

CHOOSE A RIGHT LEVEL TECHNOLOGY FOR YOUR APPLICATION

TOP 50 QUESTIONS & ANSWERS



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Choosing the Right Level Technology

Top 50 Interview Questions for Level Measuring Applications

1. What is the fundamental difference between point level and continuous level measurement?

This is the most basic distinction in level measurement, defining the type of output and control you can achieve.

Point Level Measurement

- **Function:** Acts like a switch. It indicates the presence or absence of material at a specific, predetermined point in a vessel.
- **Output:** A discrete signal (e.g., relay contact, on/off).
- **Typical Use Cases:**
 - **High-level alarm:** Prevents overfilling.
 - **Low-level alarm:** Prevents pumps from running dry.
 - **Pump control:** Starts or stops a pump to keep the level between two points (using two switches).
- **Example Technologies:** Vibrating fork, float switch, capacitance probe.

Continuous Level Measurement

- **Function:** Provides a measurement of the level over its entire range, from 0% to 100%.
- **Output:** An analog signal (e.g., 4-20 mA) or digital value that is proportional to the level.
- **Typical Use Cases:**
 - **Inventory Management:** Knowing the exact volume of material in a tank.
 - **Process Control:** Maintaining a precise level as part of a control loop.
 - **Monitoring:** Tracking fill/drain rates.
- **Example Technologies:** Guided wave radar, ultrasonic, differential pressure, magnetostrictive.

2. What are the most critical application parameters you need to know before selecting any level technology?

Before considering any specific instrument, you must create a complete profile of the application. The acronym "STAMP" is a good starting point.

Critical Application Parameters:

1. S - Size and Geometry of the Vessel:

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- Height/measuring range, diameter, shape (cylindrical, conical).
- Presence of internal obstructions like nozzles, agitators, heating coils, or ladders.
- 2. **T - Temperature and Pressure:**
 - What are the minimum, normal, and maximum operating temperatures and pressures? This dictates the material of construction and sensor limitations.
- 3. **A - Application/Material Properties:**
 - **Fluid Type:** Is it a liquid, solid (powder/granule), slurry, or interface between two liquids?
 - **Physical Properties:** Density (or specific gravity), viscosity, dielectric constant.
 - **Chemical Properties:** Is it corrosive, abrasive, or likely to coat or build up on a sensor?
- 4. **M - Medium/Process Conditions:**
 - Is there foam, vapor, dust, or turbulence? These conditions are known failure points for certain technologies.
- 5. **P - Power and Output:**
 - What power is available (e.g., loop-powered 24 VDC, 120 VAC)? What output is required (4-20 mA HART, Fieldbus, relay)?

3. Differentiate between contacting and non-contacting level measurement technologies, giving examples of each.

This choice depends on whether the process fluid can be touched by a sensor and the maintenance implications of doing so.

Contacting Technologies

- **Definition:** The sensor or a part of the measurement system is in direct physical contact with the process material.
- **Pros:** Often less affected by conditions in the headspace (vapor, foam). Can be very accurate.
- **Cons:** Sensor is exposed to corrosion, abrasion, and coating. Requires shutdown for maintenance.
- **Examples:**
 - **Guided Wave Radar (GWR):** A probe guides the signal.
 - **Differential Pressure (DP):** Diaphragms or seals are wetted.
 - **Capacitance Probes:** A rod or cable is in the material.
 - **Vibrating Forks / Float Switches:** The sensor itself is in the fluid.
 - **Displacers:** A large float is suspended in the fluid.

Non-Contacting Technologies

- **Definition:** The sensor is mounted above the material and measures the level without touching it, typically by sending and receiving a wave (sound, microwave, light).
- **Pros:** Immune to corrosion or coating from the process fluid. Can often be maintained without shutting down the process.
- **Cons:** Can be affected by conditions in the headspace (vapors, dust, temperature gradients, pressure).
- **Examples:**
 - **Non-Contact Radar:** Uses microwaves.
 - **Ultrasonic:** Uses sound waves.
 - **Laser:** Uses a focused beam of light.
 - **Nuclear (Gamma):** Measures from outside the vessel.

4. How does a Differential Pressure (DP) transmitter measure level, and what are its main limitations?

DP level measurement is one of the oldest and most common technologies. It is an *inferred* measurement, meaning it doesn't measure level directly but calculates it based on pressure.

Principle of Operation:

1. It measures the hydrostatic pressure exerted by a column of liquid. The formula is: **Level = Pressure / (Density × Gravity)**.
2. The high-pressure (HP) port is connected to a tap at the bottom of the vessel, and the low-pressure (LP) port is connected to the top (vapor space).
3. The transmitter measures the difference between these two pressures, which is directly proportional to the height of the liquid, assuming a constant density.

Main Limitations:

- **Density Dependence:** The biggest limitation. If the fluid's density changes with temperature or composition, the level reading will be inaccurate unless compensation is applied.
- **Maintenance Issues:** Impulse lines can clog, freeze, or leak. Wet legs can evaporate.
- **Open vs. Closed Tanks:**
 - For an **open (vented) tank**, the LP side is left open to the atmosphere.
 - For a **closed (pressurized) tank**, the LP side must be connected to the vapor space to compensate for vessel pressure.
- **Cost of Installation:** Requires two process taps, impulse lines, and often manifolds, making it more labor-intensive to install than a top-mounted radar.

5. When would you choose a Non-Contact Radar transmitter over an Ultrasonic transmitter?

Both are top-down, non-contacting technologies, but they use different wave types, making them suitable for different conditions in the headspace of the vessel.

Choose Non-Contact Radar when:

- **There are heavy vapors or changing vapor composition:** Radar (microwaves) is virtually unaffected by the density or composition of the gas/vapor layer, while Ultrasonic (sound waves) speed changes dramatically with these variables, causing errors.
- **The application is under vacuum or high pressure:** Sound cannot travel in a vacuum, so ultrasonic is unusable. High pressure also significantly affects the speed of sound. Radar is unaffected by pressure.
- **There are significant temperature variations or gradients:** Temperature changes affect the speed of sound much more than the speed of light/microwaves. Radar is more stable.
- **Foam is present:** Light, airy foam will often be penetrated by radar, allowing it to measure the true liquid level. Ultrasonic signals are often absorbed or scattered by foam.
- **Wind or turbulence is a factor:** Strong air currents can disrupt the path of an ultrasonic pulse, but have no effect on radar.

When might Ultrasonic still be a good choice?

- **Simple, atmospheric applications:** For a simple water tank open to the atmosphere, ultrasonic is a very cost-effective and reliable solution.
- **Some solids applications:** The broader beam of an ultrasonic transmitter can sometimes be better at finding an average level on an uneven solids surface.

6. Explain the working principle of Guided Wave Radar (GWR) and list its key advantages over non-contact radar.

GWR combines the benefits of radar technology with the focus of a contacting probe, making it one of the most versatile level technologies available.

Principle of Operation:

1. A low-energy microwave pulse is sent down a rigid rod or flexible cable probe.
2. When the pulse hits the surface of the material, a significant portion of the energy is reflected back up the probe to the transmitter.
3. The transmitter's electronics measure the time it takes for the pulse to travel down and back (Time of Flight). This time is directly proportional to the distance to the material surface.

Key Advantages over Non-Contact Radar:

- **Focused Energy / Signal Strength:** Because the signal is guided directly down the probe, there is very little energy loss. This makes GWR excellent for measuring materials with a very **low dielectric constant** (e.g., oils, solvents, plastics) that would reflect too little energy for a non-contact radar to detect.
- **Unaffected by Vessel Internals:** The signal is confined to the area around the probe, so GWR is not affected by ladders, nozzles, or other obstructions that could create false echoes for a non-contact radar.
- **Handles Foam and Turbulence Better:** The probe acts as a natural stilling well. The signal travels through light foam to find the true liquid surface, and turbulence around the probe has minimal effect.
- **Interface Measurement Capability:** A unique advantage. GWR can measure the interface between two immiscible liquids (e.g., oil and water) because a small reflection occurs at the top layer and a larger reflection occurs at the interface layer.

7. What is the dielectric constant (ϵ_r), and why is it critical for Radar and Capacitance level technologies?

The dielectric constant (also known as relative permittivity) is a measure of a substance's ability to store electrical energy in an electric field. For level measurement, it determines how "visible" a material is to certain technologies.

Importance for Level Technologies:

1. Radar (GWR and Non-Contact):

- The amount of microwave energy reflected from a material's surface is directly proportional to its dielectric constant.
- **High Dielectric (e.g., Water ≈ 80):** Reflects a strong signal, easy to measure.
- **Low Dielectric (e.g., Oils $\approx 2-3$, Plastic Pellets $\approx 1.5-2.5$):** Reflects a very weak signal. This is why non-contact radar struggles with these materials, but the focused energy of GWR can often succeed.

2. Capacitance:

- This technology measures the change in capacitance as the level rises. Capacitance is the ability to store a charge.
- The probe and the tank wall act as the plates of a capacitor. The process material becomes the dielectric medium between them.
- The change in capacitance is directly proportional to the material's dielectric constant. Therefore, a material with a **very low or fluctuating dielectric constant** is difficult to

measure reliably with this technique.

8. Your application involves a liquid that heavily coats everything it touches. Which level technologies would you immediately eliminate and which would you consider?

Coating or buildup is a major cause of instrument failure. The key is to choose a technology that is either immune to it or can compensate for it.

Technologies to Eliminate or Use with Caution:

- **Capacitance Probes:** These are highly susceptible. The buildup on the probe creates a false high reading because the instrument cannot distinguish between the coating and the actual process material.
- **Vibrating Forks / Paddles:** Buildup on the tines can dampen their vibration, causing the switch to remain in a false state (either on or off).
- **Displacers / Floats:** Heavy coating can change the buoyancy and weight of the displacer/float, leading to significant errors or causing it to become stuck.
- **Guided Wave Radar (GWR):** While tolerant of light coating, very heavy buildup on the probe can weaken the signal to the point of signal loss. Some GWRs have special probes and software to ignore buildup.

Technologies to Consider:

- **Non-Contact Radar/Ultrasonic:** Since nothing touches the fluid, these are excellent first choices. The main concern would be buildup on the antenna/transducer itself, which can be mitigated with air purges.
- **Nuclear (Gamma):** Completely non-invasive. The source and detector are mounted outside the tank, so they are completely immune to coating. This is the ultimate solution for the most difficult applications, but it's expensive and highly regulated.
- **Differential Pressure with Diaphragm Seals:** Using flush-mounted diaphragm seals prevents the clogging of impulse lines. The diaphragm can be made of robust materials and may be less prone to buildup than an intrusive probe.
- **Load Cells (Weigh System):** Measures the total weight of the vessel and its contents. It is completely non-contacting with the process fluid and immune to its properties.

9. How does a magnetostrictive level transmitter work, and what is its primary advantage?

Magnetostrictive technology is a contacting method known for extremely high accuracy in clean liquids.

Principle of Operation:

1. A float containing a set of permanent magnets moves up and down a rigid probe.
2. The transmitter electronics send a short electrical pulse down a wire (the "waveguide") inside the probe.
3. This pulse creates a magnetic field that interacts with the magnetic field of the float.
4. This interaction creates a tiny mechanical twist, or strain, in the waveguide. This twist travels back to the transmitter head at a known speed (the speed of sound in that material).
5. By measuring the time between sending the initial pulse and receiving the return "twist," the instrument can calculate the float's position with very high precision.

Primary Advantage:

- **High Accuracy:** Magnetostrictive transmitters are one of the most accurate continuous level technologies available, often with accuracies of ± 1 mm or better. This makes them ideal for custody transfer applications or processes requiring precise inventory control.

Limitations:

- Requires a float, making it unsuitable for solids, viscous, or coating liquids.
- The float's density must be correctly specified for the liquid being measured.

10. Explain the concept of "interface level measurement" and name two technologies capable of performing it.

Interface level measurement involves measuring the boundary between two immiscible liquids in the same vessel, such as oil and water.

The Challenge:

- The instrument must be able to detect the small change in physical properties between the two liquids.
- Often, the overall level (the top liquid's surface) and the interface level are both required.

Capable Technologies:

1. Guided Wave Radar (GWR):

- **How it works:** The microwave pulse travels down the probe. A small reflection is generated at the surface of the upper, low-dielectric liquid (e.g., oil). A second, larger reflection is generated when the pulse hits the high-dielectric lower liquid (e.g., water).
- The transmitter can process both reflections to provide both the overall level and the interface level.

2. Differential Pressure (DP) with a Displacer:

- **How it works:** A large float (displacer) is suspended in the liquids. The displacer is engineered to be heavier than the top liquid but lighter than the bottom liquid, so it will float at the interface.
- A torque tube or other mechanism measures the apparent weight of the displacer. As the interface level changes, the buoyancy force on the displacer changes, which is measured by the instrument and converted to an interface level reading.

11. What is a "stilling well," and in what situations would you specify one?

A stilling well is a simple but highly effective mechanical device used to improve the quality of a level measurement in difficult conditions.

What It Is:

- A stilling well (or still pipe) is a vertical pipe installed inside a tank, typically with small holes or slots at the bottom and top.
- The level instrument (e.g., GWR, float, ultrasonic) is mounted inside this pipe.

When to Use One:

1. **High Turbulence:** In vessels with powerful agitators or high inlet/outlet flow rates, the liquid surface can be extremely turbulent. The stilling well acts as a baffle, providing a calm, stable

surface inside the pipe that accurately reflects the average level in the tank.

2. **Foam:** For applications with heavy foam, a stilling well can sometimes separate the foam and allow the instrument to see the true liquid level inside the pipe.
3. **Mounting in crowded tanks:** If a tank has many internal obstructions, a stilling well provides a clear, unobstructed path for the measurement.

12. You need to measure the level of a corrosive acid. What is the most important consideration in your technology choice?

When dealing with aggressive chemicals, material compatibility is the number one priority, overriding almost all other factors.

Key Considerations:

1. Material of Construction (Wetted Parts):

- **Contacting Technology:** If you choose a contacting technology like a GWR probe or a DP seal, the wetted parts must be made from a material that can withstand the specific acid at its operating temperature and concentration. This might require exotic alloys (e.g., Hastelloy, Monel) or plastics (e.g., PTFE, PFA).
- **Non-Contacting Technology:** A non-contacting technology like radar is often preferred. However, you must still ensure the antenna material and the process connection gasket are compatible with any fumes or vapors from the acid.

2. Safety and Containment:

- The instrument's process connection (flange, thread) and seals must be robust to prevent any leaks, which could be extremely hazardous.
- Choosing a non-contacting technology eliminates an intrusion point into the tank, which can be a safer long-term option.

13. Describe the principle of a Vibrating Fork level switch. For which applications is it well-suited?

A vibrating fork is a popular and robust point level switch used across many industries.

Principle of Operation:

1. The switch has a set of two tines (the "fork") which are made to vibrate at their natural resonant frequency by piezoelectric crystals.
2. When the fork is in air (uncovered), it vibrates freely.
3. When the process material covers the tines, it dampens the vibration.
4. The instrument's electronics detect this change in frequency/amplitude and trigger the output relay.

Well-Suited Applications:

- **High/Low Level Alarms in Liquids:** It is extremely reliable for overfill protection and pump dry-run protection in a wide range of liquids.
- **Solids and Powders:** It is also effective for detecting the level of granular materials, powders, and pellets in silos.
- **Slurries:** Its vibrating nature helps to shake off some buildup, making it suitable for certain slurry applications.
- **Safety Instrumented Systems (SIS):** Due to its high reliability and simple principle, it is often certified and used as the sensor in safety loops.

14. Why is a non-contact radar's beam angle an important specification to consider?

The beam angle determines the "footprint" of the radar signal on the material surface and dictates where the instrument can be mounted.

Importance of Beam Angle:

- **Avoiding False Echoes:** A wide beam angle means the radar signal spreads out more. In a narrow tank or a tank with many obstructions, a wide beam can hit the tank wall or internal pipes, generating false echoes that interfere with the true level reading. A narrow beam focuses the energy directly downwards.
- **Mounting Nozzle Considerations:** The radar must be mounted on a nozzle that is tall enough to allow the beam to clear the edge of the nozzle. A wider beam requires a taller nozzle to avoid interference.
- **Higher Frequency = Narrower Beam:** As a general rule, higher frequency radars (e.g., 80 GHz) have a much narrower beam angle (e.g., 3-4 degrees) compared to lower frequency radars (e.g., 26 GHz might have a 10-degree beam). This is a key advantage of modern high-frequency radars, allowing them to be installed in more complex vessel geometries.

15. What are load cells, and how can they be used for level measurement? What is their main advantage?

Load cells are sensors that measure force or weight. Using them for level measurement creates a completely non-invasive system.

How They Work for Level:

1. Load cells are installed under the support legs or structure of a tank, silo, or hopper.
2. They continuously measure the total weight of the vessel and its contents.
3. A weighing indicator or controller subtracts the known weight of the empty vessel (the "tare" weight) to calculate the net weight of the material inside.
4. If the material's density is known, this weight can be converted directly into a volume or level reading.

Main Advantage:

- **Completely Non-Invasive:** Nothing touches the process material. This makes weighing an ideal solution for materials that are extremely corrosive, abrasive, viscous, hot, or sanitary. It is immune to any changes in material properties like dielectric or density (when measuring by mass).

Disadvantages:

- Can be expensive, especially for retrofitting large silos.
- Affected by external forces like wind, vibration, or connecting pipes that are not flexible.

16. Explain what a "wet leg" vs. a "dry leg" is in DP level measurement.

These terms refer to the state of the impulse line connected to the low-pressure (LP) side of a DP transmitter on a closed tank.

Dry Leg:

- **What it is:** The LP impulse line is filled with a non-condensing gas (e.g., air or nitrogen) from the vessel's vapor space.
- **When it's used:** This is the standard method for most closed-tank applications where the vapor in the headspace will not condense into a liquid under normal operating conditions.
- **Advantage:** Simple to set up. The transmitter is calibrated assuming a zero head pressure on the LP side.

Wet Leg:

- **What it is:** The LP impulse line is intentionally filled completely with a liquid. This liquid exerts a constant hydrostatic pressure on the LP side of the transmitter.
- **When it's used:** This is used when the vapor in the headspace is condensable (like steam). If a dry leg were used, condensate would accumulate randomly, creating a variable and erroneous pressure on the LP side. A wet leg creates a stable, known head pressure.
- **Calibration:** The transmitter must be calibrated with a zero offset to account for the constant pressure from the wet leg.

17. What is a "stilling well" or "bypass chamber" and when would you use it?

A stilling well (internal) or bypass chamber (external) is a way to isolate a level instrument from the main process volume to ensure a more reliable measurement.

Description:

- An external bypass chamber (often called a bridle) is a pipe mounted on the side of a vessel, connected via taps at the top and bottom.
- The liquid level in the chamber will always be the same as the level in the vessel due to gravity.
- Multiple instruments (e.g., GWR for continuous control, magnetic level indicator for visual indication, vibrating forks for alarms) can be mounted on this single chamber.

When to Use It:

1. **High Turbulence/Agitation:** Like an internal stilling well, it provides a calm surface for measurement away from agitators.
2. **Instrument Isolation:** This is a key advantage. Instruments can be blocked off from the process, vented, and maintained or replaced without shutting down the main vessel.
3. **Centralized Mounting:** It provides a convenient, single location to mount all level instrumentation for a vessel.
4. **Boiling or Flashing Liquids:** It can help provide a more stable surface for liquids at their boiling point.

18. What is the main limitation of capacitance level sensors?

Capacitance technology is effective but has one major vulnerability that limits its application range.

Main Limitation: Dependence on Dielectric Constant

- The entire principle of operation is based on measuring the change in capacitance, which is directly proportional to the dielectric constant (ϵ_r) of the process material.
- **Changing Material:** If the material being measured changes, its dielectric constant may also change, which will invalidate the instrument's calibration and cause an incorrect level reading. It is not suitable for applications where different products are stored in the same tank.
- **Buildup/Coating:** If the material coats the probe, the instrument reads the dielectric of the coating, not the empty space, leading to a false high-level reading. This makes it unsuitable for

sticky or coating applications unless a special anti-coating probe is used.

- **Low Dielectric Materials:** It can be difficult to get a large enough change in capacitance to measure materials with a very low ϵ_r (e.g., oils, plastics).

19. How does a bubbler system measure level?

A bubbler is a simple, old, but effective way to measure level in open tanks, especially for difficult fluids.

Principle of Operation:

1. A dip tube is installed vertically in a tank with its open end near the bottom.
2. A very low, constant flow of air or inert gas is fed into the tube.
3. The gas flows down the tube and "bubbles" out the bottom.
4. The pressure required to push the bubbles out is equal to the hydrostatic pressure exerted by the liquid level above the end of the tube.
5. A standard pressure transmitter is connected to the dip tube. It measures this back-pressure and converts it to a level reading ($\text{Level} = \text{Pressure} / \text{Density}$).

Advantages:

- **Only the dip tube touches the fluid.** The tube can be made from any corrosion-resistant material. The expensive transmitter is located safely away from the process.
- **Excellent for sludges, slurries, and corrosive liquids.** The constant flow of air helps keep the tube clear.

20. What is a "dead zone" or "blanking distance" in a non-contact level transmitter?

This is a physical limitation of all time-of-flight instruments that prevents them from measuring level right up to the sensor's face.

Explanation:

- When a non-contact transmitter (ultrasonic or radar) emits a pulse, the electronics cannot simultaneously transmit and receive. There is a brief period of "ringing" after the pulse is sent.
- The **blanking distance** (or dead zone) is the minimum distance from the sensor face within which the instrument cannot make a valid measurement. Any echo received from within this zone will be ignored.
- **Installation Impact:** The transmitter must be mounted high enough so that the maximum liquid level never enters this blanking distance. If it does, the instrument will show an inaccurate reading or an error. This distance is a standard specification on any non-contact transmitter's data sheet (e.g., 0.3 meters).

21. How do you measure the level of solid materials like grain or plastic pellets in a silo? What is a key challenge?

Measuring solids is significantly more challenging than measuring liquids due to the nature of the material surface.

Suitable Technologies:

- **Non-Contact Radar (especially 80 GHz):** This is now the preferred technology. The narrow beam of high-frequency radar can map the surface and is less affected by dust.
- **Guided Wave Radar:** A flexible cable probe can be used, but there is a risk of high mechanical stress on the cable from the shifting material.
- **Weight/Load Cells:** Provides an accurate mass inventory, immune to surface issues.
- **Ultrasonic (with caution):** Can be used, but heavy dust can block the signal.
- **3D Level Scanners:** Use multiple acoustic or radar beams to map the entire surface, providing a highly accurate volume measurement.

Key Challenge: Angle of Repose

- Unlike liquids which have a flat surface, solids pile up unevenly. They form peaks and valleys during filling and emptying (the "angle of repose"). A single-point measurement from a radar or ultrasonic will only measure the distance to one spot on that uneven surface, which may not represent the true average volume in the silo. This is why careful aiming and, in large silos, multiple sensors or 3D scanners are used.

22. What is a Magnetic Level Indicator (MLI)?

An MLI is a mechanical instrument that provides a simple, highly reliable visual indication of level without using any glass.

Principle of Operation:

1. It consists of an external bypass chamber connected to the main vessel.
2. Inside the chamber is a float containing a powerful magnet.
3. On the outside of the chamber is an indicator rail with a series of small, colored flags or a magnetic follower. Each flag is also a small magnet.
4. As the float moves up and down with the liquid level, its magnetic field flips the colored flags, providing a clear visual representation of the level.

Advantages:

- **Highly Reliable and Safe:** It is a simple mechanical device with no power required. It eliminates the risk of leaks and breaks associated with traditional sight glasses, especially in high-pressure or hazardous fluid applications. Can be equipped with magnetostrictive or GWR transmitters
- mounted on the chamber to provide both a local visual indication and a continuous electronic signal from a single process connection.

23. What does it mean to "zero and span" a level transmitter?

This is the basic calibration process for setting the measurement range of any analog transmitter.

Calibration Steps:

1. **Setting the Zero (0% or 4 mA point):**
 - The process level is brought to its lowest required measurement point (the 0% point).
 - The transmitter's "zero" adjustment is used to set the output signal to exactly 4.00 mA.
2. **Setting the Span (100% or 20 mA point):**
 - The process level is then brought to its highest required measurement point (the 100% point).
 - The transmitter's "span" adjustment is used to set the output signal to exactly 20.00 mA.

This process ensures that the transmitter's output signal accurately represents the desired measurement range. For modern smart transmitters, this is done digitally using a handheld

communicator or software rather than physical adjustment screws.

24. Your application has heavy, dense foam. Which technologies would struggle and which might work?

Foam is a common and difficult challenge. Its effect depends on the type of foam and the technology being used.

Technologies That Struggle:

- **Ultrasonic:** Sound waves are very easily absorbed and scattered by foam, making it one of the worst choices.
- **Non-Contact Radar:** Can be a problem. If the foam is dense and has a high liquid content, the radar may reflect off the top of the foam layer instead of the true liquid level.
- **Capacitance:** Will typically read the foam as if it were liquid, leading to a false high reading.

Technologies That Might Work:

- **GuidedWave Radar (GWR):** Often the best choice. The guided pulse can typically travel through the foam to detect the liquid surface, especially with the right probe type (e.g., a single coaxial probe).
- **Differential Pressure (DP):** Measures based on hydrostatic head (mass). If the foam has a very low density compared to the liquid, the DP transmitter will largely ignore it and read the true level. This is often a very reliable method in foamy applications.
- **Nuclear (Gamma):** Since it measures based on density, it can be set up to ignore low-density foam and detect only the higher-density liquid.

25. What is the key difference between a float switch and a displacer switch?

Both are point level switches, but they operate on slightly different principles of buoyancy, which affects their application and mounting.

Float Switch:

- **Principle:** Based on buoyancy. The float itself is lighter than the liquid and physically floats on the surface.
- **Action:** The physical movement of the float on the liquid surface is used to trip a switch (e.g., via a magnet or a tilting mechanism).
- **Typical Use:** Simple on/off control in sumps, tanks. Often mounted horizontally on the side of a tank.

Displacer Switch:

- **Principle:** Based on Archimedes' principle. The "displacer" element is heavier than the liquid and is suspended by a spring.
- **Action:** When the liquid level rises to cover the displacer, the buoyant force of the liquid "helps" the spring, reducing the apparent weight. This small change in apparent weight is used to trip a switch.
- **Typical Use:** Often used for larger tanks and higher pressures. They are typically mounted vertically from the top of the vessel. The switching point can be adjusted by changing where the displacer is suspended on its cable.

26. What does SIL rating (e.g., SIL 2) on a level instrument signify?

A SIL (Safety Integrity Level) rating is a quantitative measure of reliability for a component used in a Safety Instrumented System (SIS).

Key Concepts:

- **Purpose:** Used for critical safety functions, like preventing a tank from overfilling (a high-high level alarm).
- **Rating:** SIL 1 is the lowest level of risk reduction, and SIL 4 is the highest. SIL 2 and SIL 3 are common in the process industries.
- **Meaning:** A SIL rating on an instrument means it has been independently certified by agencies (like TÜV) to have a very low and predictable Probability of Failure on Demand (PFD). The manufacturer must provide extensive data from a rigorous design and testing process (FMEDA report) to prove this reliability.
- **Implication:** When you specify a SIL-rated instrument, you are choosing a device with a documented high level of reliability for use in a safety-critical application.

27. How does temperature compensation work for a DP level transmitter?

Since DP level relies on density, and density changes with temperature, compensation is needed for accuracy in applications with varying temperatures.

Methods of Compensation:

1. **Manual Entry:** For applications with stable temperatures, the operator simply calculates the density at that temperature and configures it in the transmitter. This is the most common method.
2. **Dynamic Compensation (Multivariable Transmitter):**
A multivariable DP transmitter incorporates a process temperature sensor (like an RTD). The transmitter continuously measures both the differential pressure and the process temperature. Using pre-programmed fluid property tables, it calculates the density at the current temperature in real-time. It then uses this dynamic density value in the level calculation ($\text{Level} = \text{Pressure} / \text{Density}$), providing a temperature-compensated and much more accurate level reading.

28. What is a Laser level transmitter and where is it most commonly used?

A laser level transmitter is a non-contacting technology that uses a highly focused beam of light for measurement.

Principle of Operation:

- It emits a short pulse of laser light, which travels to the material surface.
- The light reflects off the surface and travels back to a detector in the instrument.
- It measures the time-of-flight of this light pulse with extreme precision to calculate the distance.

Common Applications:

- **Solids Measurement:** Its biggest advantage is an extremely narrow beam. This allows it to be aimed very precisely to avoid obstructions and measure levels in very narrow silos or compartments. It is excellent for mapping the surface of uneven solids.
- **Opaque Liquids in Narrow Vessels:** Can be used for liquids, especially where a very tight beam is needed.

Limitations:

- The laser can be scattered by dust, steam, or translucent liquids, making it unsuitable for those conditions.

29. Explain the term "span" in the context of a level measurement.

The "span" defines the total range of the measurement that the instrument is configured to report.

Definition:

- **Span=UpperRangeValue(URV) - LowerRangeValue(LRV).**
- For example, if you are measuring level in a 10-meter-tall tank, but you only care about the range from the 2-meter mark to the 8-meter mark:
 - The **LRV (0% point)** would be 2 meters. This corresponds to the 4 mA output.
 - The **URV (100% point)** would be 8 meters. This corresponds to the 20 mA output.
 - The **Span** would be $8\text{m} - 2\text{m} = 6\text{ meters}$.
- The span is the distance over which the 4-20 mA signal will be scaled.

30. Why is grounding important for electronic level instruments?

Proper grounding is essential for both safety and the integrity of the measurement signal.

Reasons for Grounding:

1. **Personnel Safety:** This is the most critical reason. Grounding provides a safe path for fault currents to flow to the earth in case of an insulation failure or short circuit, preventing the instrument's housing from becoming energized at a lethal voltage.
2. **Signal Noise Protection (EMI/RFI):** In a 4-20 mA loop, the cable shield is connected to ground at one end (typically the control system end). This drains away electrical noise that the shield picks up from nearby power cables or motors, preventing that noise from corrupting the low-level measurement signal.
3. **Lightning Protection:** Proper grounding helps to dissipate the massive energy from a nearby lightning strike, protecting the sensitive electronics of the transmitter.

31. What is HART protocol and what benefit does it provide for a level transmitter?

HART (Highway Addressable Remote Transducer) is a hybrid communication protocol that combines digital and analog signaling.

How it Works:

- It superimposes a low-level digital signal on top of the standard 4-20 mA analog signal.
- The analog 4-20 mA signal is used for real-time process control.
- The digital signal is used for configuration, diagnostics, and retrieving additional process variables.

Key Benefits:

- **Remote Configuration:** A technician can remotely configure, calibrate, and diagnose a HART-enabled level transmitter from the control room or any point on the 4-20 mA loop using a handheld communicator, without needing to go to the physical device.
- **Advanced Diagnostics:** The digital signal can convey detailed diagnostic information, such as "electronics failure," "sensor degradation," or "low signal quality," which is much more useful than just an out-of-range analog signal.

- **Additional Variables:** A multivariable transmitter can send its primary variable (e.g., level) as the 4-20 mA signal, while simultaneously sending secondary variables (e.g., temperature, interface level) over the digital HART signal.

32. For a high-purity or sanitary application (food, pharma), what technology would you choose and why?

Sanitary applications have unique requirements for cleanliness, material finish, and process connections.

Key Requirements:

- **No Crevices:** Instruments must not have any small cracks, threads, or dead spaces where bacteria could grow.
- **Material Finish:** All wetted parts must have a highly polished surface finish (measured in Ra) to prevent material from sticking.
- **Clean-in-Place (CIP) / Steam-in-Place (SIP):** The instrument must be able to withstand the high temperatures and chemicals used in cleaning cycles.

Preferred Technologies:

- **Non-Contact Radar:** An excellent choice as it is non-invasive. The antenna is typically encapsulated in a material like PEEK or PTFE to provide a smooth, sealed surface.
- **Differential Pressure with Sanitary Diaphragm Seals:** These seals are designed to be flush with the tank wall and have a highly polished surface, eliminating any crevices.
- **Vibrating Fork:** These are available in highly polished, single-piece designs that are ideal for high/low level detection in sanitary tanks.

All these instruments would be connected to the process using sanitary fittings like Tri-Clamp®, not standard pipe threads.

33. You need to measure the level in a tank with boiling liquid. What problems can this cause and how would you address them?

Boiling liquids create a highly turbulent surface and a dense vapor space, which can be very challenging for level measurement.

Problems Caused by Boiling:

- **Turbulence:** The boiling action creates a constantly moving, chaotic surface that is hard to measure accurately.
- **Vapors:** The dense vapor layer can interfere with non-contact technologies. It will stop ultrasonic signals and can attenuate radar signals.
- **Flashing:** The rapid state change from liquid to gas can cause pressure fluctuations and erratic behavior.

Solutions:

- **Bypass Chamber / Stilling Well:** This is often the best solution. It provides a calmer liquid surface for the instrument, isolated from the most violent boiling in the main vessel.
- **Guided Wave Radar (GWR):** AGWR in a stilling well is a very robust combination, as the signal is guided and less affected by the turbulent conditions.

- **Differential Pressure (DP):** DP measurement is based on mass and is often unaffected by the surface turbulence. It is a very common and reliable method for measuring level in boilers and evaporators. A wet leg must be used on the LP side to handle the condensable vapor.

34. What is a "displacer" level transmitter and how is it different from a simple float?

While both use buoyancy, they operate differently. A displacer measures apparent weight, while a float physically follows the liquid surface.

Displacer Transmitter:

- **Principle:** It uses a large, heavy element (the displacer) that is suspended from a spring or torquetube. The displacer is always submerged to some degree.
- **How it Works:** Based on Archimedes' Principle, the buoyant force on the displacer is equal to the weight of the liquid it displaces. As the liquid level rises and covers more of the displacer, the buoyant force increases, and the displacer's "apparent weight" decreases. This change in apparent weight is measured by the instrument and is proportional to the level.
- **Key Difference:** The displacer itself only moves a very small amount, whereas a float moves over the entire level range. This makes displacers more robust for continuous measurement.

35. Describe a situation where nuclear (gamma) level measurement would be the best or only choice.

Nuclear gauging is reserved for the most extreme applications where no other technology can survive or function reliably.

Principle:

- A low-strength radioactive source is mounted on one side of the vessel, and a detector is mounted on the other.
- The source emits a beam of gamma radiation that passes through the vessel walls and the process material.
- The process material absorbs some of this radiation. As the level rises, more radiation is blocked, and less reaches the detector. The detector's reading is inversely proportional to the level.

Ideal (and often only) Choice When:

- **Extreme Temperatures/Pressures:** For applications like a catalytic cracker in a refinery, where temperatures and pressures are far beyond the limits of any intrusive instrument.
- **Extremely Corrosive or Toxic Materials:** Since the system is completely external to the vessel, there is zero contact with the process and no risk of leaks through an instrument nozzle.
- **Very Abrasive Solids/Slurries:** For measuring level in things like ore chutes or cement kilns where any internal device would be destroyed instantly.

36. What does the term "wetted parts" refer to?

"Wetted parts" is a critical term used to define the components of an instrument that are in direct physical contact with the process fluid.

Examples of Wetted Parts:

- For a **pressure transmitter**: The diaphragm and the process connection (e.g., flange or threads).
- For a **Guided WaveRadar**: The entire probe (rod or cable) and the process seal/gasket.
- For a **control valve**: The valve body, plug, seat, stem, and packing.
- For a **vibrating fork**: The fork tines themselves.

Why It's Important:

- **Material Selection**: When specifying an instrument, you must ensure that all wetted parts are made of materials that are chemically compatible with the process fluid to prevent corrosion and failure. Non-wetted parts, like the instrument housing or mounting bracket, can typically be made from standard materials like aluminum or carbon steel.

37. How can you verify the reading of a level transmitter in the field without changing the process level?

Simulating a level is a common practice during commissioning and troubleshooting to verify the entire control loop.

Methods:

1. For DPT Transmitters:

- The transmitter is isolated from the process using its manifold.
- A hand pump and pressure calibrator are connected to the HP and LP ports.
- Known pressures corresponding to 0%, 50%, and 100% of the level range are applied, and the technician verifies that the 4-20 mA output and the reading on the control system display are correct at each point.

2. For Radar/Ultrasonic Transmitters:

- **Target Simulation**: For some non-contact devices, a technician can hold a metal plate or other reflective target at a known distance below the transmitter to simulate a level.
- **Parameter Simulation**: Modern transmitters have a simulation mode. Using a handheld communicator, a technician can command the transmitter to output a specific mA value (e.g., "Simulate 12 mA") to verify that the wiring, control system input card, and scaling are all correct.

38. What is the purpose of a "boot" or "sump" on the bottom of a large storage tank in relation to level measurement?

The boot (or sump) is the lowest point in a tank, designed for water drainage, but it affects how the level instrument is installed and calibrated.

Purpose and Impact:

- **Water Drainage**: In large oil or product storage tanks, water will settle out and collect at the bottom. The boot provides a collection point from which this water can be drained off periodically.
- **Level Measurement Impact**:
 - The continuous level transmitter (e.g., radar) used for inventory is typically installed to measure the product level, not the water in the boot.
 - Therefore, the **0% level (LRV)** is usually set at the top of the boot, not the physical bottom of the tank. The instrument is configured to ignore the level within the boot itself.
 - Separate point level switches are often installed within the boot to detect when the water level is high and needs to be drained.

39. What is the difference between Accuracy and Repeatability in a level instrument?

These two terms describe different aspects of an instrument's performance. An instrument can be very repeatable but not very accurate.

Accuracy:

- **Definition:** How close a measurement is to the true, actual value.
- **Example:** If the true level is exactly 5.00 meters, an accurate instrument might read 5.01 meters. An inaccurate one might read 5.20 meters.
- **Importance:** Critical for inventory management and custody transfer, where knowing the exact quantity is important.

Repeatability:

- **Definition:** How close multiple measurements are to each other when measuring the same level under the same conditions. It is a measure of consistency.
- **Example:** An instrument might consistently read 5.20 meters every time the true level is 5.00 meters. It is not accurate (it has a 0.20m error), but it is perfectly repeatable.
- **Importance:** For process control, repeatability is often more important than absolute accuracy. A consistent measurement, even with a small offset, allows a PID controller to effectively maintain a stable process.

40. In a tank containing liquefied gas (e.g., LPG), what technology is commonly used and why?

Liquefied gases present challenges of high pressure, low temperature, and low dielectric constant.

Commonly Used Technologies:

1. **Differential Pressure(DP):** This is a very common, traditional, and reliable method. It works well because the fluid properties are well-known, and the technology is proven to handle the high pressures.
2. **Guided Wave Radar (GWR):** GWR has become very popular for these applications.
 - **Why it works well:** It is a direct measurement, unaffected by density variations. The focused energy of the probe provides a strong signal return even from the low dielectric LPG. It can be installed in a stilling well to handle any boiling at the surface. High-pressure probe designs are readily available.
3. **Magnetostrictive:** Also used, but requires a float that is compatible with the low temperatures and pressures.

Non-contact radar is generally not used because the signal is too weak to get a reliable reflection off the low-dielectric liquid surface.

41. What is a "redundant" level measurement setup? Why would you use one?

Redundancy involves using multiple instruments to measure the same process variable to improve safety and reliability.

How It's Implemented:

- **2oo3 (Two-out-of-Three) Voting:** A common scheme in safety systems. Three independent level transmitters are installed. The control system looks at all three readings. If one transmitter fails or provides a reading that disagrees with the other two, it is ignored, and the system continues to operate safely based on the two "good" readings. An alarm is raised to notify maintenance that one channel has failed.

Why It's Used:

- **High Reliability and Safety:** It ensures that a single random failure of one instrument cannot cause a dangerous situation (like an overfill) or a false trip of the plant.
- **Fault Tolerance:** The system can tolerate a single failure without shutting down the process.
- **Application:** Used in critical applications like high-high level shutdown systems in reactors, separators, or critical storage tanks where a failure would have severe safety, environmental, or economic consequences.

42. What are the limitations of using a float switch?

While simple and cost-effective, float switches have several limitations that restrict them to less critical applications.

Key Limitations:

- **Moving Parts:** They are mechanical devices with pivots and arms that can wear, stick, or break over time.
- **Buildup and Coating:** The float can become coated with process material, changing its buoyancy and preventing it from moving freely.
- **Turbulence:** In a turbulent liquid, the float can bounce around, causing the switch to rapidly cycle on and off ("chatter").
- **Limited Diagnostics:** It's a simple on/off device. There is no way to know if it's working correctly until it's actually needed, unless it is manually proof-tested.
- **Fluid Compatibility:** The float material must have the correct specific gravity to float properly in the process liquid.

43. What is a "stilling well" made of? What are common materials?

The material for a stilling well must be chosen based on the same criteria as any other wetted part: chemical compatibility and process conditions.

Common Materials:

- **Carbon Steel:** Used for non-corrosive applications like hydrocarbon or water storage tanks.
- **Stainless Steel (304, 316):** The most common choice for a wide range of process fluids due to its good corrosion resistance.
- **High-Nickel Alloys (Hastelloy, Monel):** Used for highly corrosive services like acids or chlorine.
- **Plastics (PVC, CPVC, Fiberglass):** Can be used for highly corrosive liquids at lower temperatures and pressures, such as in chemical storage tanks or water treatment sumps.

44. Can you use Guided Wave Radar to measure solids? What are the risks?

Yes, GWR can be used for solids, but it comes with significant mechanical risks that must be carefully evaluated.

How it Works:

- A flexible cable probe is typically used, anchored to the bottom of the silo.
- The microwave pulse travels down the cable and reflects off the solid material's surface. It is effective even for low-dielectric plastics.

Major Risks:

- **High Mechanical Stress:** This is the biggest problem. As the solid material is loaded and unloaded, it creates immense downward drag and lateral forces on the cable. This can stretch or even snap the cable, leading to instrument failure and the risk of the broken cable falling into downstream machinery (like a crusher or conveyor).
- **Uneven Surface:** Like any single-point device, it measures the level at one spot, which may not be representative of the silo's total volume due to the angle of repose.

Because of the high risk of mechanical failure, non-contact radar is now strongly preferred for most solids applications.

45. What is the main difference in mounting a DP transmitter for liquid service versus gas service?

The mounting position is determined by the need to keep the impulse lines filled with a known, constant fluid and to vent any unwanted phases.

Liquid Service:

- **Goal:** Keep the lines full of liquid and vent any trapped gas.
- **Mounting:** The transmitter should be mounted **below** the process taps.
- **Slope:** The impulse lines should be sloped continuously **upwards** from the transmitter to the process taps. This allows any gas bubbles to naturally travel up and vent back into the process line.

Gas Service:

- **Goal:** Keep the lines full of gas and drain any condensed liquid.
- **Mounting:** The transmitter should be mounted **above** the process taps.
- **Slope:** The impulse lines should be sloped continuously **downwards** from the transmitter to the process taps. This allows any liquid condensate to drain back into the process line.

46. What is "overpressure protection" for a DP transmitter?

Overpressure protection refers to the ability of the transmitter's sensor to withstand a pressure far beyond its calibrated measurement range without being damaged.

How it Happens:

- In a DP transmitter, one side (e.g., the HP side) could be exposed to full line pressure while the other side (LP) is vented to atmosphere. This can happen if a manifold valve is opened incorrectly.
- This exposes the delicate measuring diaphragm to a differential pressure equal to the static line pressure, which can be hundreds of times greater than the actual measurement span.

Importance of the Specification:

- A good overpressure rating (e.g., up to 2000 psi) means the sensor is robust enough to survive these common installation and maintenance mistakes without needing to be replaced. Modern

DP transmitters have very high overpressure ratings.

47. A non-contact radar in a tank farm gives a fluctuating reading on a hot, sunny day but is stable at night. What could be the cause?

This points to an environmental factor related to the sun's heat affecting the vapor space in the tank.

Likely Cause: Convection Currents

- On a hot day, the sun heats the top of the tank, creating thermal layers and convection currents in the vapor space above the liquid.
- These moving layers of air/vapor at different temperatures and densities can slightly distort or scatter the radar signal, causing the reading to fluctuate.
- At night, the temperature stabilizes, the convection currents stop, and the reading becomes stable.

How to Differentiate from Vapors:

- This is different from heavy vapors from the product itself (which would be present day and night). The key clue is the correlation with solar heating, pointing to thermal effects in the headspace. Using a higher frequency (80 GHz) radar with better focusing can sometimes help mitigate this effect.

48. Why would you use a flexible probe instead of a rigid probe for a Guided Wave Radar?

The choice between a rigid and flexible probe is primarily driven by the measurement length and installation constraints.

Reasons to Use a Flexible Cable Probe:

1. **Long Measurement Range:** Rigid probes are generally only practical for lengths up to about 6 meters (20 feet). Beyond that, they are too difficult to ship, handle, and install. Flexible cable probes can be used for measurements of 30 meters (100 feet) or more, as they can be coiled for shipping.
2. **Limited Headroom:** To install a 6-meter rigid probe, you need at least 6 meters of clearance above the tank nozzle. In many indoor installations or areas with overhead piping, this space is not available. A flexible probe can be inserted easily with minimal headroom.

When to Use a Rigid Probe:

- For shorter measuring ranges where its stiffness makes it easier to handle and less prone to unwanted movement in turbulent conditions.

49. What is a "fly-by-wire" or "wireless" level instrument, and what are its advantages?

Wireless instruments transmit their data via a radio protocol instead of a traditional 4-20 mA wired connection.

How They Work:

- The level instrument is powered by a long-life internal battery.

- It periodically "wakes up," takes a measurement, and transmits the data wirelessly (e.g., using WirelessHART protocol) to a central gateway.
- The gateway collects data from many wireless instruments and communicates it to the main control system.

Key Advantages:

- **Reduced Installation Cost:** The biggest advantage. It completely eliminates the high cost of engineering, installing, and commissioning signal wiring, cable trays, and conduits. This is especially beneficial for monitoring remote tanks or retrofitting instruments in an existing plant.
- **Flexibility:** Easy to deploy instruments in temporary locations or hard-to-reach areas.

Disadvantage:

- Not suitable for fast-acting process control loops due to the slower, periodic update rate. They are primarily used for monitoring and alarms.

50. What is the most important factor for ensuring a successful level measurement installation?

While many factors are important, the entire process hinges on one foundational step.

The Most Important Factor:

- **A complete and accurate understanding of the application.**
- Before any instrument is chosen, the engineer must thoroughly define all the process conditions: the fluid properties (density, dielectric, viscosity, corrosiveness), the vessel geometry, the temperature and pressure, and the presence of any challenging conditions like foam, vapor, dust, or turbulence.
- Nearly every measurement failure can be traced back to a misunderstanding or an unknown condition at this initial stage. Choosing the right technology is impossible without first perfectly defining the problem it needs to solve.



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