

Carbon Capture Technology

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



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Carbon capture technology has transitioned from a niche experimental field to a cornerstone of global industrial decarbonization strategies. For process engineers and facility managers, the successful implementation of Carbon Capture, Utilization, and Storage (CCUS) depends heavily on the precision of process control. Within these complex systems, level measurement plays a critical role in managing chemical solvents, monitoring phase transitions of carbon dioxide (CO₂), and ensuring the safety of high-pressure storage vessels.

As industries such as power generation, cement manufacturing, and steel production integrate carbon capture technology into their operations, selecting the correct instrumentation becomes a matter of both efficiency and safety. This guide examines the principles of level measurement within CCUS frameworks and provides technical insights for selecting the appropriate sensors for these demanding environments.

| The Role of Level Measurement in Carbon Capture

Carbon capture technology typically involves three main stages: capture, transport, and storage. Each stage presents unique challenges for level instrumentation.

1. **Capture (Absorption/Adsorption):** Most commercial systems use amine-based post-combustion capture. Level sensors monitor the height of the amine solvent in absorber and stripper columns. Inaccurate readings here can lead to solvent carryover or pump cavitation.
2. **Compression and Liquefaction:** Captured CO₂ is compressed and cooled into a liquid or supercritical state for transport. Level measurement in these high-pressure separators is vital for maintaining the efficiency of the compression string.
3. **Storage and Utilization:** Liquid CO₂ is stored in large, insulated tanks before being pumped into geological formations or used in industrial processes. Precise inventory management is required to monitor storage volumes and detect potential leaks.

| Core Measurement Principles

Before selecting a device for carbon capture technology applications, it is essential to understand the underlying measurement principles. Each technology interacts differently with the physical properties of CO₂ and the solvents used in the capture process.

| Radar Level Measurement (FMCW)

Frequency Modulated Continuous Wave (FMCW) radar is a non-contact technology that emits a high-frequency signal. The frequency of this signal increases linearly over time. The signal reflects off the material surface and returns to the antenna. The difference in frequency between the emitted and received signal is proportional to the distance.

Relevance to CCUS: Radar is highly effective for liquid CO₂ storage because it is unaffected by pressure and temperature changes. However, liquid CO₂ has a low dielectric constant ($\epsilon_r \approx 1.6$), which means the reflection is weak. High-sensitivity radar sensors with advanced signal processing are required to track the surface reliably.

| Ultrasonic Level Measurement

Ultrasonic sensors emit sound pulses that reflect off the surface of the medium. The time-of-flight is used to calculate the distance.

Relevance to CCUS: These are best suited for atmospheric tanks, such as wastewater sumps or chemical storage for water treatment within the capture plant. They are generally not suitable for pressurized CO₂ tanks because the speed of sound changes significantly with gas density and composition.

| Hydrostatic Pressure Measurement

This principle relies on the relationship between the height of a liquid column and the pressure it exerts at the base of the tank ($P = \rho gh$). By measuring the head pressure and compensating for any vapor space pressure (using a differential pressure transmitter), the level can be calculated.

Relevance to CCUS: Hydrostatic transmitters are robust and widely used in amine tanks. In pressurized CO₂ vessels, a dual-seal differential pressure setup is often required to account for the dense gas phase above the liquid.

| Magnetic Level Gauges (MLG)

Magnetic gauges use a float containing a magnet that moves with the liquid level inside a bypass chamber. This magnet flips external flags or interacts with a magnetostrictive sensor to provide a visual and electronic reading.

Relevance to CCUS: MLGs provide a highly reliable mechanical backup for electronic sensors. They are frequently used on high-pressure separators where visual verification is mandatory for safety protocols.

| Technical Challenges in Carbon Capture Applications

Implementing carbon capture technology introduces several environmental factors that can interfere with standard instrumentation.

| Phase Changes and Supercritical Fluids

CO₂ is often handled near its critical point (31.1°C and 73.8 bar). In this state, the distinction between liquid and gas disappears. Level sensors that rely on a clear interface, such as radar or ultrasonic, may struggle if the CO₂ enters a supercritical state. In such cases, mass-based measurement or specialized density-compensated hydrostatic systems are necessary.

| Solvent Foaming

In amine scrubbing units, the interaction between the flue gas and the solvent can cause significant foaming. If a level sensor cannot distinguish between the foam and the liquid, it may provide a false high reading. Guided wave radar (GWR) or specialized non-contact radar with foam-rejection algorithms are typically preferred for these vessels.

| Material Compatibility

Amine solutions can be corrosive, especially when loaded with CO₂ (rich amine). Level instruments must be constructed from compatible materials, such as 316L stainless steel, Hastelloy, or PTFE-lined components, to prevent premature failure. For a detailed look at material options and instrument specifications, you may visit the Main Page of Welk's technical catalog.

| Selection Criteria for CCUS Level Instrumentation

Selecting the right instrument requires a systematic evaluation of the process conditions. The following table summarizes common recommendations for carbon capture technology components.

Application	Recommended Technology	Key Considerations
Amine Absorber/Stripper	Guided Wave Radar (GWR)	Handles foam and turbulence; requires chemical compatibility.
Liquid CO2 Storage	Non-Contact Radar (80GHz)	Must handle low dielectric constant; high pressure rating required.
High-Pressure Separators	Magnetic Level Gauge	Provides visual redundancy; high pressure and temperature resistance.
Water Treatment Sumps	Ultrasonic	Cost-effective for atmospheric, non-volatile liquids.
Solvent Makeup Tanks	Hydrostatic Pressure	Simple installation; reliable for stable density liquids.
CO2 Pipelines (Scrapers)	Level Switches (Vibrating Fork)	Used for point level detection to prevent liquid carryover into compressors.

Installation Considerations

Proper installation is as important as technology selection. For carbon capture technology applications, the following guidelines should be observed:

- Nozzle Geometry:** For non-contact radar, ensure the nozzle is short and the diameter is sufficient to prevent signal interference from the nozzle walls. For 80GHz radar, smaller nozzles are often acceptable due to the narrow beam angle.
- Stilling Wells:** In tanks with heavy agitation or internal obstructions, installing a radar sensor inside a stilling well can stabilize the surface and amplify the reflected signal, which is particularly useful for low-dielectric liquid CO2.
- Pressure Seals:** High-pressure CO2 is highly diffusive. Level instruments must use high-quality process seals (such as Dual Seal designs) to prevent gas migration into the electronics housing.

4. **Temperature Compensation:** For hydrostatic measurements, ensure the transmitter includes temperature compensation, as the density of both the solvent and the CO₂ will vary with thermal shifts.

| Limitations and Maintenance

While modern instrumentation is highly reliable, every technology has limitations within carbon capture technology workflows.

Radar Limitations: While 80GHz radar is excellent for low-dielectric liquids, extremely heavy condensation on the antenna can attenuate the signal. Integrated air purges or PTFE-faced antennas are often used to mitigate this.

Ultrasonic Limitations: These should be avoided in any pressurized vessel or where the vapor space contains varying concentrations of CO₂, as the sound speed will be unpredictable.

Maintenance: Amine systems can suffer from "amine salts" buildup. Level sensors, especially contact-type sensors like GWR probes or displacement floats, should be inspected periodically for scaling or coating that could affect movement or signal clarity.

| Frequently Asked Questions (FAQ)

Q: Can I use a standard level transmitter for liquid CO₂?

A: Not usually. Liquid CO₂ has a very low dielectric constant and is stored under high pressure. You need a transmitter specifically designed for low-dielectric media and rated for the specific pressure (typically 20 to 60 bar for storage).

Q: How does foaming in amine tanks affect radar sensors?

A: Standard radar may reflect off the top of the foam. Guided Wave Radar (GWR) is often better because the signal can partially penetrate the foam to find the true liquid level, or you can use advanced non-contact radar with "multi-echo" tracking to identify the liquid surface.

Q: What is the benefit of 80GHz radar in carbon capture?

A: The 80GHz frequency allows for a much narrower beam angle (typically around 3 degrees). This makes it easier to install in tanks with internal pipes, ladders, or agitators without receiving false echoes from those obstructions.

Q: Are there specific certifications required for instruments in CCUS?

A: Depending on the region, instruments may need ATEX/IECEx certification for explosive atmospheres (if methane is present) and Pressure Equipment Directive (PED) compliance for high-pressure vessels.

| Conclusion

The success of carbon capture technology relies on the precise integration of various engineering disciplines. In the realm of process automation, level measurement is a fundamental requirement for maintaining the mass balance of the capture process and ensuring the safe containment of captured gases. By understanding the physics of the media and the principles of the sensors, engineers can implement measurement solutions that are both accurate and durable. For further technical specifications and product selection tools, refer to the Main Page for comprehensive industrial instrumentation support.