

Ammonia Cracking

A practical guide to ammonia cracking, covering the reader intent, the relationship to ammonia cracking, key evaluation criteria, common risks, and the information the intended project audience should confirm before taking the next step.



levelmeter.org

Main topic: Main Page

<https://www.level-meters.com/>

Ammonia cracking has emerged as a cornerstone technology in the transition toward a hydrogen-based energy economy. As industries seek efficient ways to store and transport hydrogen, ammonia (NH₃) serves as an ideal high-density carrier. However, the process of extracting hydrogen from ammonia—known as ammonia cracking or ammonia decomposition—requires precise process control and robust instrumentation to ensure safety, efficiency, and purity.

In industrial settings, managing the liquid ammonia feedstock and the subsequent separation of gases involves complex level measurement challenges. From high-pressure storage tanks to secondary separators, selecting the right measurement technology is essential for operational stability. This guide explores the technical principles of ammonia cracking, the critical role of level instrumentation, and practical selection criteria for engineering professionals.

| Understanding the Principles of Ammonia Cracking

Ammonia cracking is the chemical process of decomposing anhydrous ammonia into its constituent parts: nitrogen and hydrogen. The thermochemical reaction is represented as:



This reaction is endothermic, meaning it requires a significant input of heat to break the strong nitrogen-hydrogen bonds. Typically, the process occurs in a reactor (cracker) at temperatures ranging from 600°C to 900°C, depending on the catalyst used. Common catalysts include nickel-based materials, though precious metals like ruthenium are employed in high-efficiency, lower-temperature applications.

| The Process Chain

1. **Feedstock Storage:** Liquid ammonia is stored in pressurized vessels or refrigerated tanks. Maintaining accurate levels here is the first step in process control.
2. **Vaporization:** Liquid ammonia is heated to its gaseous state before entering the reactor.

3. **Decomposition:** The gaseous ammonia passes over the catalyst bed at high temperatures, where it splits into H_2 and N_2 .
4. **Purification:** The resulting gas mixture (typically 75% hydrogen and 25% nitrogen) may contain trace amounts of unreacted ammonia. Scrubbing or Pressure Swing Adsorption (PSA) is used to achieve the required hydrogen purity.
5. **Separation and Condensation:** In some systems, residual ammonia or water used in scrubbing must be separated in flash tanks or knock-out drums, where level measurement is critical to prevent liquid carryover into downstream components.

| Measurement Principles for Ammonia Applications

Before selecting specific instruments, it is vital to understand the physics behind the measurement technologies used in ammonia cracking plants. Ammonia presents unique challenges, including its toxicity, corrosive nature toward copper-based alloys, and its dielectric properties.

| Radar Level Measurement (ToF)

Radar level meters operate on the Time-of-Flight (ToF) principle. The device emits high-frequency electromagnetic pulses (typically in the 26GHz or 80GHz range). These pulses reflect off the surface of the liquid ammonia and return to the sensor. The distance is calculated based on the time interval between emission and reception.

Non-contact Radar: Ideal for ammonia because the sensor does not touch the liquid. However, ammonia has a relatively low dielectric constant ($\epsilon_r \approx 15$ to 20 at boiling point), which means the reflection is weaker than that of water. High-frequency 80GHz radar is preferred for its narrow beam and ability to handle low-dielectric liquids.

Guided Wave Radar (GWR): Uses a physical probe to guide the pulse. This is highly effective for ammonia because the concentrated energy of the pulse allows for accurate measurement even with low dielectric constants and turbulent surfaces.

| Magnetic Level Gauges

Magnetic level gauges work on the principle of buoyancy and magnetic coupling. A float containing a permanent magnet sits on the liquid surface inside a bypass chamber. As the liquid level rises or falls, the float moves accordingly. Outside the chamber, a series of magnetic flags or a transmitter senses the position of the float.

This is a preferred method for ammonia storage because it provides a clear visual indication without requiring power, and the hermetically sealed chamber prevents the escape of toxic ammonia vapors.

| Hydrostatic Level Measurement

This principle relies on the relationship between the pressure at the bottom of a tank and the height of the liquid column. The formula used is $P = \rho \cdot g \cdot h$, where P is pressure, ρ is the density of the liquid, g is gravity, and h is the height. In pressurized ammonia tanks, a differential pressure (DP) transmitter is required to compensate for the gas-phase pressure above the liquid.

| Key Evaluation Criteria for Level Instrumentation

When designing an ammonia cracking system, engineers must evaluate level sensors based on the following process conditions:

| 1. Chemical Compatibility

Ammonia is highly corrosive to copper, zinc, and their alloys (such as brass and bronze). All wetted parts of a level meter—including flanges, probes, and seals—must be constructed from compatible materials, typically 316L stainless steel, PTFE, or Hastelloy. For visual indicators, borosilicate glass with protective coatings is standard.

2. Pressure and Temperature Ratings

Storage of liquid ammonia often occurs at pressures of 10 to 20 bar (1.0 to 2.0 MPa) at ambient temperatures. In refrigerated storage, temperatures can drop to -33°C. The selected instrument, such as those found on the Welk Main Page, must be rated for these specific ranges to prevent seal failure or housing cracks.

3. Hazardous Area Certification

Ammonia is flammable under certain conditions and toxic to human health. Level instruments must carry appropriate explosion-proof (Ex d) or intrinsically safe (Ex i) certifications (ATEX/IECEX) to ensure they do not become an ignition source in the event of a leak.

Selection Table for Ammonia Cracking Applications

Application Point	Recommended Technology	Primary Benefit	Limitations
Bulk Ammonia Storage	80GHz Non-contact Radar	No contact with toxic media; high accuracy.	Requires clear path; affected by heavy foam.
High-Pressure Buffer Tanks	Guided Wave Radar (GWR)	Stable measurement despite vapor fluctuations.	Probe can be affected by buildup or coating.
Visual Monitoring (Bypass)	Magnetic Level Gauge	No power required; clear local indication.	Mechanical parts (float) can get stuck if debris is present.
Flash Tanks / Separators	Level Switches (Tuning Fork)	High/Low alarm redundancy; very reliable.	Point measurement only; no continuous data.
Condensate Collection	Hydrostatic (DP)	Cost-effective for smaller vessels.	Accuracy depends on constant liquid density.

| Installation Considerations and Safety

Proper installation is as critical as instrument selection in ammonia cracking environments. Ammonia's tendency to vaporize and its toxicity necessitate specific installation protocols.

| Sealing and Containment

To prevent leaks, instruments should use dual-seal designs. For radar and hydrostatic transmitters, a secondary glass-to-metal seal is often used to ensure that if the primary process seal fails, the ammonia gas cannot enter the electronics housing or the conduit system.

| Vapor Space Management

In pressurized ammonia tanks, the gas phase can be dense. This density can slightly slow down the speed of radar pulses. While often negligible, for high-precision custody transfer, the radar transmitter should be calibrated to account for the vapor phase's refractive index. For GWR, using a coaxial probe can eliminate the influence of the tank environment and gas phase fluctuations.

| Stilling Wells and Bypass Chambers

For tanks with internal agitators or high turbulence, installing a radar meter inside a stilling well or using a magnetic gauge in a bypass chamber is recommended. This provides a calm surface for measurement and protects the sensor from mechanical stress.

| Limitations and Common Risks

While modern instrumentation is highly advanced, ammonia cracking processes present specific risks that can lead to measurement errors:

Dielectric Shifting: The dielectric constant of ammonia changes with temperature. If using GWR or radar without compensation, a significant temperature swing could result in a level drift of 1-3%.

Bubbling and Boiling: Ammonia boils at a relatively low temperature. Surface boiling can scatter radar signals. In these cases, GWR or ultrasonic sensors with high-gain settings are necessary to maintain a stable signal.

Hydrogen Permeation: In the cracking reactor's output stage, hydrogen atoms can permeate through certain diaphragm materials used in pressure transmitters. This leads to "hydrogen embrittlement" or sensor drift. Gold-plated diaphragms are the industry standard for preventing hydrogen permeation.

Frequently Asked Questions (FAQs)

Q: Why is 80GHz radar preferred over 26GHz for ammonia storage?

A: 80GHz radar has a much narrower beam angle and a higher dynamic range. This allows it to better detect the weak reflections from the low-dielectric surface of liquid ammonia while ignoring reflections from tank walls or internal structures.

Q: Can ultrasonic level sensors be used for ammonia?

A: Generally, no. Ultrasonic sensors rely on sound waves traveling through the air/gas space. Ammonia vapors change the speed of sound significantly based on concentration and temperature, leading to large errors. Furthermore, ammonia can degrade the transducer face of many standard ultrasonic sensors.

Q: How often should magnetic level gauge floats be inspected?

A: In clean ammonia service, floats can last for years. However, an annual check is recommended to ensure no "magnetic sludge" (iron fines) has accumulated on the float, which could increase its weight and affect buoyancy.

Q: Is SIL (Safety Integrity Level) rating necessary for ammonia cracking?

A: Yes. Because ammonia is toxic and the cracking process involves high temperatures and flammable hydrogen, most plants require SIL 2 or SIL 3 rated level switches for overfill protection to comply with functional safety standards (IEC 61508/61511).

| Conclusion

Efficient ammonia cracking is dependent on the precise management of liquid and gas phases. By understanding the underlying measurement principles—whether it be the electromagnetic reflection of radar or the mechanical buoyancy of magnetic gauges—engineers can design systems that are both safe and productive. When selecting equipment, always prioritize chemical compatibility with ammonia and ensure the instrumentation is rated for the specific pressures and temperatures of the cracking cycle. For a comprehensive range of industrial measurement solutions tailored to these demanding environments, professionals should review product options and application support on the Welk Main Page.