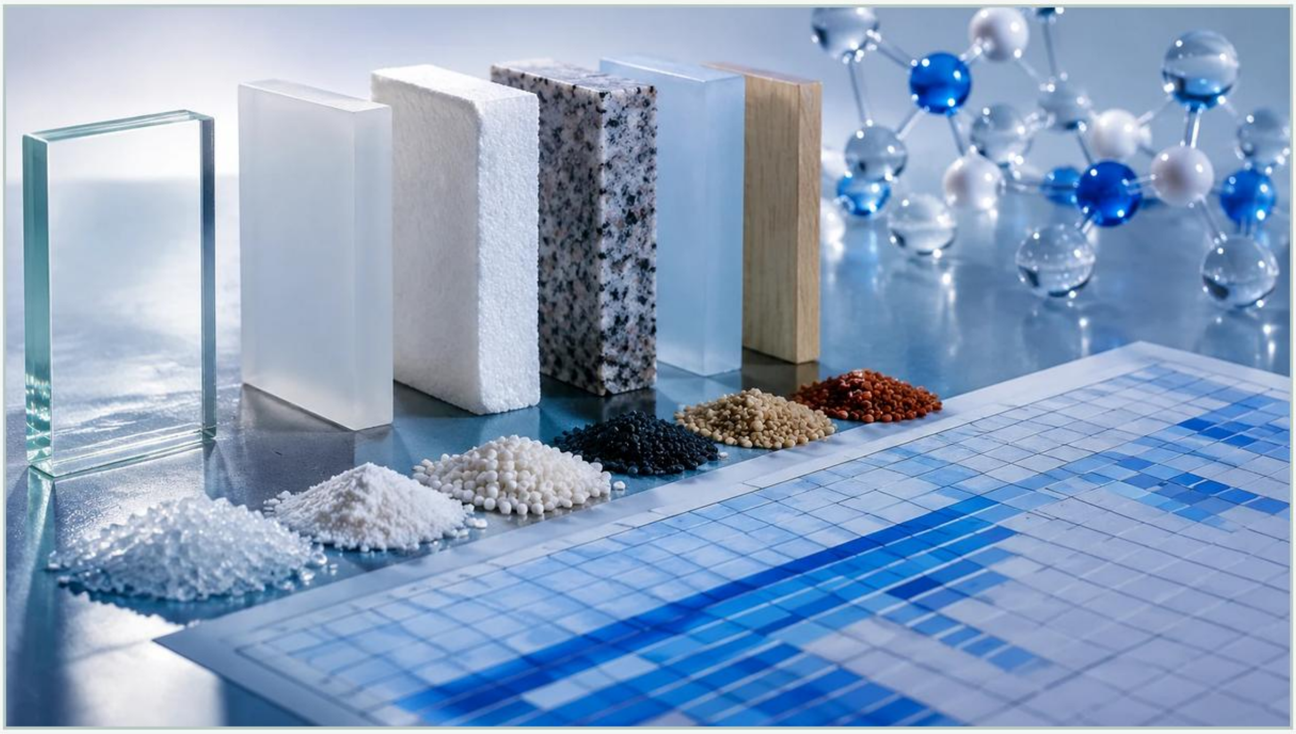
Dielectric Constant Chart

A practical guide to dielectric constant chart, covering the reader intent, the relationship to dielectric constant chart, 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 process control, the dielectric constant (εr), also known as relative permittivity, is one of the most critical physical properties to consider when selecting and calibrating level measurement instruments. Whether utilizing non-contact radar, guided wave radar (GWR), or capacitance-based sensors, the accuracy and reliability of the measurement depend heavily on how the medium interacts with electromagnetic energy. This guide provides a comprehensive dielectric constant chart and explores the engineering principles necessary for successful instrument implementation.

Understanding Dielectric Constant in Level Measurement

The dielectric constant is a dimensionless number that represents the ratio of the permittivity of a substance to the permittivity of free space (a vacuum). In practical terms, it measures a material's ability to store electrical energy in an electric field. For level measurement technologies, this property determines how much of a transmitted signal is reflected back to the sensor and how much is absorbed or transmitted through the medium.

Radar and Guided Wave Radar (GWR) Principles

Radar level transmitters emit high-frequency electromagnetic pulses. When these pulses encounter a change in the dielectric constant—specifically at the boundary between air ($\varepsilon r \approx 1$) and the process medium—a portion of the energy is reflected.

The reflection coefficient (R) is calculated using the following simplified formula for normal incidence:

$$R = \frac{\sqrt{\varepsilon{r2}} - \sqrt{\varepsilon{r1}}}{\sqrt{\varepsilon{r2}} + \sqrt{\varepsilon{r1}}}$$

Where:

$\varepsilon{r1}$ is the dielectric constant of the upper medium (usually air or vapor, approximately 1.0).

$\varepsilon{r2}$ is the dielectric constant of the process material.

A higher dielectric constant results in a stronger reflected signal (echo). For example, water ($εr ≈ 80$) reflects a massive portion of the radar signal, making it very easy to detect. Conversely, hydrocarbons like oil or solvents ($εr ≈ 1.9$ to 2.5) reflect very little energy, requiring more sensitive electronics and specialized antenna designs.

Capacitance Level Measurement Principles

Capacitance sensors treat the process vessel like a large capacitor. The probe acts as one plate, and the tank wall (or a reference ground) acts as the second plate. The process material serves as the dielectric. As the level rises, the air is replaced by the process material. Since most materials have a higher dielectric constant than air, the total capacitance increases proportionally with the level. If the dielectric constant of the material changes due to temperature or composition shifts, the calibration of a standard capacitance probe will drift.

Comprehensive Dielectric Constant Chart

The following dielectric constant chart lists common industrial materials at room temperature (approximately 20°C to 25°C). Note that $εr$ can decrease as temperature increases for many liquids.

Industrial Liquids and Chemicals

Material	Dielectric Constant (εr)	Measurement Difficulty
Vacuum	1.0	N/A
Air	1.0006	N/A
Propane (Liquid)	1.6 - 1.9	High
Hexane	1.9	High
Gasoline / Diesel	2.0 - 2.2	Moderate
Benzene	2.3	Moderate
Crude Oil	2.1 - 2.6	Moderate
Turpentine	2.4	Moderate
Phenol	4.3	Low
Ammonia (Anhydrous)	15 - 25	Low
Acetone	21	Low
Ethanol	24 - 25	Low
Methanol	33	Low
Glycol (Ethylene)	37	Low
Nitrobenzene	40	Low
Water (Pure)	80	Very Low
Sulfuric Acid	84 - 100	Very Low

Solids and Granular Materials

Material	Dielectric Constant (εr)	Notes
Teflon (PTFE)	2.0	Often used for probe insulation
Polyethylene	2.3	Solid pellets
Sand (Dry)	3.0 - 5.0	Varies with moisture content
Sugar	3.0	Granular
Cement (Dry)	4.0 - 6.0	Highly dependent on aeration
Salt	3.0 - 15.0	Varies with purity and moisture
Glass	5.0 - 10.0	Solid
Coal	2.0 - 4.0	Varies by type (Bituminous vs Anthracite)

How Dielectric Constant Influences Instrument Selection

When reviewing product options and application support from manufacturers like Welk, the dielectric constant is the primary filter for technology selection. You can explore a variety of compatible sensors on the Main Page of our technical catalog.

1. High Dielectric Media (εr > 10)

Materials like water, acids, and aqueous solutions provide excellent reflection.

Recommendation: Non-contact radar (80 GHz or 26 GHz) or ultrasonic sensors are ideal.

Advantages: High signal-to-noise ratio, minimal sensitivity to turbulence.

2. Medium Dielectric Media (εr 3 to 10)

Materials like heavy oils, some solvents, and dry solids fall into this category.

Recommendation: High-frequency non-contact radar or Guided Wave Radar (GWR).

Advantages: GWR is particularly effective here because the probe concentrates the electromagnetic energy, ensuring a reliable return signal even with moderate dielectric values.

3. Low Dielectric Media (εr 1.4 to 3)

This category includes liquefied gases (LNG/LPG), light hydrocarbons, and plastic pellets.

Recommendation: Guided Wave Radar with a coaxial probe or high-sensitivity non-contact radar with a large horn antenna.

Consideration: For extremely low dielectrics, GWR can use "End of Probe" (EOP) algorithms. If the signal from the surface is too weak to detect directly, the instrument measures the time-of-flight to the end of the probe; the signal slows down as it passes through the medium, allowing the level to be calculated based on the delay.

Practical Selection Table

Technology	Minimum εr (Standard)	Minimum εr (High Sensitivity)	Best Use Case
Non-Contact Radar	1.9	1.4	Corrosive liquids, large tanks
Guided Wave Radar	1.4	1.2	Small vessels, interface measurement
Capacitance	2.0	1.5	High pressure/temperature, simple liquids
Ultrasonic	N/A	N/A	Independent of εr (uses sound)

Note: Ultrasonic sensors are unaffected by dielectric constants but are limited by vapor pressure, foam, and vacuum conditions.

Installation and Engineering Considerations

Signal Loss and Turbulence

A low dielectric constant combined with surface turbulence can cause signal loss. In these scenarios, a stilling well or a bypass chamber (magnetic level gauge combination) is recommended. The stilling well acts as a coaxial guide for the radar signal, preventing energy dispersion and smoothing the surface.

Interface Measurement

One of the most powerful applications of GWR is measuring the interface between two liquids (e.g., oil over water). For this to work:

1. The upper layer must have a lower dielectric constant than the lower layer.

2. The upper layer dielectric constant must be known and relatively constant.

3. The difference between the two dielectric constants should be at least 10.

Probe Coating and Buildup

In capacitance measurement, conductive buildup on the probe can be interpreted as a level increase. Modern Welk transmitters often include "active shield" technology to ignore the effects of coating. For radar, buildup on the antenna can attenuate the signal, particularly for low $εr$ media where the signal is already weak.

Limitations and Challenges

Temperature and Pressure Effects

The dielectric constant is not a fixed physical constant; it is sensitive to environmental changes.

Liquids: Generally, as temperature increases, the dielectric constant decreases. This is due to increased molecular motion disrupting the alignment of dipoles.

Gases/Vapors: At high pressures, the dielectric constant of the vapor space above the liquid increases. In steam applications, this can cause a significant measurement error (up to 20% in some cases) because the radar signal travels slower through the dense vapor than through air. Specialized "Gas Phase Compensation" probes are required for high-pressure saturated steam.

Foam

Foam can behave in three ways depending on its density and the dielectric constant of the base liquid:

1. Transparent: Radar passes through the foam and reflects off the liquid (common with light, dry foam).

2. Reflective: Radar reflects off the top of the foam (common with dense, wet foam).

3. Absorptive: The foam absorbs the signal, leading to a loss of echo.

In foaming applications, ultrasonic sensors or mechanical float-based systems may be more reliable than radar.

Frequently Asked Questions (FAQs)

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

A: Yes, but it requires specific hardware. A Guided Wave Radar (GWR) with a coaxial probe is the most reliable method for materials with $εr$ as low as 1.2. The coaxial design prevents signal divergence and maximizes the return energy.

Q: How does moisture affect the dielectric constant of solids?

A: Moisture has a massive impact. Since water has a dielectric constant of 80, even a small increase in moisture content in a solid like sand (dry $εr ≈ 3$) can raise the effective dielectric constant to 10 or 15. This usually makes the level easier to measure for radar but can cause calibration errors for capacitance-based systems.

Q: Why is my radar meter losing the signal when the tank is agitated?

A: Agitation creates waves and turbulence. If the material has a low dielectric constant, the already weak reflection is scattered away from the receiver. Installing a stilling well or switching to a Guided Wave Radar probe will solve this by keeping the signal contained and the surface within the well calm.

Q: Does the dielectric constant affect ultrasonic level meters?

A: No. Ultrasonic sensors use sound waves, which reflect based on changes in material density (acoustic impedance). However, ultrasonic sensors are affected by air temperature, pressure, and heavy vapors, which radar typically ignores.

Q: Do I need to recalibrate my radar meter if I change the process fluid?

A: For non-contact radar, if the new fluid still provides a sufficient echo, you generally do not need to recalibrate the distance measurement. However, for Guided Wave Radar (especially in interface or EOP applications) and capacitance probes, a change in dielectric constant requires a full recalibration to maintain accuracy.

For further technical specifications or to request a customized level measurement solution for your specific dielectric requirements, please consult the engineering resources available on our Main Page.