Preventing False Alarms in Ammonia Gas Detection Systems

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ABSTRACT

Detection systems are required in all industrial settings that use ammonia as a refrigerant. These systems are a necessary and smart investment that save lives and reduce product loss. However, their effectiveness is greatly reduced if they react with frequent false alarms.

This paper will examine seven factors that cause false alarms and present ideas on ways to prevent them. When false alarms are minimized, your ammonia detection system becomes a trustworthy asset rather than an annoyance.

At 4:00 a.m. on January 14, 2015, three astronauts on the U.S. segment of the International Space Station were abruptly awakened by a piercing alarm announcing an ammonia leak. Because ammonia is a dangerous gas that can cause injury, death, and even explosions, the two Americans and one European were quickly evacuated to the Russian side of the station and kept safe while the alarm was investigated.

Ammonia is used on the International Space Station in a loop system to help control temperature and keep the station’s solar panels from overheating. The alarm was triggered by an increase in pressure in the water loop for one of the cooling systems, signaling a possible ammonia leak. All scheduled research activities were cancelled while the potentially life-threatening and explosive situation was evaluated.

By the end of the day, the ammonia alarm was determined to be false, and the astronauts were returned safely to the US side of the station. Although no one was hurt, the false alarm caused a full day of work to be lost, unnecessary stress, and significant media attention. It is always best to do whatever can be done to prevent false alarms in ammonia gas detection systems.

AMMONIA AS A REFRIGERANT

It is not surprising that ammonia was chosen as the refrigerant for the International Space Station. Because a small amount of ammonia can cool a large area at a relatively low cost, it is a popular choice for industrial refrigeration applications worldwide.

Ammonia has a boiling point of -28°F at normal atmospheric pressure. This is the temperature at which it converts from a liquid to a gas. When liquid ammonia vaporizes, it absorbs heat energy from its surroundings. When ammonia vapor condenses back to a liquid, it releases that heat. A closed loop refrigeration system uses pressure to control the state of ammonia, converting it back and forth from a gas to a liquid. As ammonia is continuously pumped and recirculated through the closed loop system, it absorbs unwanted heat from a space, moves it away from the area and releases it out into the atmosphere. Similar to the way blood flows through the human circulatory system, ammonia does its job without being consumed or diminished. The amount of fluid in the system should always remain the same and any leak signals a problem that must be addressed quickly to avoid serious consequences.

> The best and most simple rule of thumb is to "Keep the ammonia in the system."
>
> Accident Prevention and Response Manual for
> Anhydrous Ammonia Refrigeration Systems, EPA

Ammonia refrigeration was first used in an ice-making machine in 1858 by French engineer, Ferdinand Carre. (Ammonia Refrigeration Systems, ASHRAE 2018) He introduced his new machine at the Universal London Exhibition in 1862 and it quickly became popular around the world. In the United States, the ice made by ammonia refrigeration was used to keep railroad cars cold as they transported food and produce across the continent.

Ammonia is still a popular refrigerant due to its incredible efficiency (a small amount of ammonia can cool a very large space), its abundant supply (it occurs naturally in the environment and is easy to produce commercially), its low price compared to man-made refrigerants, and its predictable behavior.

While CFC, HCFC, and HFC refrigerants are being banned and phased out around the world due to environmental concerns, ammonia is seen as a good natural alternative because it has a global warming potential of zero and an ozone depletion potential of zero.

THE IMPORTANCE OF DETECTION

Although there are many reasons to choose Ammonia as a refrigerant, there are safety risks that must be assessed. Ammonia is toxic and can become explosive or flammable in certain situations. Because ammonia readily dissolves in water, it is attracted to the mucous membranes in the nose, eyes, mouth and throat where it causes damage at high levels. At low levels, it causes respiratory irritation and burns. At high enough concentrations it can cause death within minutes. Contact with liquid ammonia will cause severe frostbite and 3rd degree caustic burns.

Levels of ammonia in the air are measured in parts per million (ppm). Unlike smoke detectors which only announce the presence of smoke in the air, ammonia detectors must not only detect the presence of ammonia, but also measure the amount so that an appropriate response can be taken. The amount of ammonia in the air must be monitored so that leaks can be caught early and proper action can be taken to avoid damage to people and property.

CONSEQUENCES OF AMMONIA EXPOSURE

Level of Ammonia	Symptoms
5-10 ppm	Unpleasant, sharp odor is detectable by the human nose, but no adverse health effects.
25 ppm	The concentration at which a worker can be exposed to for a normal 40 hour work week without adverse effects.[1]
35 ppm	Workers should be able to withstand a 15-minute exposure with no ill effects. [2]
50 ppm	Irritation to the eyes, nose and throat after 2 hours of exposure.[3]
100 ppm	Rapid eye and respiratory tract irritation. [3]
250 ppm	Tolerable (but uncomfortable) by most people for 30-60 minutes. [3]
300 ppm	Immediately Dangerous to Life and Health. A person can survive at this level for 30 minutes without a respirator and without any escape-impairing or irreversible health effects, but it is irritating.[4]
700 ppm	Immediately irritating to eyes and throat. [3]
1500 ppm	Pulmonary edema, coughing, laryngospasm. Pulmonary edema occurs when fluid collects in air sacs of the lungs, making it difficult to breathe. [3]
2500-4500 ppm	Fatal within 30 minutes of exposure. [3]
5000+ ppm	Rapidly fatal due to airway obstruction, may also cause skin damage. [3]
Liquid ammonia	Contact causes Frostbite and caustic burns. Immerse affected part in warm water.

[1] Threshold Limit Value – Time Weighted Average (TLV-TWA) Determined by the American Congress of Governmental Industrial Hygienists (ACGIH)

[2] ACGIH Short term exposure limit (STEL)

[3] Public Health England, Ammonia Toxicological Overview

[4] Immediately Dangerous to Life and Health (IDLH) Determined by the National Institute of Occupational Safety and Health.

In addition to the danger posed to human health, exposure of food to ammonia also should be avoided. Due to ammonia's affinity to water, ammonia molecules will be quickly absorbed by most foods and they will be instantly ruined. Early leak detection and mitigation can prevent product loss and property damage.

Even though ammonia is “self-alarming” and the distinctive, unpleasant smell is noticeable well before a dangerous level is reached, one should not rely solely on the human nose for an adequate detection system. Rather, a mechanical system should be implemented because a person may not always be present in the facility. Furthermore, the human nose may be able to detect the presence of ammonia, but it cannot measure the exact amount. A mechanical detection system also has the advantage of taking automatic, almost instant action, such as turning on fans, opening vents, and shutting down equipment without any human delay.

MINIMIZING FALSE ALARMS

A good detection system is essential for the safety of everyone working in facilities that use ammonia. In addition to protecting people, a detection system also protects the food that is produced in these facilities from contamination by ammonia. It also protects the facility itself from damage that could be caused if an ammonia leak leads to an explosion.

However, safety will be compromised if the system sets off frequent false alarms. False alarms are a problem when they stop production, require unnecessary evacuations, or call in managers at all hours of the night. As workers experience the inconvenience, frustration, and loss of productivity from alarms that turn out to be inaccurate, they will begin to ignore them, stop responding to them, and sometimes even turn off the detection system completely. This increases the chance of a real leak being missed and severe damage being done.

Careful consideration should be given to the choice, installation, and maintenance of a detection system that has been designed specifically to detect ammonia leaks while minimizing false alarms. Below is a list of common causes for false alarms and what can be done to minimize each cause.

Sensor Technologies

Selecting the right technology for the environment you are placing the sensor is an import decision that will affect the number of false alarms you receive. Here is some information to help you understand and choose the best type of sensor for your specific application.

Electrochemical

Chemical reaction with target gas produces a small current proportional to the gas concentration.

Pros
- Alarm range: 10-1,000 ppm
- Very specific to NH3
- Medium cell life (3-4 years)

Cons
- Loses sensitivity over time
- Can fail silently if cell is not monitored.

Best Uses
- Compressor rooms
- Refrigerated rooms
- Rooftop units
- Processing rooms

E.C.

Catalytic Bead

A pair of detector elements (one passive and one active) catalyze the oxidation of gas, generating heat and changing its resistance.

Pros
- Alarm range: 1,000-20,000 ppm
- Relatively inexpensive
- Long life (5+ years)

Cons
- Will respond to high levels of other combustible gases
- Useful for high concentrations only

Best Uses
- Compressor rooms
- Vent lines

C.B.

Solid State

A heated semiconductor rapidly changes internal resistance when it comes in contact with ammonia.

Pros
- Alarm range: 150-10,000 ppm
- Long life (5+ years)
- Inexpensive

Cons
- Non-specificity to NH3 causes false alarms
- Non-linear
- Poor accuracy & repeatability

Best Uses
- Not recommened because of tendency to false alarm at the presence of common gases

S.S.

Infrared

Consist of an IR source, detector, and optical filter and measures light absorption at specific wavelengths.

Pros
- Alarm range: 5,000-20,000 ppm
- Ammonia specific

Cons
- Non-replacable element
- Use for high concentrations only
- More expensive

Best Uses
- Compressor rooms

I.R.

Photoionization

Breaks molecules into positively charged ions with high-energy UV photons, producing an electric current.

Pros
- Fast response/ recovery times
- Good for low ppm detection

Cons
- Expensive
- Short sensor life
- Broad spectrum- smells all VOC's

Best Uses
- Only good for portable detection units

P.I.D.

CAUSES OF FALSE ALARMS

1. **Mismatch of sensor technology to the environment and detection range.**

   Use the table above to determine the best sensor type for your specific situation. Choose the sensor technology that is best suited for the application, and make sure it can reliably detect at the required alarm set points. Sometimes choosing multiple sensor types for a particular room is necessary to achieve a wide range of alarm set points. Talk to your sensor manufacturer's application engineers to select the best sensor type for your specific situation. They have seen it all and can be the difference between extreme success and years of pain.

2. **The sensor reacts to a gas that is not ammonia.**

   Not all sensor technologies are ammonia specific. There are many gases that can cause false readings on an ammonia sensor, and some sensor technologies are better than others. Cross sensitives to carbon monoxide, and hydrogen sulfide are common, as well as sensitivities to cleaning chemicals. If off-gassing is causing issues, consider switching sensor technologies. Check with the sensor manufacturer on cross-sensitivities and consider testing a demo before purchasing.

3. **The sensor reacts to moisture and condensation.**

   Refrigerated spaces in the food industry can be very challenging to ammonia detectors. This is not only due to their extreme temperature and humidity changes, but also how fast the change occurs. An area with a large amount of refrigeration can very quickly remove all moisture from the air, causing a spike in the signal which results in a false alarm. High humidity or wet areas can also be the cause of false alarms for some detectors. Detectors should be designed to perform in the presence of high moisture and extreme humidity excursions. Features such as potted circuitry and built-in heater will keep the units dry, protected and performing properly.

4. **The sensor reacts to extreme temperature fluctuations.**

   Going from -40°F directly into defrost mode can cause an alarm due to the temperature and humidity change. Extreme temperature excursions are common in industries such as cold storage and food processing. When choosing a detector, make sure it meets the temperature requirements and has the software/hardware to sustain a consistent reading.

5. **Damage to the sensor by cleanup crews.**

   Sensor elements can give a false reading or be damaged permanently when being hit directly with water. If water or chemicals are likely to be sprayed onto the sensor element, consider a model that limits exposure from such an incident. The sensor element may need to be housed inside an enclosure, or protected by a splash shield to prevent issues.

6. **Incorrect alarm set points can cause a false alarm.**

   When choosing alarm set points, it is important to consider the range of the sensor. Keeping alarm set points at or above 10% of the full scale of the detector is a good rule of thumb. For instance, if your goal is to detect 25ppm of ammonia, choose a detector with a range no higher than 0-250 ppm. Trying to detect 25 ppm with a high range, 0-20,000 ppm detector will tend to cause a false alarm. The lowest alarm set point for a 0-20,0000 ppm detector would be 2,000 ppm (10% of full-scale). Planning out alarm set points and choosing the correct range of detector before purchasing can resolve this issue.

7. **The sensor reacts to electrical interference.**

   To avoid electrical interference, use proper cables with shielding and drain wire. Avoid running sensor cables in the same conduit as AC cables. To prevent electrical interference, keep sensor and wire runs away from mercury vapor lights, variable speed drives, and radio repeaters. Applying a short time-delay to an alarm relay can also eliminate reactions to sudden signal spikes.

WHEN CHOOSING A DETECTION SYSTEM, BE SURE TO:

- Ask about the sensor technology being used and make sure it is the best choice for your needs.
- Evaluate how the sensor will respond to:
    - Off-gassing. Is the sensor specific to ammonia?
    - Moisture, condensation and spray downs.
    - Extreme temperature fluctuations.

WHEN INSTALLING THE SYSTEM, BE SURE TO:

- Mount the detectors at a height and location recommended by the manufacturer.
- Use shielded wiring.
- Don’t pull detector wires through the same conduit used for AC electrical wiring.
- Set the detection alarm set points at no less than 10% of the full-range.

MAINTAIN THE SYSTEM BY:

- Calibrating the sensors on a regular schedule, according to the manufacturer’s recommendation.
- Replacing sensor elements as needed, following the recommendations of the manufacturer.
- Keeping a detailed record/log of all calibrations.

CONCLUSION

Not all false alarms cause the level of difficulty that was experienced on the International Space Station, but all should be avoided whenever possible. When choosing, installing, and maintaining your gas detection equipment, use the guidelines above to avoid the danger, cost and inconvenience associated with frequent false alarms. By taking steps to minimize false alarms, your detection system will become your valuable and trustworthy ally.

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