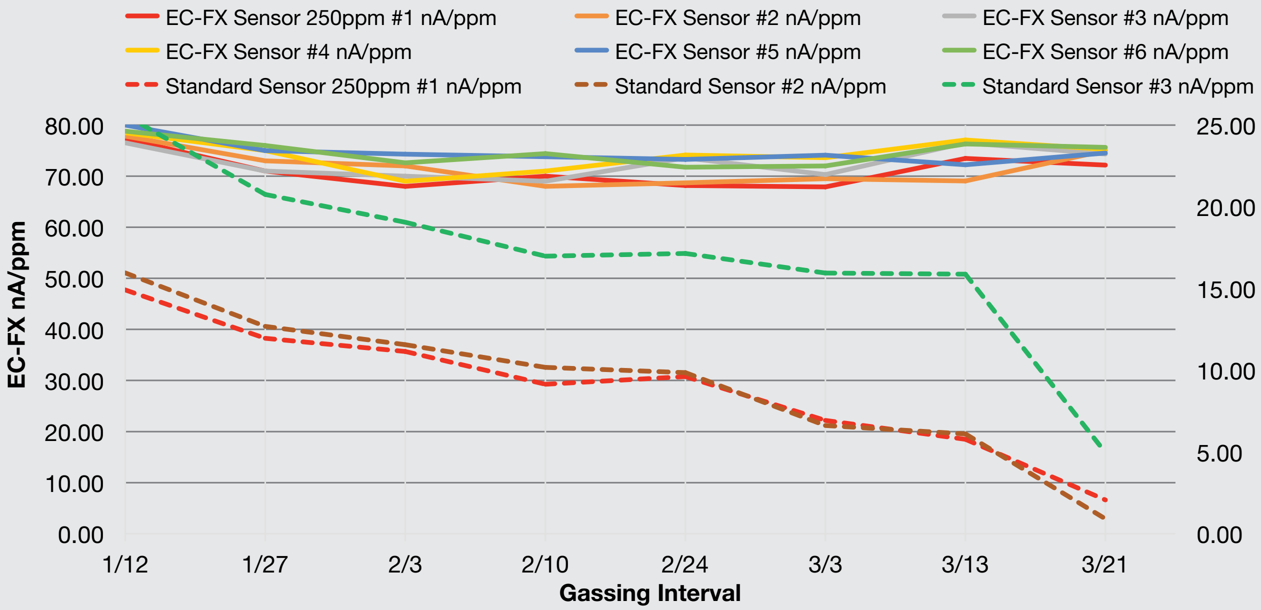
Engine Room Performance

To predict performance in engine and mechanical rooms, Honeywell Analytics conducted laboratory tests that exposed both sensor types to 20 to 30 ppm ammonia gas, at 140 degrees and 2 percent humidity for 11 weeks — conditions far more extreme than the typical. One of each sensor type was spanned to 250 ppm (NH_3 mixed with air) and the rest to 100 ppm.

While the standard sensors lost virtually all sensitivity, the non-evaporative sensors retained 95 percent of their capacity. Their output only declined, on average, from 76.5 to 70 nanoamps per ppm. Because the standard sensors lost so much sensitivity, their gain was boosted to the maximum. In addition to being at maximum gain, the standard sensors could no longer span to 20mA. However, because the reformulated sensors kept their sensitivity to ammonia, they retained significant gain headroom. ***See Figure 2.***

Figure 2

EC-FX vs. Standard Sensor nA/ppm Trend



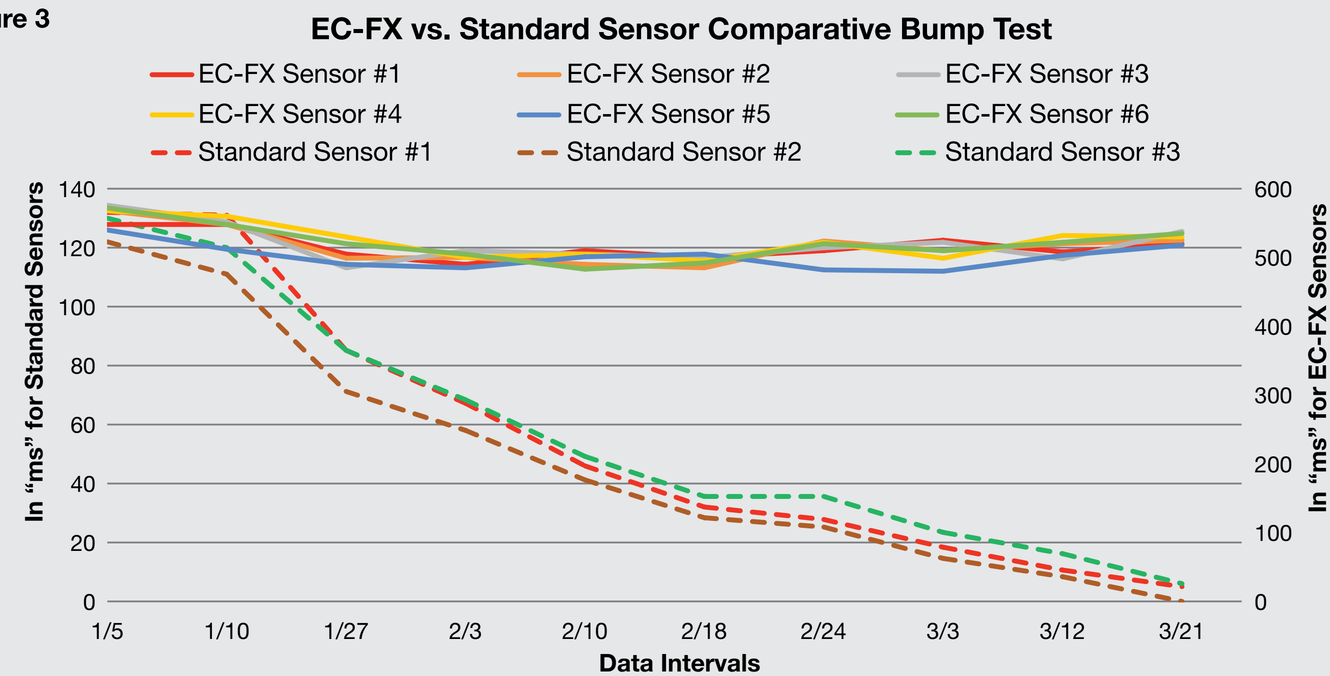
We also evaluated the new electrolyte's viscosity and electrical integrity in EC-F9 bias bump tests. During the bump tests, we applied a brief pulse to the sensing electrode to reduce free electrons. A healthier electrolyte will allow the sensor to bounce back faster from this imbalance.

In standard sensors, the electrolyte dries up as it ages or is exposed to hot, dry conditions, which impairs the sensor's response to NH_3. By comparison, the non-evaporative sensor retained both its electrolyte reservoir and its capacity to accurately detect ammonia gas. The Honeywell Analytics non-evaporative electrolyte showed almost no change in capacity during a bump test. Overall, the sensors with the reformulated electrolytes lost about 5 percent of their capacity, while the standard sensors lost about 99 percent. ***See Figure 3.***

Blast Freezer Performance

Honeywell Analytics also investigated the sensors' performance when faced with sudden, sharp humidity changes. Despite massive fluctuations between 5 percent and 99 percent relative humidity (RH) — comparable to those caused by freezer washdowns — the non-evaporative electrolyte performed exceptionally well, recovering significantly faster than the standard electrolyte. Recovery times are critically important, as lengthy down drifts can cause false alarms.

Figure 3

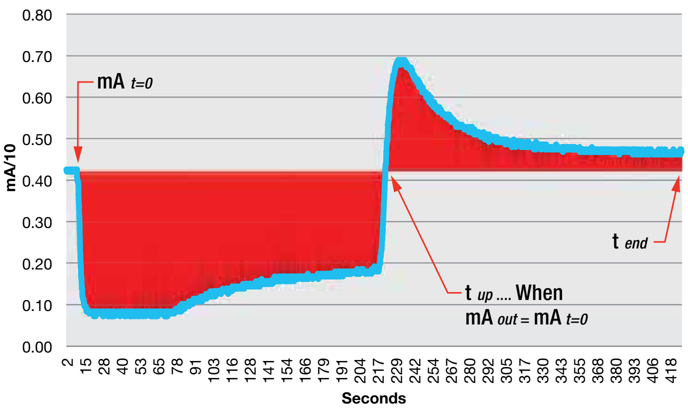


Blast Freezer Performance

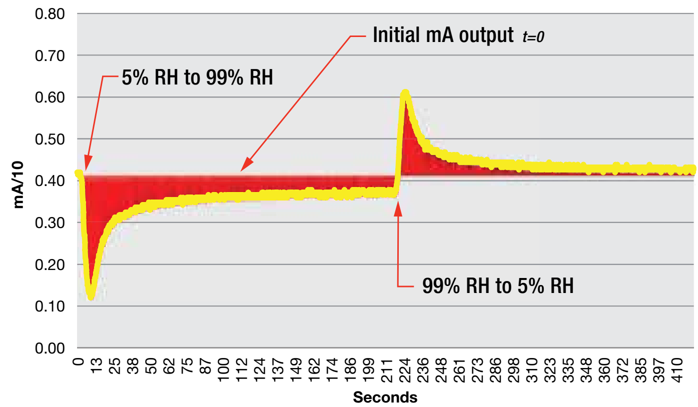
Figure 4: Typical RH Transient Response Curves

The graphs below show the typical responses for a standard sensor versus the EC-FX sensor at a 100ppm span gain setting.

Standard Sensor Transient Humidity Response (Low RH 5%) (High RH 99%) 100ppm span



EC-FX Sensor Transient Humidity Response (Low RH 5%) (High RH 99%) 100ppm span



Compared with standard sensors, the Honeywell Analytics non-evaporative electrolyte recovers much more rapidly when RH instantaneously changes from 5 to 99 percent. The sensor is equally responsive when the humidity instantaneously changes from 99 to 5 percent.

To pinpoint sensor recovery times amid sudden RH changes, we calculated the amount of energy associated with negative down-drift and positive up-drift. As shown in ***Figure 4***, the standard electrolyte exhibited significant down-drift when transitioning from low to high humidity, followed by significant up-drift when conditions were reversed. The non-evaporative electrolyte showed only minimal deviation, making it less likely to give a false alarm under these extreme conditions.

Definitions:
Testing of the Transient Humidity Response for Each Sensor

+Δ RH Energy: when the RH switches from 5% to 99%. Mathematically: $\int_{t_{down}=0}^{t_{up}} f_{mA}(t)dt$

+Δ RH Peak: the greatest null or negative down-drift from the initial 5% RH resting point.

–Δ RH Energy: when the RH switches from 99% back to 5%. Mathematically: $\int_{t_{up}}^{t_{end}} f_{mA}(t)dt$

–Δ RH Peak: the greatest signal peak or positive up-drift from the 99% RH resting point.

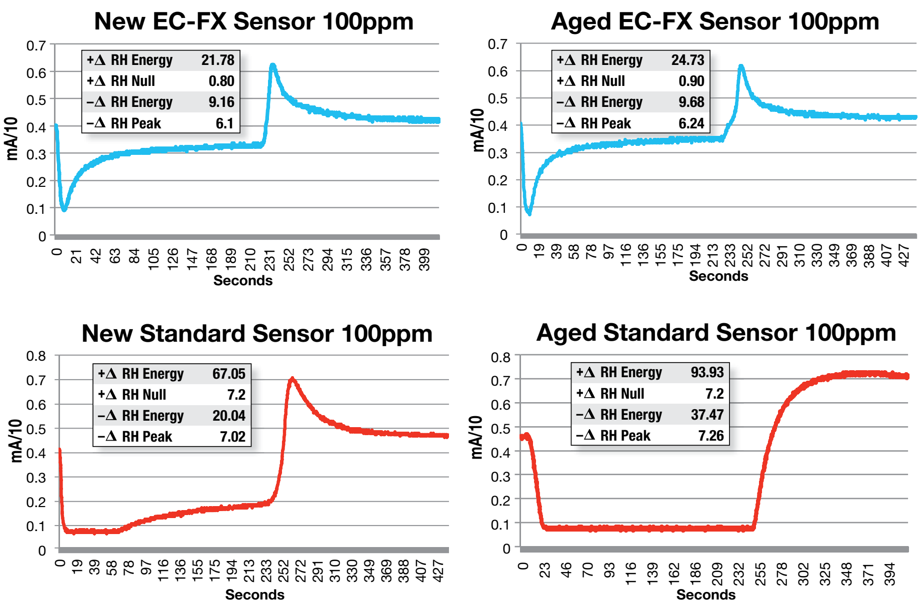
As standard sensors age and the electrolyte weakens, they require increased gain to maintain sensitivity. The RH transient response is directly proportional to these gain increases. Since the EC-FX sensor uses a non-evaporative electrolyte, sensitivity degradation is minimal and, therefore, gain increases are also reduced.

As a result of its robust electrolyte, the EC-FX sensor shows minimal response to RH transients over time. Standard sensors, on the other hand, show dramatic increases in reactivity, which can cause false alarms and fault conditions in a detection system. ***See Figure 5.***

EC-FX-NH3 Detectors

Safety, Reliability and Reduced Costs

Figure 5
Withstanding Fluctuations in Humidity for New and ageing sensors.



Safety, Reliability and Reduced Costs

Ammonia detectors perform an essential role in the challenging environments of cold storage and food processing. Whether they're exposed to the hot, dry conditions in engine rooms or the fluctuating temperature and humidity levels in refrigerators and blast freezers, ammonia sensors must combine accuracy with long life.

At Honeywell Analytics, we recognize this need — and we responded with a breakthrough sensor, featuring a non-evaporative electrolyte that enhances longevity and reliability. This sensor, engineered to Honeywell's highest standards, builds on the longstanding technological excellence of the Manning Systems product line.

In summary, rigorous tests have shown the reformulated electrolyte maintains sensitivity in conditions even harsher than those found in engine rooms, cold storage areas and blast freezers. And while other sensors quickly lose sensitivity after gas exposure, the new sensor bounces back from exposure and resumes accurate detection. Moreover, extended longevity means fewer sensor replacements, which translates to significant cost savings over time.

For more information about Honeywell Analytics' new EC-FX ammonia sensor, please contact **Honeywell Analytics. Call 800.444.9935.**

Find out more
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