

Dielectric Constant Table

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



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In the field of industrial level measurement, the dielectric constant (ϵ_r), also known as relative permittivity, is a fundamental physical property that determines the feasibility and accuracy of various sensing technologies. Whether utilizing radar level meters or capacitance-based sensors, understanding the electrical characteristics of the process medium is essential for selecting the correct instrument and ensuring long-term operational reliability.

This guide provides a comprehensive dielectric constant table for common industrial fluids and solids, explains the underlying measurement principles, and offers practical engineering advice for instrument selection and installation.

Principles of Dielectric Constant in Level Measurement

The dielectric constant is a measure of a material's ability to store electrical energy in an electric field. In level measurement, it primarily affects two types of technologies: Radar (both non-contact and guided wave) and Capacitance.

Radar Level Measurement

Radar level meters emit electromagnetic pulses that travel through the vapor space and reflect off the surface of the product. The strength of the reflected signal (the echo) is directly proportional to the dielectric constant of the medium.

High Dielectric Materials ($\epsilon_r > 10$): Products like water or aqueous solutions reflect most of the radar energy, providing a very strong, clear signal.

Low Dielectric Materials ($\epsilon_r < 3$): Hydrocarbons, oils, and certain solvents reflect only a small portion of the radar energy. A significant portion of the signal penetrates the surface, which can lead to weak echoes or, in extreme cases, signals reflecting off the bottom of the tank rather than the liquid surface.

Capacitance Level Measurement

Capacitance sensors treat the tank and the probe as two plates of a capacitor, with the process material acting as the dielectric. As the level rises, the material displaces air (which has a dielectric constant of approximately 1.0). Because the material has a higher ϵ_r than air, the total capacitance increases. The instrument converts this change in capacitance into a level reading. If the dielectric constant of the medium changes due to temperature or composition shifts, the calibration of a standard capacitance probe may drift.

Dielectric Constant Table for Industrial Media

The following table lists the approximate dielectric constants for common materials encountered in industrial processes. These values are typically measured at 20°C (68°F) at standard atmospheric pressure. Note that ϵ_r can vary significantly with temperature and frequency.

Material	Dielectric Constant (ϵ_r)	Category
Vacuum	1.0	Reference
Air	1.0005	Gas
Liquefied Natural Gas (LNG)	1.6 – 1.7	Cryogenic Liquid
Propane (Liquid)	1.6 – 1.9	Hydrocarbon
Gasoline / Petrol	1.8 – 2.0	Hydrocarbon
Kerosene	1.8 – 2.1	Hydrocarbon
Diesel Fuel	2.1	Hydrocarbon
Crude Oil	2.1 – 2.6	Hydrocarbon
Benzene	2.3	Solvent
Toluene	2.4	Solvent

Turpentine	2.4	Solvent
Vegetable Oil	2.5 – 3.5	Food/Oil
Polyethylene (Pellets)	2.3 – 2.5	Solid
Sugar	3.0	Solid
Sand (Dry)	3.0 – 5.0	Solid
Cement (Powder)	4.0 – 6.0	Solid
Anhydrous Ammonia	15.0 – 25.0	Chemical
Ethyl Alcohol (Ethanol)	24.3	Solvent/Alcohol
Methyl Alcohol (Methanol)	33.1	Solvent/Alcohol
Glycerin	47.0	Chemical
Water (Distilled)	80.0	Aqueous
Water (Sea/Tap)	80.0 – 81.0	Aqueous
Sulfuric Acid (98%)	84.0	Acid

For a wider range of industrial measurement solutions and technical specifications, engineers can consult the Main Page of professional instrumentation providers.

Technology Selection Based on Dielectric Properties

When reviewing a dielectric constant table, the primary goal is to determine which measurement technology will provide the highest signal-to-noise ratio for a specific application.

1. Non-Contact Radar (80 GHz and 26 GHz)

Modern high-frequency radar (80 GHz) has significantly improved the ability to measure low-dielectric materials.

Recommended for: Materials with $\epsilon_r > 1.4$.

Considerations: For materials with ϵ_r between 1.4 and 2.0, high-gain antennas or larger lens antennas are often required to focus the beam and capture the faint reflection.

| 2. Guided Wave Radar (GWR)

GWR utilizes a physical probe (rod or cable) to guide the microwave pulse directly to the surface. This reduces signal attenuation and energy dispersion.

Recommended for: Low dielectric liquids ($\epsilon_r < 1.9$), interface measurements, and applications with heavy foam or turbulence.

Interface Measurement: GWR is the industry standard for measuring the interface between two liquids (e.g., oil over water). The upper liquid must have a lower dielectric constant (typically $\epsilon_r < 10$) to allow the radar pulse to pass through it and reflect off the higher-dielectric liquid below.

| 3. Ultrasonic Level Sensors

Ultrasonic sensors rely on sound waves, which reflect off the physical density of the surface rather than its electrical properties.

Recommended for: Applications where the dielectric constant is extremely low or unknown, provided the vapor space is clear of heavy dust or steam.

Limitations: Not suitable for vacuum or high-pressure environments, as sound requires a medium (air) to travel.

| Practical Installation and Evaluation Criteria

When using a dielectric constant table to specify an instrument, engineers must also account for physical process conditions that can alter the effective signal strength.

| Surface Conditions

Turbulence: Agitators and splashing reduce the effective reflection by scattering the radar signal. For low-dielectric fluids, turbulence can make a signal disappear entirely. Using a stilling well or a bypass chamber is often necessary for liquids with $\epsilon_r < 3$ in turbulent tanks.

Foam: Foam can either absorb or reflect radar signals depending on its density and moisture content. If the foam is conductive and thick, it may cause a false high reading. If it is light and airy, the radar may see through it to the liquid surface.

| Temperature and Pressure Effects

The dielectric constant of many liquids decreases as temperature increases. For example, the ϵ_r of water drops from 80 at 20°C to approximately 55 at 100°C. While this change is rarely enough to stop a radar from working on water, it can be critical for hydrocarbons that are already near the lower limit of the sensor's capability.

| Tank Geometry and Obstructions

Internal structures like ladders, heating coils, and pipes create "parasitic" reflections. When measuring low-dielectric materials, these background reflections can be stronger than the actual surface echo. Modern radar software allows for "False Signal Suppression" or "Empty Tank Mapping" to ignore these echoes, but the initial signal from the medium must still be distinguishable.

| Common Risks in Low-Dielectric Applications

1. **Bottom Reflection Interference:** In shallow tanks containing low-dielectric liquids, the radar signal may pass through the liquid, reflect off the metal tank bottom, and return to the sensor. The sensor may interpret the bottom of the tank as the level, or the two signals may interfere. This is often mitigated by using a curved tank bottom or an offset mounting position.

2. Coating and Buildup: On capacitance probes, the buildup of a conductive or high-dielectric material can cause significant measurement errors. For radar, buildup on the antenna (especially for low ϵ_r media) can attenuate the signal. Lens antennas made of PTFE are typically used to minimize adhesion.

3. Vapor Phase Influence: In high-pressure applications (e.g., boiler drums), the dielectric constant of the steam in the vapor space increases. This slows down the radar pulse, leading to a "propagation delay" that makes the level appear lower than it actually is. Specialized GWR probes with gas phase compensation are required for these scenarios.

| Frequently Asked Questions (FAQ)

Q: Can I measure a material with a dielectric constant of 1.2?

A: Standard non-contact radar will struggle with $\epsilon_r = 1.2$. Guided Wave Radar with a coaxial probe or a stilling well is the preferred solution, as it concentrates the signal energy. Alternatively, a displacement-type transmitter or a high-sensitivity ultrasonic sensor may be used if pressure/vacuum allows.

Q: How does the dielectric constant affect the "Dead Zone"?

A: The dielectric constant does not change the physical dead zone (blocking distance) of the sensor, but it does affect the accuracy near the bottom of the tank. For low ϵ_r materials, the "unmeasurable zone" at the bottom of the tank increases because the signal becomes too weak to distinguish from the tank floor reflection.

Q: Does the dielectric constant matter for hydrostatic level transmitters?

A: No. Hydrostatic transmitters measure the pressure exerted by the liquid column, which depends on the liquid's density and height, not its electrical properties. However, density and dielectric constant are often correlated in hydrocarbons.

Q: What is the best way to determine the dielectric constant if it is not in the table?

A: Many modern radar transmitters have a "dielectric estimate" function. By measuring a known physical distance to the surface, the instrument can back-calculate the relative permittivity of the medium. For laboratory verification, a dielectric constant meter can be used on a sample of the fluid.

| Conclusion

Selecting the right level measurement technology requires a balance between the physical properties found in a dielectric constant table and the specific environmental conditions of the process. For materials with high dielectric constants, such as water-based liquids, most technologies will perform reliably. However, for low-dielectric hydrocarbons and solids, engineers must prioritize signal focus and sensitivity, often opting for 80 GHz radar or guided wave solutions. By confirming the ϵ_r and accounting for temperature and turbulence, operators can ensure accurate, maintenance-free level monitoring across their industrial applications.