The Consumer Guide to Non-Contact Level Gauges

Seminar Presented by
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Seminar Outline

- ***Introduction***
- *Level Measurement Fundamentals*
- *Level Measurement Technology*
- *Level Gauge Performance*
- *Consumer Guide*

Introduction

- *Working Definition of a Process*
- *Why Measure Level?*

Working Definition of a Process

- *A process is anything that changes*

Why Measure Level?

- *Level measurements provide information about the process*
- *The information that is needed depends on the process*

Why Measure Level?

- *Custody transfer*
  - *Measurements are often required to determine the total quantity of material that will be transferred to another party*
  - *Billing purposes*

Why Measure Level?

- *Monitor the process*
  - *Level measurements can be used to ensure that the process is operating satisfactorily*

Why Measure Level?

- *Improve the process*
  - *Level measurements can be used for some heat and material balance calculations that can be used to improve the process*

Why Measure Level?

- *Monitor a safety parameter*
  - *Level measurements can be used to ensure that critical portions of the process operate safely*
    - *Overflow*
    - *Underflow*

Seminar Outline

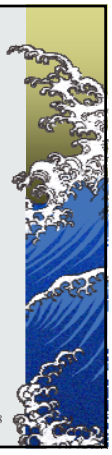
- *Introduction*
- ***Level Measurement Fundamentals***
- *Level Measurement Technology*
- *Level Gauge Performance*
- *Consumer Guide*

Level Measurement Fundamentals

- ***Temperature***
- *Density*
- *Pressure*
- *Expansion*
- *Viscosity*
- *Static Interface Geometry*
- *Types of Level Measurement*
- *Vessel Geometry*
- *Dynamic Phenomena*

Temperature

- *Measure of relative hotness/coldness*
  - *Water freezes at 0°C (32°F)*
  - *Water boils at 100°C (212°F)*



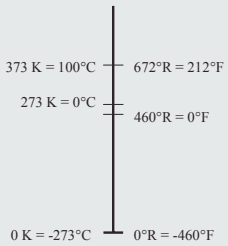
Temperature

- *Removing heat from fluid lowers temperature*
  - *If all heat is removed, absolute zero temperature is reached at approximately -273°C (-460°F)*

Temperature

- *Absolute temperature scales are relative to absolute zero temperature*
  - *Absolute zero temperature = 0 K (0°R)*
    - *Kelvin = °C + 273*
    - *° Rankin = °F + 460*

Temperature



Level Measurement Fundamentals

- *Temperature*
- ***Density***
- *Pressure*
- *Expansion*
- *Viscosity*
- *Static Interface Geometry*
- *Types of Level Measurement*
- *Vessel Geometry*
- *Dynamic Phenomena*

Density

- *Density is defined as the ratio of the mass of a fluid divided its volume ($\rho=m/V$)*

Liquid Density

- *Specific Gravity of a liquid is the ratio of its operating density to that of water at standard conditions*
  - $SG = \rho_{liquid} / \rho_{water\ at\ standard\ conditions}$

Liquid Density

Problem

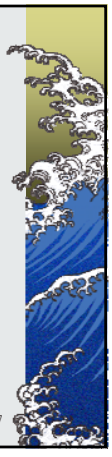
- *What is the density and specific gravity of a liquid where 0.33 kg of the liquid occupies 300 ml?*

Liquid Density

- *The density can be calculated:*
  - *Mass = 0.33 kg = 330 g*
  - *Volume = 300 ml = 300 cm^3*
  - *Density = 330/300 = 1.10 g/cm^3*

Liquid Density

- *The specific gravity can be calculated (at 15°C)*
  - *Density = 1.10 g/cm^3*
  - *Density of water = 0.999099 g/cm^3*
  - *Specific Gravity = 1.10 / 0.999099 = 1.101*



Bulk Density

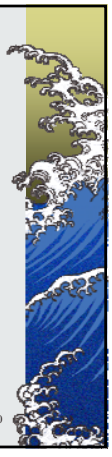
- *The bulk density is defined as the ratio of the mass of solids divided its volume ($\rho=m/V$)*

Bulk Density

- *Typical bulk densities*
  - *Alfalfa (ground)* $250\ kg/m^3$
  - *Clay* $1100\text{-}1700\ kg/m^3$
  - *Coal* $800\text{-}1500\ kg/m^3$
  - *Coke* $570\text{-}650\ kg/m^3$
  - *Sand* $1400\text{-}2100\ kg/m^3$

Bulk Density

- *Bulk density variations can be caused by:*
  - *Material grade*
  - *Particle size*
  - *Moisture*
  - *Loose or packed*



Level Measurement Fundamentals

- *Temperature*
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Pressure

- *Pressure is defined as the ratio of a force divided by the area over which it is exerted (P=F/A)*

Pressure

Problem

- *What is the pressure exerted on a table by a 2 inch cube weighing 5 pounds?*
  - *(5 lb) / (4 inch^2) = 1.25 lb/in^2*
  - *If the cube were balanced on a 0.1 inch diameter rod, the pressure on the table would be 636 lb/in^2*

Gas Pressure

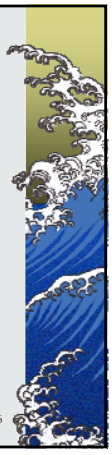
- *Atmospheric pressure is caused by the force exerted by the atmosphere on the surface of the earth*
  - *2.31 feet WC / psi*
  - *10.2 meters WC / bar*

Gas Pressure

- *Removing gas from a vessel reduces the number of molecules in the vapor phase*
  - *Some forms of energy may not propagate well when there are fewer molecules*
    - *Ultrasonic*

Gas Pressure

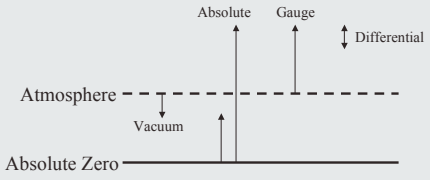
- *Removing gas from a container lowers the pressure in the container*
  - *If all gas is removed, absolute zero pressure (full vacuum) is reached at approximately -1.01325 bar (-14.696 psig)*



Gas Pressure

- *Absolute pressure scales are relative to absolute zero pressure*
  - *Absolute zero pressure*
    - *Full vacuum = 0 bar abs (0 psia)*
    - *bar abs = bar + 1.01325*
    - *psia = psig + 14.696*

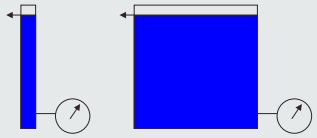
Gas Pressure



Liquid Pressure

- *Bernoulli's Theorem states that the pressure exerted by a liquid in an open tank is independent of the cross-sectional area of the liquid*

Liquid Pressure

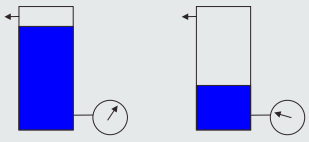


Open tanks overflowing with the same liquid

Liquid Pressure

- *The pressure exerted by a liquid in an open tank is dependent on the height of the liquid*

Liquid Pressure

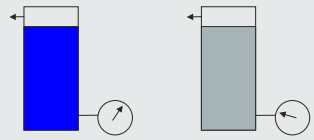


Open tanks with the same liquid

Liquid Pressure

- *The pressure exerted by a liquid in an open tank is dependent on the density of the liquid*

Liquid Pressure



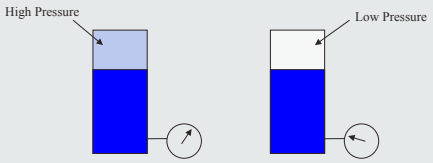
Open Tank
High Density Liquid

Open Tank
Low Density Liquid

Liquid Pressure

- *The pressure exerted by a liquid in a pressurized tank is dependent on the height of the liquid, its density, and the pressure in the vapor space*

Liquid Pressure

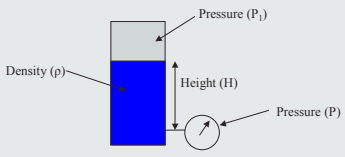


Liquids have the same density and same level

Liquid Pressure

- *The liquid pressure exerted can be calculated (in like units):*
  - *(Height x Density) + Static Pressure*

Liquid Pressure



$P = P_1 + \rho \bullet H$

Level Measurement Fundamentals

- *Temperature*
- *Density*
- *Pressure*
- ***Expansion***
- *Viscosity*
- *Static Interface Geometry*
- *Types of Level Measurement*
- *Vessel Geometry*
- *Dynamic Phenomena*

Liquid Expansion

- *The density of most liquids is nearly unaffected by pressure*
- *Expansion of liquids*
  - $V = V_0 (1 + \beta \cdot \Delta T)$
    - *V = new volume*
    - V_0 *= old volume*
    - β *= cubical coefficient of expansion*
    - ΔT *= temperature change*

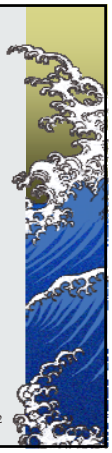
Liquid Expansion

Problem

- *What is the change in density of a liquid caused by a 10°C temperature rise where β is 0.0009 per °C ?*

Liquid Expansion

- *Calculate the new volume*
  - $V = V_0 (1 + 0.0009 \bullet 10) = 1.009\ V_0$
  - *The volume of the liquid increased to 1.009 times the old volume, so the new density is (1/1.009) or 0.991 times the old density*

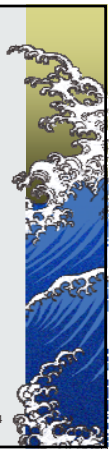


Expansion of Metals

- *Expansion of metals*
  - $V = V_0 (1 + \beta \bullet \Delta T)$
    - *where* $\beta = 3 \bullet \alpha$
    - α *= linear coefficient of expansion*
- *Temperature coefficient*
  - *Stainless steel temperature coefficient is approximately 0.5% per 100°C*

Expansion of Metals

- *What is the change in size of a round stainless steel tank if its temperature increases by 100°C ?*



Expansion of Metals

- *The tank circumference will increase in proportion to α*
  - *β = 3•α, so*
  - *α = 0.5/3 = 0.1667 percent (approx)*

Expansion of Metals

- *The contents of the tank at a given level will increase in proportion to its diameter*
- *Diameter changes with the square of the change in circumference*
  - *$(1.001667)^2 = 1.00333$ or 0.333 percent*

Expansion of Metals

- *The tank height will also increase and can affect level measurement*
  - *Different distance to sensor*
  - *Effect depends on level in tank*
    - *Larger effect near empty*

Level Measurement Fundamentals

- *Temperature*
- *Density*
- *Pressure*
- *Expansion*
- ***Viscosity***
- *Static Interface Geometry*
- *Types of Level Measurement*
- *Vessel Geometry*
- *Dynamic Phenomena*

Viscosity

- *Viscosity is the ability of the fluid to flow over itself*
- *Units*
  - *cP, cSt*
  - *Saybolt Universal (at 100ºF, 210 ºF)*
  - *Saybolt Furol (at 122ºF, 210 ºF)*

Viscosity

- *Viscosity can be highly temperature dependent*
  - *Water*
  - *Honey at 40°F, 80°F, and 120°F*
  - *Peanut butter*

Viscosity

- *Viscosity can affect level measurement*
  - *Coating*
  - *Sticking*

Level Measurement Fundamentals

- *Temperature*
- *Density*
- *Pressure*
- *Expansion*
- *Viscosity*
- ***Static Interface Geometry***
- *Types of Level Measurement*
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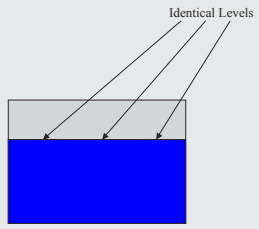
Static Liquid Interface

- *Static liquid interface tends to be perpendicular to direction of gravity*
  - *Level identical across vessel*
  - *One level measurement can be representative of level in entire vessel*

Static Liquid Interface



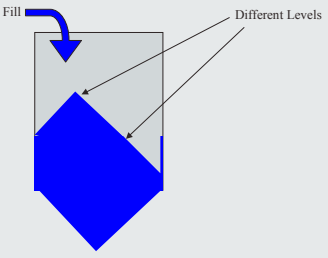
Static Solids Interface

- *Static liquid interface tends not to be perpendicular to direction of gravity*
  - *Level is not identical across vessel*
  - *One level measurement is generally not representative of level in entire vessel*

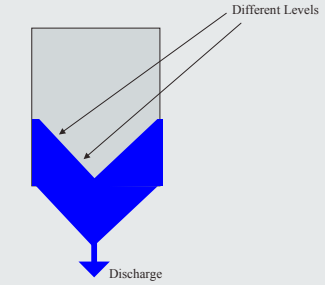
Static Solids Interface

- *Angle of Repose*
- *Rat Holing*

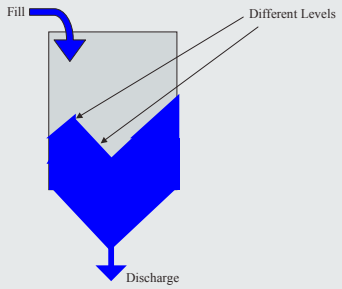
Static Solids Interface



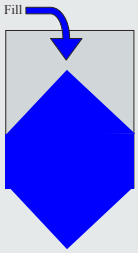
Static Solids Interface



Static Solids Interface

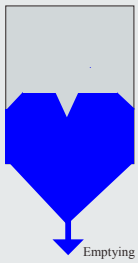


Rat Holing



Rat Holing

Rat Holing



Rat Holing

- *Level generally falls slowly while discharging*
- *Level rises suddenly when material fills in the rat hole*

Level Measurement Fundamentals

- *Temperature*
- *Density*
- *Pressure*
- *Expansion*
- *Viscosity*
- *Static Interface Geometry*
- ***Types of Level Measurement***
- *Vessel Geometry*
- *Dynamic Phenomena*

Types of Level Measurement

- *Related Quantities*
  - *Level*
  - *Volume*
  - *Mass*

Types of Level Measurement

- $m = \rho \bullet V$
  - m *mass*
  - ρ *density or bulk density*
  - V *volume*

Types of Level Measurement

- *Typical Units* ($m = \rho \bullet V$)
  - $lb/ft^3 \bullet ft^3 = lb$
  - $kg/m^3 \bullet m^3 = kg$

Types of Level Measurement

- *Level measurement*
  - *Height of material in vessel*
    - *feet*
    - *meters*

Types of Level Measurement

- *Inferred volume of material in vessel*
  - *Measure level*
  - *Use tank geometry to calculate volume*

Types of Level Measurement

- *Volume of material in vessel*
  - *Round vertical flat bottom tank*

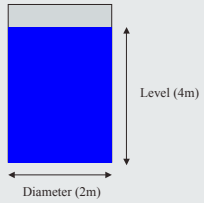
    $V = \frac{1}{4} \bullet \pi \bullet D^2 \bullet H$
  - *Dish / cone*
  - *Horizontal tank*

Types of Level Measurement

Problem

- *What is the inferred volume of liquid in a round vertical flat bottom tank that is 2 meters in diameter when the liquid level is measured to be 4 meters above the bottom?*

Types of Level Measurement



Types of Level Measurement

- *Calculate the inferred liquid volume*

$V = ¼ \bullet \pi \bullet D^2 \bullet H$

$= ¼ \bullet \pi \bullet 2^2 \bullet 4$

$= 12.57\ m^3$

Types of Level Measurement

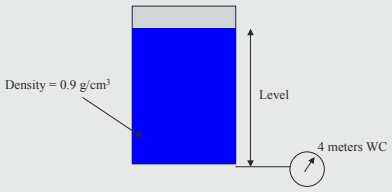
- *Inferred level measurement*
  - *Measure*
  - *Use material properties (density / bulk density) to calculate level*
    - $H = \Delta P / \rho$

Types of Level Measurement

Problem

- *What is the level of liquid with a density of 0.9 g/cm³ in a round vertical flat bottom tank that is 2 meters in diameter when the pressure at the bottom of the tank is 4 meters of water column?*

Types of Level Measurement



Types of Level Measurement

- *Calculate the inferred level*
  - *Noting that 1 meter of liquid is generates the same pressure as 0.9 meters of water (WC)*

$$H = 4 \text{ m WC} \bullet (1 \text{ m liquid} / 0.9 \text{ m WC})$$
$$= 4.44 \text{ meters}$$

Types of Level Measurement

- *Mass measurement*
  - *Quantity (mass) of material in vessel*
    - *pounds*
    - *kilograms*

Types of Level Measurement

- *Inferred volume measurement*
  - *Measure mass of material*
  - *Use material properties (density / bulk density) to calculate volume*

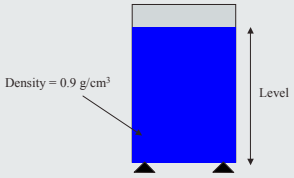
$$V = m / \rho$$

Types of Level Measurement

Problem

- *What is the volume of liquid with a density of 0.9 g/cm³ in a round vertical flat bottom tank that is 2 meters in diameter when the weight of the liquid is 12 MT?*

Types of Level Measurement



Types of Level Measurement

- *Calculate the volume*

  $V = m / \rho$

  $= 12000\ kg / 900\ kg/m^3$

  $= 13.33\ m^3$

Types of Level Measurement

- *Inferred mass measurement*
  - *Measure level*
  - *Use tank geometry to calculate volume*
  - *Use volume and material properties (density / bulk density) to calculate mass*

Types of Level Measurement

- *Inferred mass measurement*
  - *Calculate volume using tank geometry*
    - *Vertical round flat bottom tank*

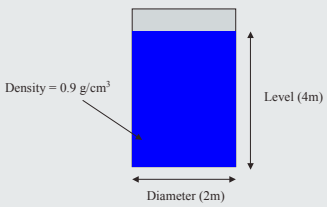
      $V = \frac{1}{4} \bullet \pi \bullet D^2 \bullet H$
  - *Calculate mass using density*
    - $m = \rho \bullet V$

Types of Level Measurement

Problem

- *What is the inferred mass of a liquid with a density of 0.9 g/cm³ in a round vertical flat bottom tank that is 2 meters in diameter when the liquid level is measured to be 4 meters above the bottom?*

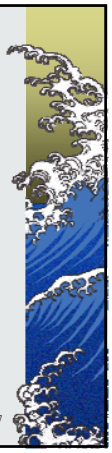
Types of Level Measurement



Types of Level Measurement

- *The inferred liquid volume was previously calculated*

$$V = \frac{1}{4} \cdot \pi \cdot D^2 \cdot H$$
$$= \frac{1}{4} \cdot \pi \cdot 2^2 \cdot 4$$
$$= 12.57\ m^3$$



Types of Level Measurement

- *Calculate the mass of the liquid*

$$m = \rho \cdot V$$
$$= 900\ kg/m^3 \cdot 12.57\ m^3$$
$$= 11313\ kg$$

Types of Level Measurement

- *Level and mass measurements are subject to uncertainty*
- *Inferred measurements are subject to additional uncertainty*
  - *Density / bulk density*
  - *Geometry*

Level Measurement Fundamentals

- *Temperature*
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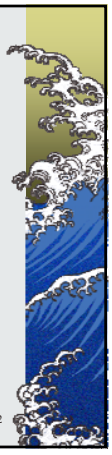
- *Types of Level Measurement*
- ***Vessel Geometry***
- *Dynamic Phenomena*

Vessel Geometry

- *The inside vessel dimensions are important for inferring volume/mass*
  - *Drawings often show outside dimensions*
    - *Wall thickness*

Vessel Geometry

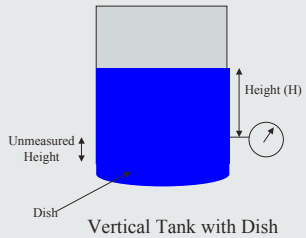
- *Drawings often state nominal tank volume*
  - *Calculations based upon actual dimensions will likely be different*



Vessel Geometry

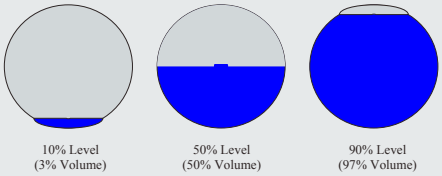
- *Inferred (level and mass) measurements should take into account:*
  - *Unmeasured volume*
  - *Dish / cone volume*
  - *Vessel orientation*

Vessel Geometry



Vertical Tank with Dish

Vessel Geometry

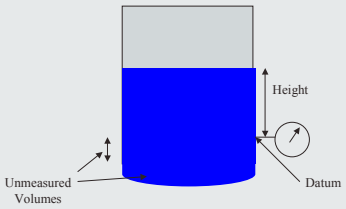


Horizontal Tank (Non-linear Level Measurement)

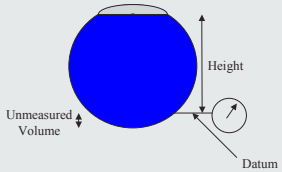
Vessel Geometry

- *A reference location (datum) should be determined based upon*
  - *Sensing technology*
  - *Sensor location*
  - *Vessel geometry*

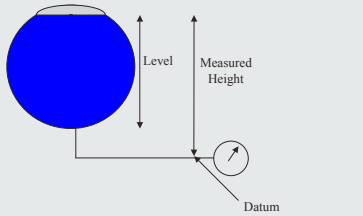
Vessel Geometry



Vessel Geometry



Vessel Geometry



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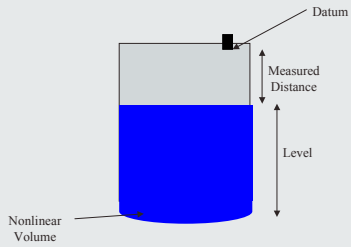
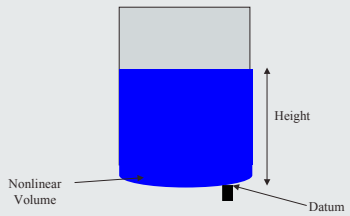
Vessel Geometry



110

Vessel Geometry



111

Vessel Geometry

- *Units of Measurement*
  - *Percent level*
  - *Volume (m^3)*
  - *Mass (kg)*
  - *Height (m)*

Vessel Geometry

- *Units of Measurement*
  - *Can be zero-based or offset to account for vessel geometry*
  - *Two (or more) units may be used to meet the requirements of multiple users*

Vessel Geometry

- *Units of Measurement*
  - *Percent level (e.g. 0-100 percent)*
    - *Advantage - common value for all tanks*
      - *Can help avoid over/underflows*
    - *Disadvantage - amount of material in vessel not indicated*

Vessel Geometry

- *Units of Measurement*
  - *Volume (e.g. 0.55-8.5 m^3)*
    - *Advantage - indicates volume of material in vessel*
    - *Disadvantage - amount of material in vessel not indicated*

Vessel Geometry

- *Units of Measurement*
  - *Volume (e.g. 0.55-8.5 m^3)*
    - *Disadvantage - most tanks are different sizes, so operator should be trained to avoid overflowing the vessel*
      - *More confusing for operator due to different numbers for each tank*

Vessel Geometry

- *Units of Measurement*
  - *Mass (e.g. 550-8500 kg)*
    - *Advantage - indicates amount of material in vessel*

Vessel Geometry

- *Units of Measurement*
  - *Mass (e.g. 550-8500 kg)*
    - *Disadvantage - most tanks are different sizes, so operator should be trained to avoid overflowing the vessel*
      - *More confusing for operator due to different numbers for each tank*

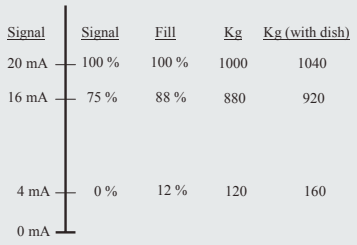
Vessel Geometry

- *Units of Measurement*
  - *Height (e.g. 0-10 meters)*
    - *Advantage - indicates actual level*
    - *Disadvantage - amount of material in vessel not indicated*

Vessel Geometry

- *Units of Measurement*
  - *Mass (e.g. 0-10 meters)*
    - *Disadvantage - most tanks are different heights, so operator should be trained to avoid overflowing the vessel*
      - *More confusing for operator due to different heights for each tank*

Vessel Geometry



Signal	Fill	Kg	Kg (with dish)
100 %	100 %	1000	1040
75 %	88 %	880	920
0 %	12 %	120	160

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Level Measurement Fundamentals

- *Temperature*
- *Density*
- *Pressure*
- *Expansion*
- *Viscosity*
- *Static Interface Geometry*
- *Types of Level Measurement*
- *Vessel Geometry*
- ***Dynamic Phenomena***

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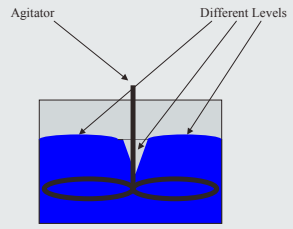
Dynamic Phenomena - Mixing

- *Can affect interface*
  - *Non-static interface*
  - *Alters interface geometry*
  - *Can scatter energy and weaken reflected energy signal*

123

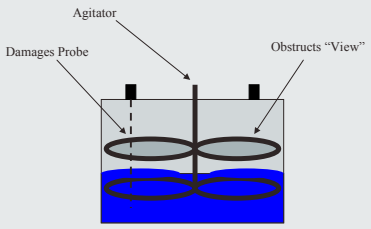
Dynamic Phenomena - Mixing



Dynamic Phenomena - Mixing

- *Can affect ability to measure*
  - *Damage probe*
  - *Obstruct "view"*

Dynamic Phenomena - Mixing



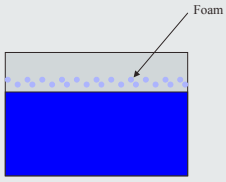
Dynamic Phenomena - Foam

- *Affects interface*
  - *Type of foam*
    - *Level gauge may measure top, bottom, or middle of foam*
      - *Depends on technology and foam properties*
  - *Alters interface geometry*

Dynamic Phenomena - Foam

- *Affects interface*
  - *Excessive foam can raise level measurement to 100%*
  - *Foam can scatter energy and weaken reflected energy signal*

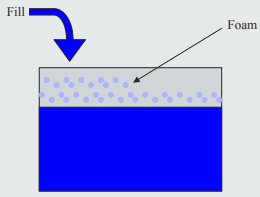
Dynamic Phenomena - Foam



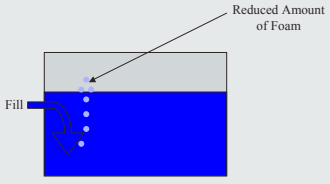
Dynamic Phenomena - Foam

- *Reduce foam as much as practical*
  - *De-foaming additives*
  - *Submerged fill can sometimes reduce formation of foam*

Dynamic Phenomena - Foam



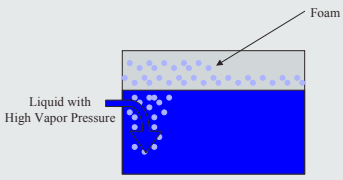
Dynamic Phenomena - Foam



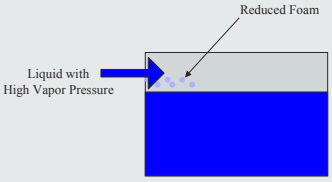
Dynamic Phenomena - Foam

- *Reduce foam as much as practical*
  - *Submerged fill can sometimes increase formation of foam*
    - *High vapor pressure*

Dynamic Phenomena - Foam



Dynamic Phenomena - Foam



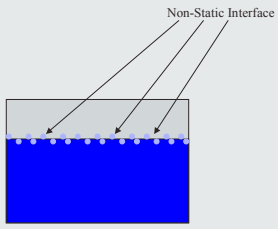
Dynamic Phenomena - Boiling

- *Affects interface*
  - *Non-static interface*
    - *Measurement can usually be averaged*
  - *Alters interface geometry*

Dynamic Phenomena - Boiling

- *Affects interface*
  - *Can raise level (from static)*
  - *Can scatter energy and weaken reflected energy signal*

Dynamic Phenomena - Boiling



Dynamic Phenomena - Vapor

- *Composition changes*
  - *Can attenuate energy and signal*

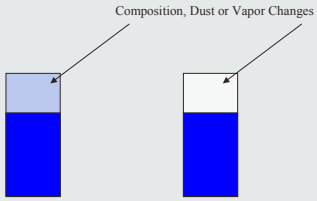
Dynamic Phenomena - Vapor

- *Dust*
  - *Can attenuate energy and signal*

Dynamic Phenomena - Vapor

- *Temperature changes*
  - *Can change velocity of energy in vapor space*

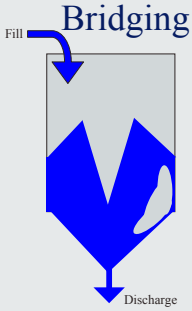
Dynamic Phenomena - Vapor



Dynamic Phenomena - Bridging

- *Voids formed in the vessel*
  - *Affects the inferred amount of material in the vessel*
  - *Can affect the ability of the material to discharge from the vessel*

Dynamic Phenomena - Bridging



Seminar Outline

- *Introduction*
- *Level Measurement Fundamentals*
- ***Level Measurement Technology***
- *Level Gauge Performance*
- *Consumer Guide*

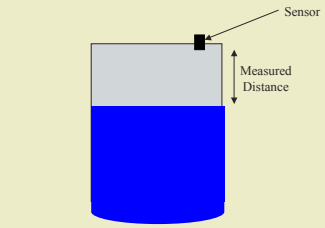
Non-Contact Level Gauge Technology

- ***Principle of Operation***
- *Sensor Geometry*
- *Transmitter Design*
- *Installation*
- *Accessories*
- *Other Level Gauge Technologies*

Principle of Operation

- *Non-contact level gauge*
  - *Sensor located above material*
  - *Measure distance from sensor to material*

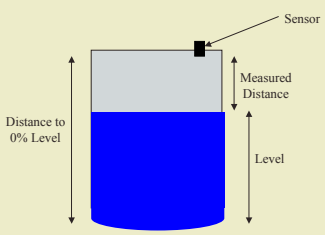
Principle of Operation



Principle of Operation

- *Non-contact level gauge*
  - *Use vessel dimensions to determine level as compared to a reference (say, 0% level)*

Principle of Operation



Principle of Operation

- *Non-contact level gauge*
  - *Use vessel dimensions and physical properties to determine the quantity of material in the vessel*

Principle of Operation

- *Time-of-Flight (Pulsed)*
  - *Measure time between:*
    - *Energy sent to material surface*
    - *Energy received after being reflected off the material surface*

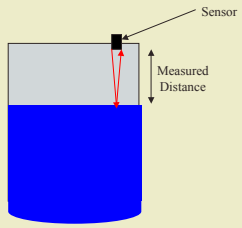
Principle of Operation

- *Time-of-Flight (Pulsed)*
  - *Velocity of energy in vapor space*
    - *Laser - speed of light*
    - *Radar - speed of light*
    - *Ultrasonic - speed of sound*

Principle of Operation

- *Time-of-Flight (Pulsed)*
  - *Short measured time*
    - *Laser*
    - *Pulsed radar*
  - *Longer measured time*
    - *Ultrasonic*

Principle of Operation Laser



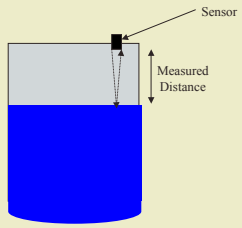
Principle of Operation Laser

- *Measurement quality dependent on:*
  - *Strength of laser beam*
  - *Distance from sensor*
  - *Reflective nature of material surface*
    - *Light can penetrate liquid*
    - *Light can reflect poorly*

Principle of Operation Laser

- *Measurement quality dependent on:*
  - *Static and dynamic interface geometry*
    - *Light can be scattered*
  - *Vapor space attenuation*
    - *Opacity of vapor*
    - *Dust*

Principle of Operation Ultrasonic



Principle of Operation Ultrasonic

- *Measurement quality dependent on:*
  - *Strength of ultrasonic energy beam*
  - *Distance from sensor*
  - *Reflective nature of material surface*
    - *Ultrasonic energy can reflect poorly*

Principle of Operation Ultrasonic

- *Measurement quality dependent on:*
  - *Static and dynamic interface geometry*
    - *Ultrasonic energy can be scattered*

Principle of Operation Ultrasonic

- *Measurement quality dependent on:*
  - *Vapor space - Speed of sound*
    - *Pressure*
      - *Vary 0.5 - 2 bar absolute <<1% change*
    - *Temperature*
      - *331.3+0.6*T (T in °C)*
      - *0.18% per °C (at 0 °C)*

Principle of Operation Ultrasonic

- *Measurement quality dependent on:*
  - *Vapor space - Speed of sound*
    - *Composition*
      - *Different materials have different speeds and different temperature effects*
        - *Hydrogen (~20% per 20 °C)*
    - *Humidity*

Principle of Operation Ultrasonic

- *Measurement quality dependent on:*
  - *Vapor space - Attenuation*
    - *Opacity of vapor to ultrasonic beam*
      - *Vapor absorbs energy*
      - *Methane with CO_2*
    - *Dust*
    - *Low pressure (vacuum)*

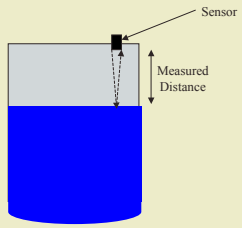
Principle of Operation Ultrasonic

- *Measurement quality dependent on:*
  - *Vapor space - Beam deflection*
    - *Wind effect*
    - *Thermal gradient*
      - *Hot material with cool vapor space*
      - *Erroneous reflections at temperature boundary*

Principle of Operation Ultrasonic

- *Attenuation factors (Magnetrol)*
  - *Vortex* 0.7-1
  - *Condensation* 0.8-1
  - *Interference* 0.5-1
  - *Beam perpendicular to surface* 0.5-1
  - *Foam* 0.1-1
  - *Dust* 0.1-1
  - *Air movement* 0.7-1

Principle of Operation
Pulsed Radar



Principle of Operation
Pulsed Radar

- *Measurement quality dependent on:*
  - *Strength of radar energy beam*
  - *Distance from sensor*
  - *Reflective nature of material surface*
    - *Radar energy can reflect poorly*

Principle of Operation
Pulsed Radar

- *Measurement quality dependent on:*
  - *Radar energy can be absorbed by liquid*
    - *Dielectric constant*
      - *Typically greater than 1.4-2.0*
      - *Depends on design*

Principle of Operation Pulsed Radar

- *Measurement quality dependent on:*
  - *Static and dynamic interface geometry*
    - *Radar energy can be scattered*

Principle of Operation Pulsed Radar

- *Type of media (Endress+Hauser)*

	Dielectric	
A	*1.4 - 1.9*	*Non-conducting liquids, liquefied gas*
B	*1.9 - 4*	*Non-conducting liquids, benzene, oil*
C	*4 - 10*	*Acids, solvents, alcohol*
D	*>10*	*Water*

Principle of Operation Pulsed Radar

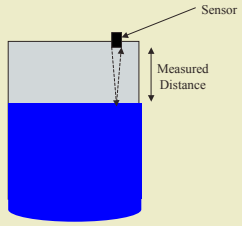
- *Maximum sensor distance depends on surface condition and sensor size (Endress+Hauser)*

	Calm Surface		Moving Surface		Agitated Surface	
	40mm	100mm	40mm	100mm	40mm	100mm
A	*Use stilling well*		*Use stilling well*		*Use stilling well*	
B	*3m*	*15m*	*2m*	*7.5m*	*1m*	*3m*
C	*5m*	*20m*	*3m*	*10m*	*1.5m*	*5m*
D	*9m*	*20m*	*5m*	*12.5m*	*2m*	*7m*

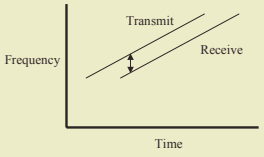
Principle of Operation FMCW Radar

- *Frequency Modulated Continuous Wave*
  - *Measure frequency difference between:*
    - *Frequency of radar energy sent to material surface*
    - *Frequency of radar energy received after being reflected off the material surface*

Principle of Operation FMCW Radar



Principle of Operation FMCW Radar



Principle of Operation FMCW Radar

- *Frequency Modulated Continuous Wave*
  - *Advantage - frequency difference can often be measured more accurately than time difference*
    - *Time difference is usually small due to radar traveling at the speed of light*

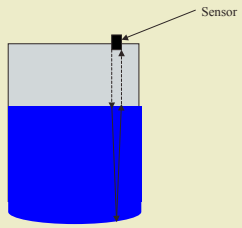
Principle of Operation FMCW Radar

- *Frequency Modulated Continuous Wave*
  - *Advantage - in some applications, peaks in frequency spectrum can detect other levels*
    - *Actual level*
    - *Liquid-liquid interface*
    - *Stratification*

Principle of Operation Proprietary FMCW Radar

- *Tank Bottom Following*
  - *Radar energy sent through vapor space and liquid*
  - *Radar energy received after being reflected off bottom of vessel*

Principle of Operation
Proprietary FMCW Radar



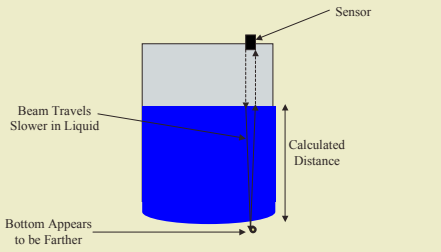
Principle of Operation
Proprietary FMCW Radar

- *Tank Bottom Following*
  - *Radar energy travels slower through liquid*
  - *Higher liquid level makes the tank bottom measurement appear to be farther away*

Principle of Operation
Proprietary FMCW Radar

- *Tank Bottom Following*
  - *Liquid level can be calculated for a known dielectric based upon the difference between the actual and measured tank bottom distances*

Principle of Operation
Proprietary FMCW Radar



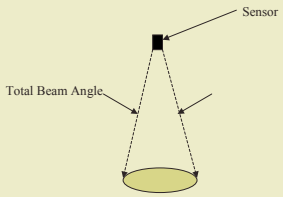
Principle of Operation
Proprietary FMCW Radar

- *Tank Bottom Following*
  - *Advantage*
    - *Dielectric constant as low as 1.05*
  - *Disadvantage*
    - *Need relatively constant dielectric for accurate measurement*
    - *Dielectric constant can be affected by temperature and composition*

Principle of Operation
Beam Angle

- *Energy beam disperses*
- *Smaller beam emits a more concentrated beam as a percentage of total energy*
  - *Stronger return signal*

Principle of Operation
Total Beam Angle



Principle of Operation
Beam Angle

- *Beam angle is usually defined by the 3db energy level*
- *Many suppliers specify the beam angle from normal*
  - *One-half of the total beam angle*

Principle of Operation
Beam Angle

- *Strongest reflections occur in the cone*
- *Keep obstructions out of the cone*

Principle of Operation
Beam Angle

- *Laser sensors*
  - *Narrow beam angles (less than 1 degree)*

Principle of Operation
Beam Angle

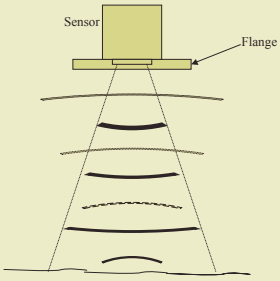
- *Radar and ultrasonic*
  - *Larger sensors tend to have narrower beam angles*
  - *Higher excitation frequency tends to:*
    - *Narrow beam angle*
    - *Increase resolution*

Non-Contact Level Gauge Technology

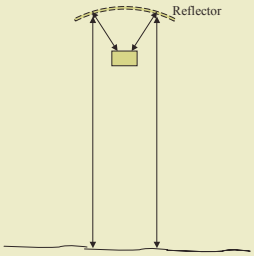
- *Principle of Operation*
- ***Sensor Geometry***
- *Transmitter Design*
- *Installation*
- *Accessories*
- *Other Level Gauge Technologies*

Sensor Geometry - Laser

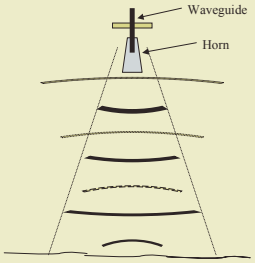
Sensor Geometry - Ultrasonic



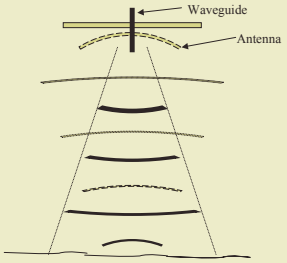
Sensor Geometry - Ultrasonic



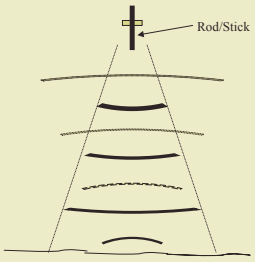
Sensor Geometry Radar (Horn)



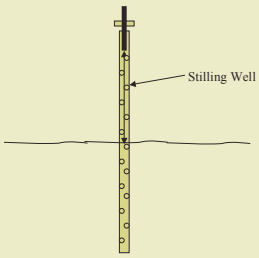
Sensor Geometry Radar (Parabolic)



Sensor Geometry Radar (Rod/Stick)



Sensor Geometry
Radar (Stilling Well)



Non-Contact Level Gauge Technology

- *Principle of Operation*
- *Sensor Geometry*
- ***Transmitter Design***
- *Installation*
- *Accessories*
- *Other Level Gauge Technologies*

Level Gauge Transmitter Designs

- *Analog*
  - *Electrical components subject to drift*
  - *Mathematical corrections difficult*
  - *Four-wire design*

Level Gauge Transmitter Designs

- *Digital*
  - *Microprocessor is less susceptible to drift*
  - *Mathematical corrections in software*
  - *Four-wire design*
  - *Remote communication (with HART)*

Level Gauge Transmitter Designs

- *Fieldbus*
  - *Microprocessor is less susceptible to drift*
  - *Mathematical corrections in software*
  - *Multi-drop wiring*
  - *Remote communication*
  - *Issues with multiple protocols*

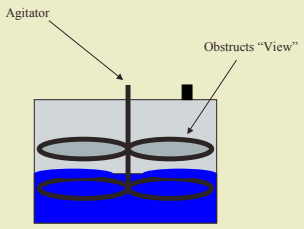
Level Gauge Transmitter Designs

- *Calculations*
  - *Level*
  - *Volume*
  - *Mass*
  - *% Full*

Level Gauge Transmitter Designs

- *Calculations*
  - *Damping*
  - *Fixed target blanking*
  - *Moving target blanking*
    - *Agitator*

Level Gauge Target Blanking



Non-Contact Level Gauge Technology

- *Principle of Operation*
- *Sensor Geometry*
- *Transmitter Design*
- ***Installation***
- *Accessories*
- *Other Level Gauge Technologies*

Installation

- *Material Characteristics*
- *Vapor Characteristics*
- *Vessel Considerations*
- *Sensor Considerations*
- *Electrical Installation*
- *Calibration*
- *Ambient Conditions*
- *Setup Information*

Material Characteristics

- *Reflection at Surface*
  - *Sensor range is degraded as surface reflection is reduced*

Material Characteristics

- *Surface Reflection*
  - *Laser - reflect light*
  - *Ultrasonic - reflect sound*

Material Characteristics

- *Surface Reflection*
  - *Radar - reflect RF energy*
    - *Dielectric constant*
      - *Over 10 is similar to reference conditions*
      - *Under 10 may require more energy*
        - *Some energy absorbed in material*
      - *Radar typically not advised under 1.5*
        - *More energy absorbed in material*

Material Characteristics

- *Surface - Dynamic Phenomena*
  - *Boiling*
  - *Mixing*

Material Characteristics

- *Surface - Dynamic Phenomena*
  - *Foam*
    - *Laser – top of opaque, bottom of transparent, ??? of translucent*
    - *Ultrasonic – typically top of foam*
    - *Radar – top, bottom, or ???, depending on dielectric constant of foam*

Material Characteristics

- *Build-up on Sensor*
  - *Laser – dirt/dust*
  - *Ultrasonic – dirt/dust*
  - *Radar - typically not affected*

Vapor Characteristics

- *Transparent - reference conditions*
- *Translucent*
  - *Weakens energy*
  - *Degrades distance*
  - *May require higher power sensor*

Vapor Characteristics

- *Opaque - failure to operate*
  - *Cloud of dust*
  - *Cloud of smoke*
  - *These conditions should be taken into account even though they may occur only under certain conditions*

Vapor Characteristics

- *Ultrasonic*
  - *Speed of sound can be affected by:*
    - *Pressure*
    - *Temperature*
    - *Composition of vapor*

Vapor Characteristics

- *Ultrasonic*
  - *Speed of sound compensation*
    - *Internal (in sensor)*
    - *External*

Vessel Considerations

- *Energy beam orientation*
  - *Measure level representative of contents*
    - *Rat holes (discharge)*
    - *Piles (fill)*

Vessel Considerations

- *Energy beam orientation*
  - *Avoid turbulent locations*
  - *Avoid internal obstructions*
  - *Avoid moving parts*
    - *Many transmitters can ignore moving agitators*

Sensor Considerations

- *Wetted parts compatible with material*
- *Withstand pressure/temperature*
  - *High temperature - insulate sensor*
  - *Condensation - avoid these locations*

Sensor Considerations

- *Blanking distance*
  - *Cannot measure close to sensor*
  - *Do not locate sensor too close to nearest distance to be measured*

Sensor Considerations

- *Better reflection when sensor is mounted perpendicular to material*
- *Select and install sensor to not intrinsically collect material or dust*

Sensor Considerations

- *Laser and radar*
  - *Windows are available to eliminate contact with material*
  - *Sensors can be mounted on nozzle*

Sensor Considerations

- *Laser and radar*
  - *Do not install sensor symmetrically in vessel*
    - *Can cause multiple reflections*

Sensor Considerations

- *Laser and radar*
  - *Coupling of vessel lining should be known and taken into account*
    - *Can be (poor) waveguide and cause spurious reflections*

Sensor Considerations

- *Radar and Ultrasonic*
  - *Wide beam angle*
    - *Locate sensor away from wall*
    - *Helps avoid multiple reflections*
    - *Stilling well sensor geometry should be considered when sensor must be located close to the wall*

Sensor Considerations

- *Ultrasonic*
  - *Soft gasket for flanged sensors*

Electrical Installation

- *Integral sensors reduce wiring cost*
- *Wiring*
  - *Low voltage power supply can eliminate power conduit*
  - *Fieldbus reduces wiring*

Ambient Conditions

- *Outdoor applications (-20 to 60°C)*
  - *Some designs are for indoor locations*
- *Hazardous locations*
  - *Some designs are general purpose*

Calibration

- *Calibrate close to the range to be used*
- *When two applicable transmitters are considered, better performance is usually achieved with the lower range transmitter*

Calibration

- *Typical empty/full levels*
  - *Lower/upper tangent lines (vertical vessel)*
  - *Lower/upper shell (horizontal vessel)*

Calibration

- *Typical calibration units*
  - *Height*
  - *Vessel content*
  - *Percent fill*
    - *Usually preferred for uniformity*
- *Displays can indicate more than one*

Setup Information

- *GIGO (garbage in – garbage out)*
- *Entering correct information correctly is critical*
  - *Dimensions*
  - *Blanking*
  - *Dynamic effects*
  - *Material properties*

Setup Information

- *Failure to use correct information can cause significant error and startup problems*

Non-Contact Level Gauge Technology

- *Principle of Operation*
- *Sensor Geometry*
- *Transmitter Design*
- *Installation*
- ***Accessories***
- *Other Level Gauge Technologies*

Accessories

- *Level Sensor*
  - *Purge connection*
  - *High temperature*
  - *Sanitary*

Accessories

- *Transmitter*
  - *NEMA 4X and IP67*
  - *Compensation for fill shape*
  - *Data logging functionality*

Accessories

- *Transmitter signals*
  - *Analog output*
  - *Alarms*
  - *HART, Foundation Fieldbus, Profibus*

Non-Contact Level Gauge Technology

- *Principle of Operation*
- *Sensor Geometry*
- *Transmitter Design*
- *Installation*
- *Accessories*
- ***Other Level Gauge Technologies***

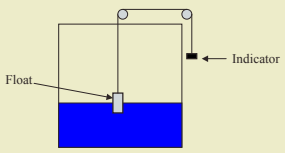
Other Level Gauge Technologies

- *Mechanical*
- *Level Gauges with Fluid Contact*
- *Level Gauges without Fluid Contact*
- *Externally-Mounted*
- *Open Channel*

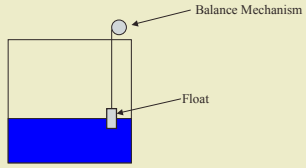
Mechanical Level Gauges

- *Float*
- *Magnetostrictive*
- *Retracting*

Level Gauge - Mechanical Float



Level Gauge - Mechanical Float



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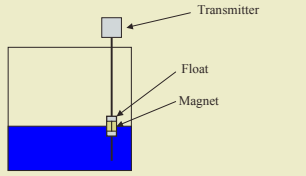
Level Gauge - Mechanical Magnetostrictive



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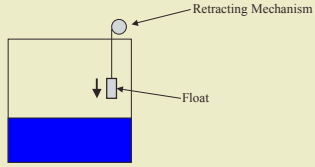
Level Gauge - Mechanical Retracting



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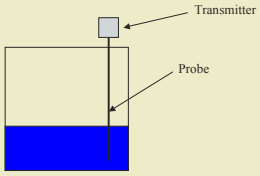
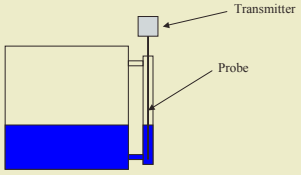
Level Gauges with Fluid Contact

- *Capacitance*
- *Hydrostatic*
- *Radar (contact)*
- *Ultrasonic (submerged)*

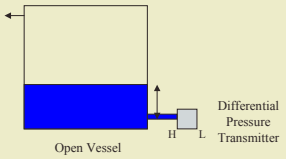
Level Gauge - Fluid Contact Capacitance



Level Gauge - Fluid Contact Capacitance(External Chamber)



Level Gauge - Fluid Contact Hydrostatic



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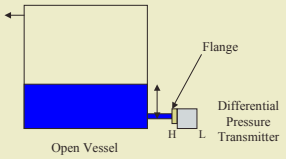
Level Gauge - Fluid Contact Hydrostatic



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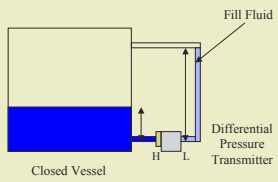
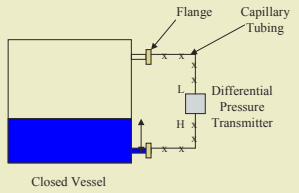
Level Gauge - Fluid Contact Hydrostatic



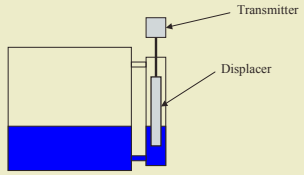
249

Level Gauge - Fluid Contact Hydrostatic



250

Level Gauge - Fluid Contact Hydrostatic (Displacer)



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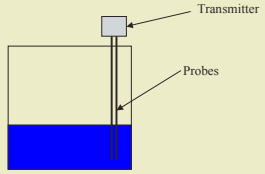
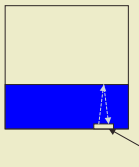
Level Gauge - Fluid Contact Radar



252

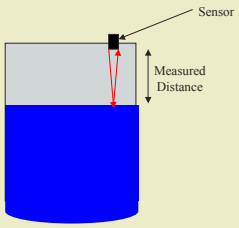
Level Gauge - Fluid Contact Ultrasonic (Submerged)



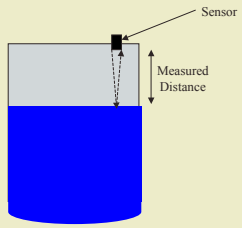
Level Gauges - Non-Contact

- *Laser*
- *Radar (non-contact)*
- *Ultrasonic*

Level Gauge - Non-Contact Laser



Level Gauge - Non-Contact Pulsed Radar and Ultrasonic



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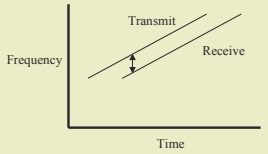
Level Gauge - Non-Contact FMCW Radar



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Level Gauges Externally-Mounted

- *Laser (with window)*
- *Radar (non-contact with isolator)*
- *Ultrasonic (bottom-up)*
- *Nuclear*
- *Weighing*

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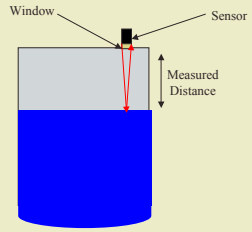
Level Gauge - External Laser with Window



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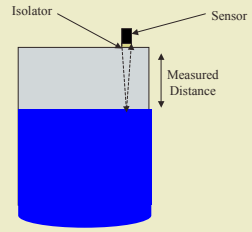
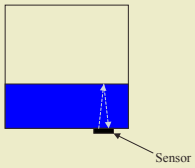
Level Gauge - External Radar with Isolator



260

Level Gauge - External Ultrasonic (Bottom-Up)



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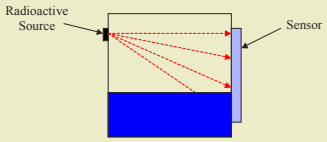
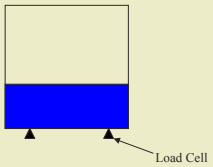
Level Gauge - External Nuclear



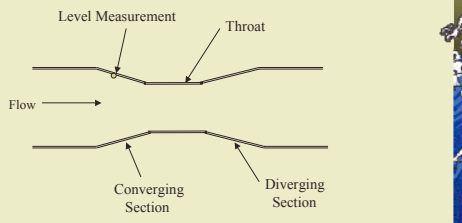
Level Gauge - External Weighing



Open Channel Flowmeter Technologies

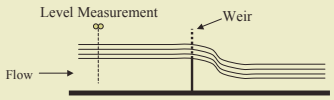
- *Flowmeters*
  - *Flume*
  - *Weir*

Open Channel Flowmeter Flume



265

Open Channel Flowmeter Weir



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Open Channel Flowmeter Level Gauge Technologies

- *Level Gauges*
  - *Capacitance*
  - *Float*
  - *Hydrostatic*
  - *Ultrasonic*
  - *Others*

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Seminar Outline

- *Introduction*
- *Level Measurement Fundamentals*
- *Level Measurement Technology*
- ***Level Gauge Performance***
- *Consumer Guide*

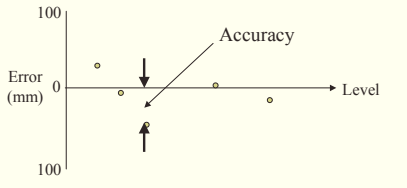
Level Gauge Performance

- ***Level Gauge Performance***
- *Performance Statements*
- *Reference Performance*
- *Actual Performance*
- *Supplier Claims*

Level Gauge Performance

- *Accuracy is the ability of the instrument to produce a measurement that corresponds to its true value*

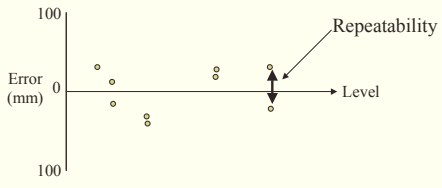
Level Gauge Performance



Level Gauge Performance

- *Repeatability is the ability of the flowmeter to reproduce a measurement each time a set of conditions is repeated*

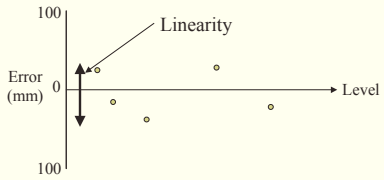
Level Gauge Performance



Level Gauge Performance

- *Linearity is the ability of the relationship between level and the level gauge output to approximate a linear relationship*

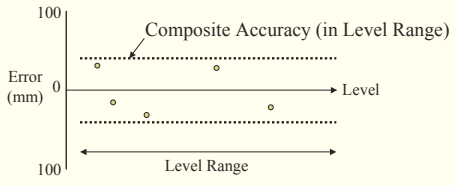
Level Gauge Performance



Level Gauge Performance

- *Level gauge suppliers often specify the composite accuracy that represents the combined effects of repeatability, linearity and accuracy*

Flowmeter Performance



Level Gauge Performance

- *Level Gauge Performance*
- ***Performance Statements***
- *Reference Performance*
- *Actual Performance*
- *Supplier Claims*

Performance Statements

- *Absolute (fixed) distance (mm)*
- *Percent of measured distance*
- *Percent of set span*
- *Percent of maximum span*
- *Percent of empty distance (farthest measurement in span)*
- *Percent of maximum sensor distance*

Performance Statements

- *Span* *Full span* *Span in air*
- *Rated span* *Maximum span* *Calibrated span*
- *Maximum measured span* *Maximum span of sensor*
- *Maximum measuring span* *Span value*

Performance Statements

- *Range* *Full range* *Detected range*
- *Measured range* *Target range* *Measuring range*
- *Maximum range* *Range distance*
- *Maximum target range (in air)*
- *Set measuring range* *Range with no temp. gradient*

Performance Statements

- *Full scale*

- *Maximum distance* *Target distance*
- *Measured distance* *URL*
- *Distance* *Tank height*

- *Undefined parameter (such as 0.25%)*

Performance Statements

- *Sample application*
  - *1000 mm between 0 and 100% level*
  - *100% level is 100 mm below sensor*
  - *Maximum sensor distance = 8000 mm*
  - *Maximum span = 7600 mm*

Performance Statements

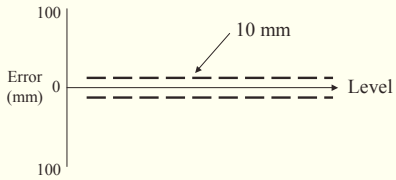
- *Sample application*
  - *Level measurement 100-1100 mm*
  - *Set span 1000 mm*
  - *Maximum span 7600 mm*
  - *Empty distance 1100 mm*
  - *Maximum sensor distance 8000mm*

Performance Statements

- *Absolute (fixed) distance (10 mm)*

		Error
0% level	→ *1100 mm*	*10 mm*
25% level	→ *850 mm*	*10 mm*
50% level	→ *600 mm*	*10 mm*
75% level	→ *350 mm*	*10 mm*
100% level	→ *100 mm*	*10 mm*

Performance Statements

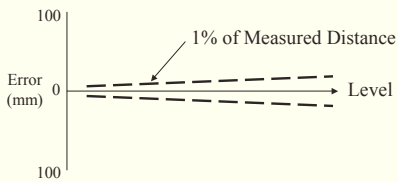


Performance Statements

- *Percent of measured distance (1%)*

		Error
▪	*0% level → 1100 mm*	*11.0 mm*
▪	*25% level → 850 mm*	*8.5 mm*
▪	*50% level → 600 mm*	*6.0 mm*
▪	*75% level → 350 mm*	*3.5 mm*
▪	*100% level → 100 mm*	*1.0 mm*

Performance Statements

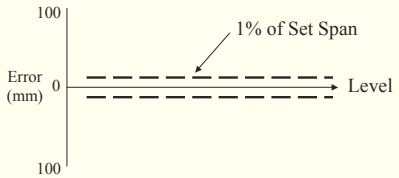


Performance Statements

- *Percent of set span (1%)*

	Error
0% level → 1000 mm	*10 mm*
25% level → 1000 mm	*10 mm*
50% level → 1000 mm	*10 mm*
75% level → 1000 mm	*10 mm*
100% level → 1000 mm	*10 mm*

Performance Statements

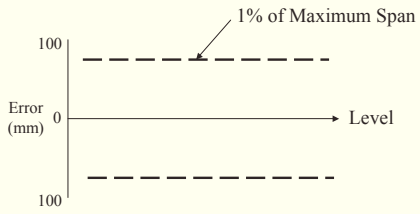


Performance Statements

- *Percent of maximum span (1%)*

	Error
0% level → 7600 mm	*76 mm*
25% level → 7600 mm	*76 mm*
50% level → 7600 mm	*76 mm*
75% level → 7600 mm	*76 mm*
100% level → 7600 mm	*76 mm*

Performance Statements

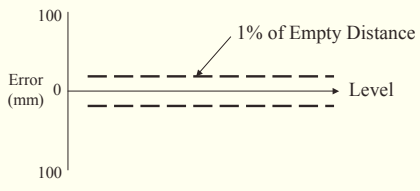


Performance Statements

- *Percent of empty distance (1%)*

	Error
0% level → 1100 mm	*11 mm*
25% level → 1100 mm	*11 mm*
50% level → 1100 mm	*11 mm*
75% level → 1100 mm	*11 mm*
100% level → 1100 mm	*11 mm*

Performance Statements

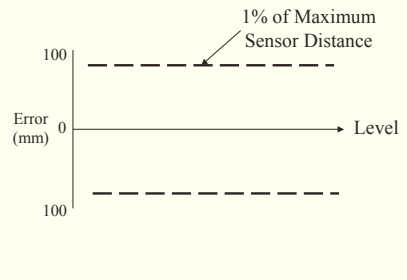


Performance Statements

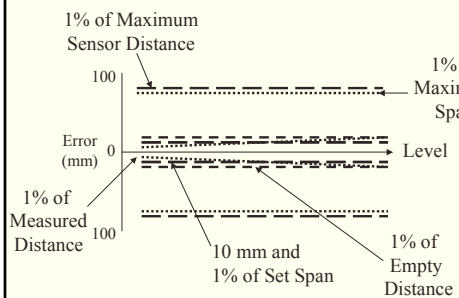
- *Percent of maximum sensor distance (1%)*

	Error
0% level → 8000 mm	*80 mm*
25% level → 8000 mm	*80 mm*
50% level → 8000 mm	*80 mm*
75% level → 8000 mm	*80 mm*
100% level → 8000 mm	*80 mm*

Performance Statements



Performance Statements



Performance Statements

- *Performance statements can be manipulated because their meaning may not be clearly understood*
- *Technical assistance may be needed to analyze the statements*

Performance Statements

- *Performance statements may not reflect the supplier's intent*

Level Gauge Performance

- *Level Gauge Performance*
- *Performance Statements*
- ***Reference Performance***
- *Actual Performance*
- *Supplier Claims*

Reference Performance

- *Reference performance is the quality of measurement at a nominal set of operating conditions (reference conditions)*

Reference Performance

- *Typical reference conditions*
  - *Ambient*
    - *20°C*
    - *Atmospheric pressure*
    - *50 % RH*

Reference Performance

- *Typical reference conditions*
  - *Reflective material (typically water)*
    - *Good reflectivity*
    - *20°C*
    - *Calm surface*
  - *Reflective target*

Reference Performance

- *Typical reference conditions*
  - *Geometry*
    - *Beam is not obstructed*
    - *Beam does not hit vessel wall*

Reference Performance

- *In the context of the industrial world, reference performance reflects performance under controlled laboratory conditions*

Reference Performance

- *Level Gauge Calibration Standard Performance*
  - *Standard is used to ensure that the level gauge performs per specifications*

Reference Performance

- *Uncertainty Analysis*
  - *Formal document that quantifies the performance of the standard*
  - *Opportunity to take a critical look at the standard*

Reference Performance

- *Uncertainty Analysis*
  - *Performance degrades as the look becomes more in-depth*
    - *Temperature effects*
    - *Analog input error*

Reference Performance

- *Uncertainty Analysis*
  - *Best when performed/reviewed independently*
  - *Results can suggest improvements*

Reference Performance

- *Calibration Standard Performance*
  - *The "Rule of Thumb" is that the calibration standard should be at least 4 times better than instrument*

Level Gauge Performance

- *Level Gauge Performance*
- *Performance Statements*
- *Reference Performance*
- ***Actual Performance***
- *Supplier Claims*

Actual Performance

- *Operating Effects*
  - *Ambient conditions*
    - *Humidity*
    - *Precipitation*
    - *Temperature*
    - *Direct sunlight*

Actual Performance

- *Transmitters are often rated to 10-90% relative humidity (non-condensing)*
  - *Outdoor locations are subject to 100% relative humidity and precipitation in various forms*

Actual Performance

- *Operating Effects*
  - *Can be significant, even though the numbers seem small*
  - *Not published by most suppliers*
    - *Information is not generally available to fairly evaluate actual performance*

Actual Performance

- *Operating Effects*
  - *Ambient temperature*
  - *Sensor temperature*
    - *Characterize at different temperatures*
  - *Process temperature*

Actual Performance

- *Operating Effects*
  - *Vapor space temperature (ultrasonic)*
    - *Changes speed of sound*
    - *Temperature compensation*
      - *Internal*
      - *External*
      - *Temperature stratification*

Actual Performance

- *Operating Effects*
  - *Vapor space pressure (ultrasonic)*
    - *Changes speed of sound*
    - *Changes attenuation of sound*

Actual Performance

- *Operating Effects*
  - *Vapor space composition (ultrasonic)*
    - *Changes speed of sound*
    - *Changes attenuation of sound*

Actual Performance

Tank Diameter (mm)	Tank Diameter (inch)	Volume Error (Liters) 5 mm	10 mm	25 mm	50 mm	100 mm	<--- Level Error
100	3.94	0.0393	0.0785	0.196	0.393	0.785	
200	7.87	0.157	0.314	0.785	1.57	3.14	
500	19.7	0.982	1.96	4.91	9.82	19.6	
1,000	39.4	3.93	7.85	19.6	39.3	78.5	
1,500	59.1	8.84	17.7	44.2	88.4	177	
2,000	78.7	15.7	31.4	78.5	157	314	
3,000	118	35.3	70.7	177	353	707	
5,000	197	98.2	196	491	982	1963	
10,000	394	393	785	1963	3927	7854	
20,000	787	1571	3142	7854	15708	31416	

Level Gauge Performance

- *Level Gauge Performance*
- *Performance Statements*
- *Reference Performance*
- *Actual Performance*
- ***Supplier Claims***

Supplier Claims

- *High Rangedown*
  - *Rangedown is the ratio of the maximum to minimum full scale range*
    - *Fewer sensors*
    - *Wider range of applications for each sensor/transmitter*

Supplier Claims

- *High Rangedown*
  - *Error is often relatively large in small ranges when performance is expressed as:*
    - *Percent of maximum span*
    - *Percent of maximum distance*

Supplier Claims

- *High Rangedown - Example*
  - *What are the measurement errors associated with two sensors that are accurate to 0.2 percent of maximum sensor range? The maximum sensor ranges are 6000 mm and 10,000 mm.*

Supplier Claims

- *High Rangedown - Example*
  - *0.002*6000 = 12 mm*
  - *0.002*10000 = 20 mm*
    - *Note that either could be used to measure 2000 mm, but the 6000 mm would be more accurate*

Supplier Claims

- *High Accuracy*
  - *High accuracy claims often refer to measurements made near the maximum sensor distance*
    - *Accuracy can be relatively poor at short distances*

Supplier Claims

- *High Accuracy*
  - *Performance statements may not reflect suppliers' intentions*

0.25% of range	*0.25% of empty distance*
1.2% of range	*1.2% of maximum sensor range*
0.25% of measuring range	*0.25% of maximum sensor range*
0.25% of span	*0.25% of maximum sensor range*
0.25%	*0.25% of maximum sensor range*
0.3%	*0.3% of measured distance*

Supplier Claims

- *High Accuracy*
  - *Users are advised to investigate statements expressed as percentages in order to verify their meaning*
    - *It would be conservative to assume that they are a percentage of maximum sensor distance until verified*

Supplier Claims

- *Not Affected by Temperature*
  - *Radar and laser are not affected*
  - *Vapor space temperature affects the speed of sound*
    - *Ultrasonic level gauges are affected by temperature*

Supplier Claims

- *Measure Large Distances*
  - *May be achievable under reference conditions*

Supplier Claims

- *Measure Large Distances*
  - *May not be achievable under operating conditions*
    - *Foam*
    - *Agitation*
    - *Boiling*
    - *Dust /Smoke*
    - *Type of material*
    - *Other*

Seminar Outline

- *Introduction*
- *Level Measurement Fundamentals*
- *Level Measurement Technology*
- *Level Gauge Performance*
- ***Consumer Guide***

Consumer Guide

User Equipment Selection Process

- *Learn about the technology*
- *Find suitable vendors*
- *Obtain specifications*
- *Organize specifications*
- *Evaluate specifications*
- *Select equipment*

Consumer Guide

User Equipment Selection Process

- *Performing this process takes time and therefore costs money*

Consumer Guide

User Equipment Selection Process

- *Haphazard implementation with limited knowledge of alternatives does not necessarily lead to a good equipment selection*

Consumer Guide

Guide Provides First Four Items

- ***Learn about the technology***
- ***Find suitable vendors***
- ***Obtain specifications***
- ***Organize specifications***
- *Evaluate specifications*
- *Select equipment*

Consumer Guide

Guide Provides First Four Items

- ***Information focused on technology***
- ***Comprehensive lists of suppliers and equipment***

Consumer Guide

Guide Provides First Four Items

- ***Significant specifications***
- ***Lists of equipment organized to facilitate evaluation***

Consumer Guide

User Equipment Selection Process

- *By providing the first four items, the Consumer Guides:*
  - *make technical evaluation and equipment selection easier, more comprehensive, and more efficient*

Consumer Guide

User Equipment Selection Process

- *By providing the first four items, the Consumer Guides:*
  - *allow selection from a larger number of suppliers*
  - *simplifies the overall selection process*

Consumer Guide

- ***Supplier Data and Analysis***
- *Attachments*
  - *Flowmeter categories*
  - *Availability of selected features*
  - *Models grouped by performance*
  - *Models grouped by supplier*

Supplier Data and Analysis

- *Process Limits*
  - *Pressure*
    - *Ultrasonic - Typically less than 10 bar*
      - *May be atmospheric*
    - *Radar - Typically 10 bar*
      - *400 bar available*

Supplier Data and Analysis

- *Process Limits*
  - *Temperature*
    - *Ultrasonic - Typically less than 100 °C*
    - *Radar - Typically less than 150 °C*
      - *250 °C available (at flange)*
      - *400-600 °C available*

Supplier Data and Analysis

- *Sensor Ambient*
  - *Ambient temperature*
    - *-20 to 60°C typical*
    - *Compensation for vapor space temperature*

Supplier Data and Analysis

- *Sensor Ambient*
  - *Ambient humidity*
    - *Indoor*
    - *Outdoor*
  - *Vibration*

Supplier Data and Analysis

- *Sensor Limits*
  - *Wetted parts*
    - *Ultrasonic*
      - *Stainless steel*
      - *PVC*
      - *Kynar*
    - *Radar*
      - *Stainless steel*
      - *Hastelloy*

Supplier Data and Analysis

- *Sensor Limits*
  - *Size of connection*
    - *Can be too large for installation*

Supplier Data and Analysis

- *Sensor Installation/Maintenance*
  - *Suitable access*
  - *Proper support*
  - *NEMA 4X, 6; IP67, 68*
  - *Integral sensor/transmitter more economical*
  - *Hazardous location considerations*

Supplier Data and Analysis

- *Transmitter*
  - *2, 3- or 4-wire device (separate power/analog wires)*
    - *Using DC power can eliminate power conduit*
  - *Data logging*
  - *Alarms*
  - *HART, Profibus, Foundation Fieldbus*

Supplier Data and Analysis

- *Transmitter*
  - *Mounting*
    - *Integral*
    - *Remote*
    - *Spacing (distance)*

Supplier Data and Analysis

- *Transmitter Installation/Maintenance*
  - *Suitable access*
  - *Proper support*
  - *Integral sensor/transmitter more economical*
  - *Hazardous location considerations*

Supplier Data and Analysis

- *Transmitter Installation/Maintenance*
  - *Range adjustment mechanism provide insight into age of design*
    - *Analog (potentiometer)*
    - *Dip switch*
    - *Digital*

Supplier Data and Analysis

- *Transmitter Installation/Maintenance*
  - *Filtering can be used*
  - *Excessive damping can affect response*

Supplier Data and Analysis

- *Reference Performance*
  - *Reference conditions generally not stated*
  - *Typically digital display*
    - *Analog output adds uncertainty*

Supplier Data and Analysis

- *Performance*
  - *It can be difficult to compare the performance of different suppliers' equipment*

Supplier Data and Analysis

- *Operating Effects*
  - *Ambient*
    - *Temperature, humidity*
  - *Process conditions*
    - *Temperature, pressure, vapor composition*
    - *Dielectric constant (radar)*
    - *Foam, boiling…*

Supplier Data and Analysis

- *Operating Effects*
  - *It can be difficult to compare the operating effects of different suppliers' equipment*

Consumer Guide

- *Supplier Data and Analysis*
- ***Attachments***
  - *Flowmeter categories*
  - *Availability of selected features*
  - *Models grouped by performance*
  - *Models grouped by supplier*

Flowmeter Categories

- *Summary of offerings*
  - *Liquid*
  - *Solids*

Flowmeter Categories

- *Suppliers (62)*
- *Manufacturers (47)*
  - *22 USA*
  - *6 Germany*
  - *4 Canada*
  - *5 UK*
  - *2 South Africa*
  - *1 Australia, Austria, China, Czech Republic, France, Hungary, Israel, Korea, Netherlands, Russia, Singapore, Sweden, Switzerland,*

Availability of Selected Features

- *Hazardous location*
- *Custody transfer*
- *IP/NEMA ratings*
- *Maximum temperature and pressure*
- *Fixed target blanking*
- *Temperature compensation*

Availability of Selected Features

- *Data logging*
- *Communications*
  - *HART*
  - *Foundation Fieldbus*
  - *Profibus*

Models Grouped by Performance

- *Set span*
  - *2000 mm*
  - *5000 mm*
  - *10,000 mm*

Review and Questions

- *Introduction*
- *Level Measurement Fundamentals*
- *Level Measurement Technology*
- *Level Gauge Performance*
- *Consumer Guide*

The Consumer Guide to Non-Contact Level Gauges

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