

Setting the Standard for Automation™



Level Measurement

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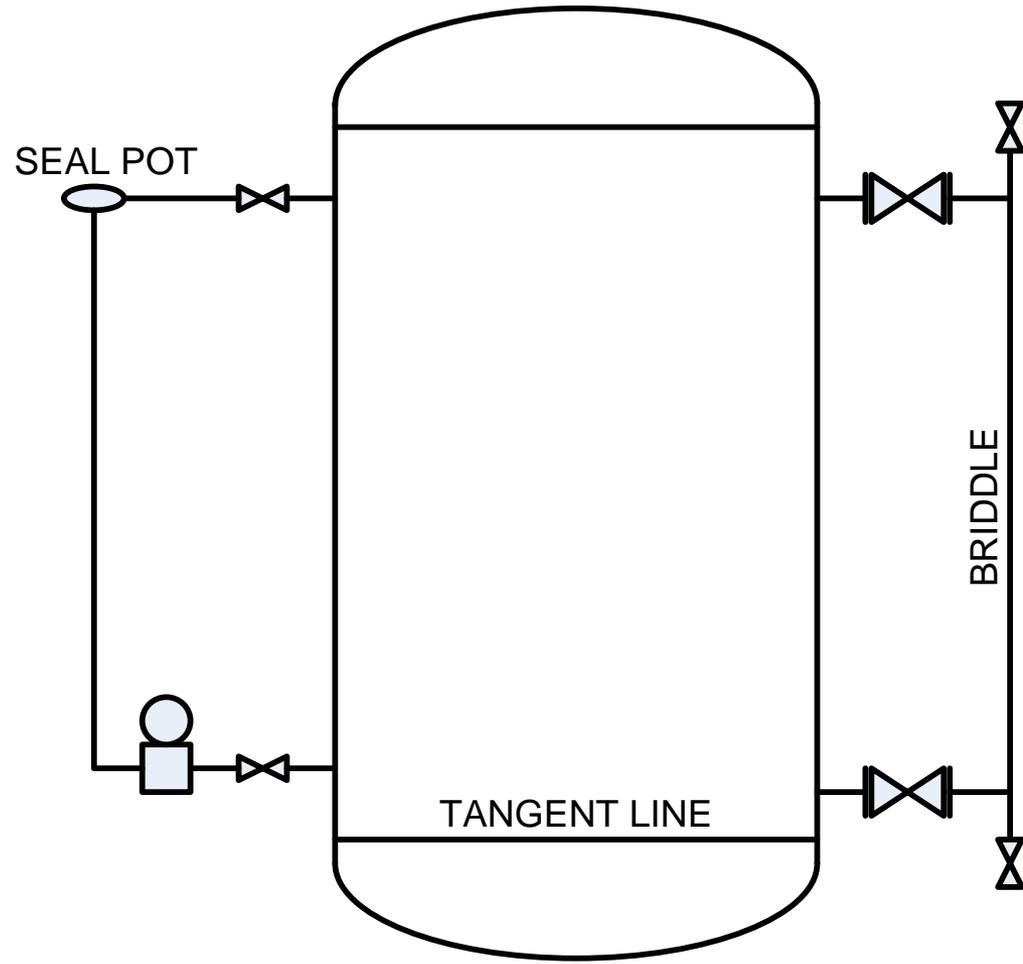
Level Instrumentation - Selection Criteria

- Vessel Type – Atmospheric or Pressurized
- Vessel Nozzle Orientation
- Material to be Measured – Liquid, Interface or Solid
- Process Conditions - Temperature, Pressure, Density, Viscosity, Conductive, Turbulence, Foam, Vaporization Occur at the Surface, Sour or Corrosive Service
- Measurement Range
- Measurement Type – Continuous (Transmitter), Point (Switch), Local (Gauge)
- Contact or Non-Contact Measurement

Level Instrumentation – Categories

- Head Meters
 - Based on the Measurement of Hydrostatic (Downward) Force of the Liquid Head
 - Level = Pressure = $h \cdot sg$
 - Calibration in inches of H₂O
- Height Meters
 - Based on the Identification of the Surface of the Liquid
 - Calibration in inches, feet, %

TYPICAL VESSEL



Level Instrumentation Concepts – Level Equipment

Bridle

- An Instrument Standpipe
- Allows for Multiple Instruments to be Connected to the Vessel While the Number of Nozzle Connections on the Vessel Remains Two
- Allows the Instruments to be Isolated from the Vessel without Removing the Vessel from Service
- Bridle Connection Ratings and Material Should Match Those of the Vessel
- Should be Provided with Both Vent and Drain Connections
- Typical Bridle Pipe Size is 2" or 3"

Level Instrumentation

Concepts – Level Equipment



Stilling Well

- An Instrument Standpipe which is Open at the Bottom and is Drilled with Vent Holes along the Length of the Standpipe
- Flanged on Top of Standpipe where Level Instrument will be Mounted
- Should Allow for Space between Bottom of Vessel and Stilling Well (Minimum of 6") to Minimize Plugging
- Provides Additional Protection for Level Instrumentation
- Reduces Effects of Process (Turbulence, Foaming)
- Typical Pipe Size is 2" to 4"

Level Instrumentation Concepts – Level Equipment



Seal Pot

- Metal Container used Either to:
 - To Keep the Seal Fluid in the Reference Legs from Boiling Away in Hot Applications (Steam Drums)
 - Allow Maintenance to Fill the Impulse Lines with Seal Fluid or Act as a Reservoir to Keep the Impulse Lines Full

Level Instrumentation Concepts – Level Equipment



Jig Set

- Mechanical Device Used to Exactly Space Vessel, Bridle or Level Gauge Nozzle Connections when Nozzles are Welded in Place

Level Instrumentation

Concepts – Measurement Types



- Level Gauges
- Guided Wave Radar
- Radar
- Differential Pressure
- Float / Displacer
- Ultrasonic
- Capacitance
- Nuclear
- Other

Level Instrumentation Types – Level Gauges

Operating Philosophy

- To Obtain a Reliable and Inexpensive Indication of Liquid Level in a Vessel

Considerations

- The Visible Length Should Cover the Full Operating Range of Interest Including any Other Level Instrumentation on the Vessel
- If More than One Gauge is Required, the Gauges Must Overlap Each Other

Level Instrumentation Types – Level Gauges

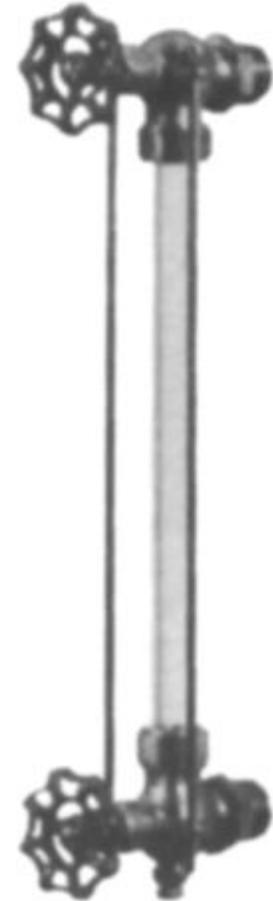
Designs

- Tubular
- Flat Glass
 - Transparent
 - Reflex
- Magnetically Coupled

Level Instrumentation Types – Level Gauges

Tubular

- Glass Tube with Option of Graduations
- Not Popular for Process Applications
- Typically Used for Calibrating Metering Pumps (Calibration Tubes)



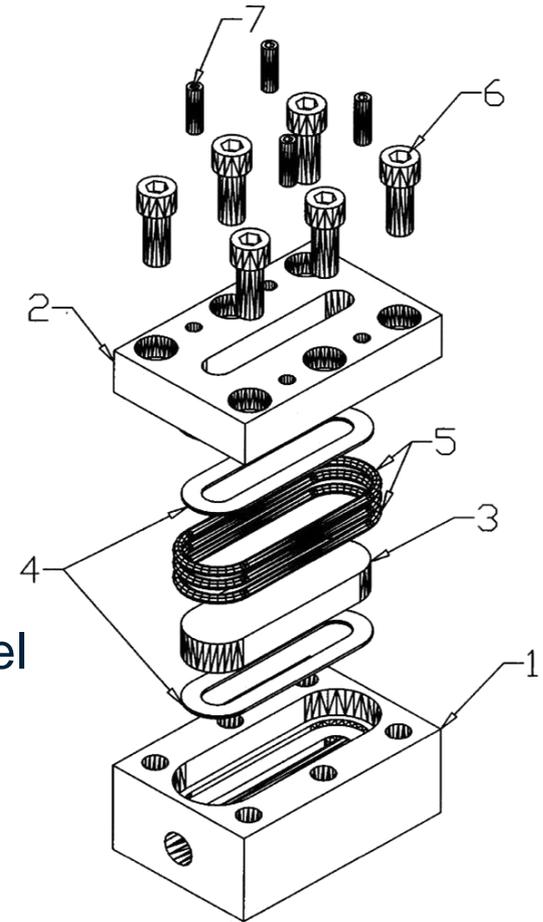
Level Instrumentation Types – Level Gauges

Flat Glass Gauges are Comprised of:

- Metal Chamber (1 & 2)
- Gasket (5)
- Glass (3)
- Cushion (4)
- Bolts and Nuts (6 & 7)

Gauge Limitations:

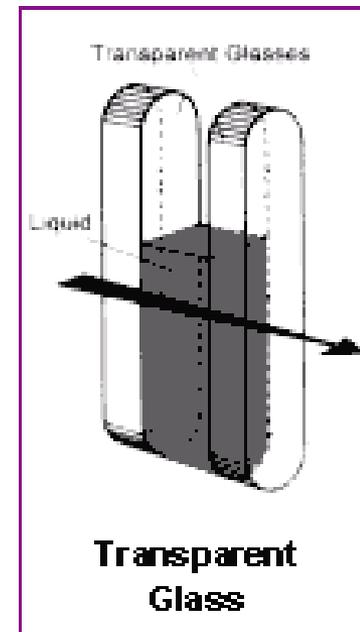
- Very High or Very Low Temperatures
- Poor Design With Multiple Gauges May Limit Level Visibility
- Gauge Connection Plugging
- Glass Becoming Etched or Discolored



Level Instrumentation Types – Level Gauges

Transparent Flat Glass Gauge

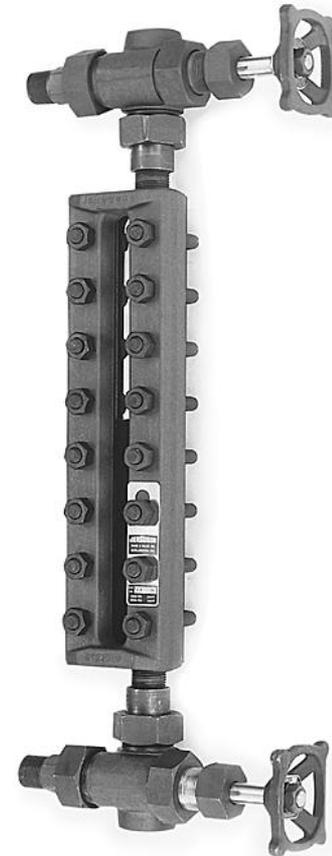
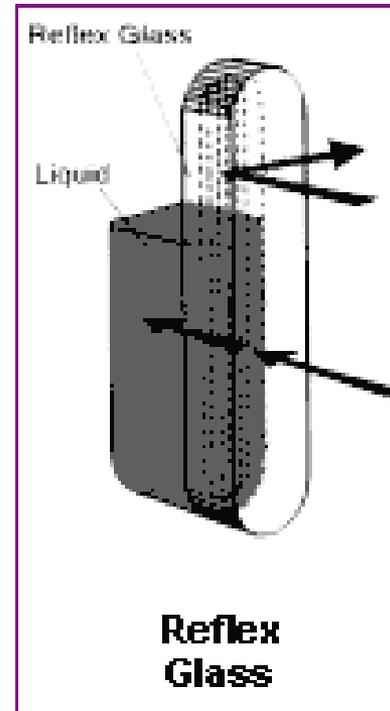
- Glass Sections on Opposite Sides of the Chamber
- View the Liquid Level through the Gauge
- Used on Interface Applications and Dirty or Viscous Liquids
- Illuminators Can be Used to Diffuse Light Evenly on the Back of the Gauge



Level Instrumentation Types – Level Gauges

Reflex Flat Glass Gauge

- Single Glass Section with Prisms Cut in the Glass on the Process Side
- Light Striking the Vapor Phase is Refracted to the Viewer which Appears Silvery White
- Light Striking the Liquid Phase is Refracted into the Liquid which Appears Black
- Used on Clean, Clear, Noncorrosive Liquids

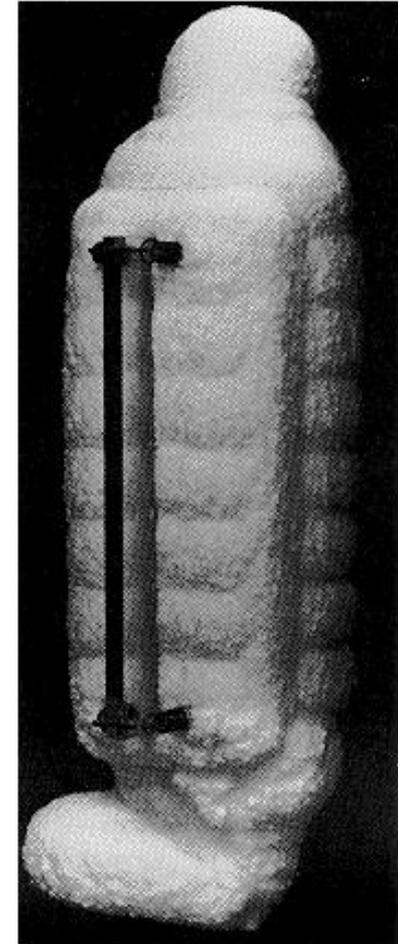


Level Instrumentation Types – Level Gauges



Accessories

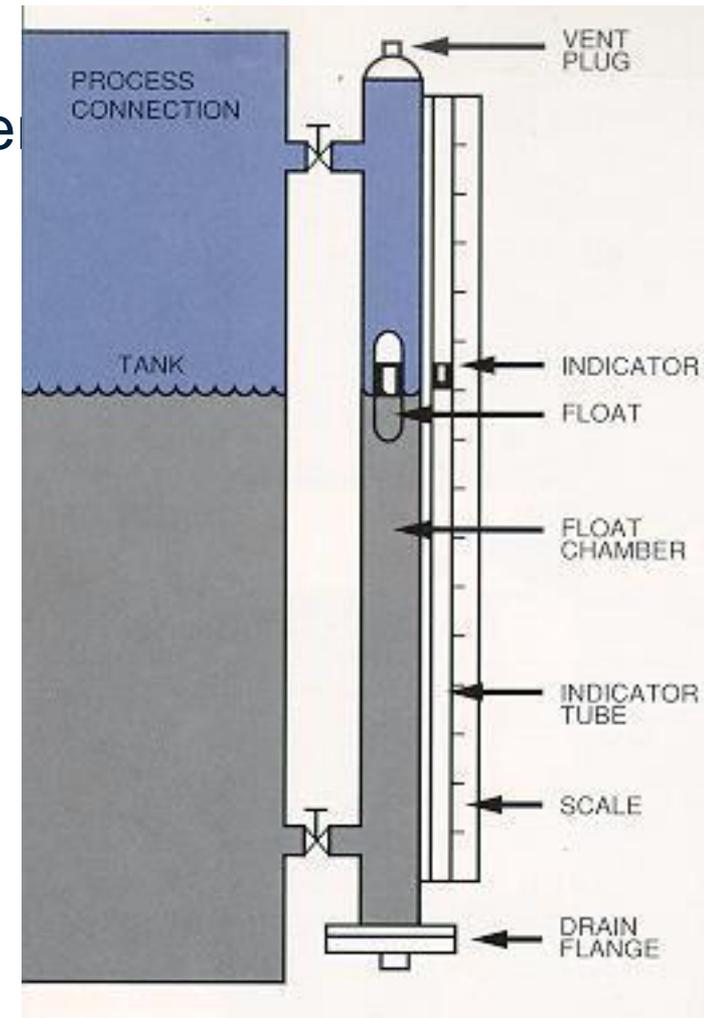
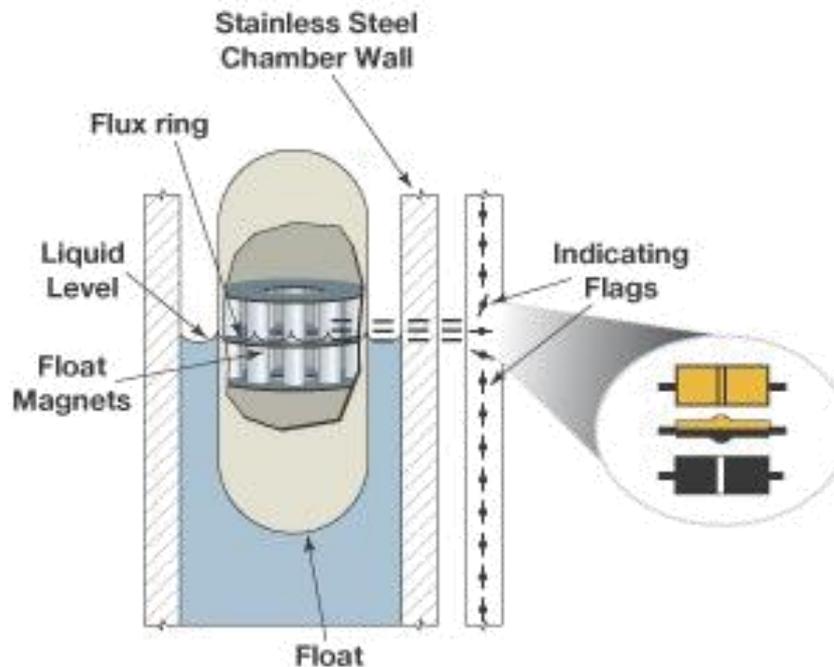
- Illuminators Can be Used to Diffuse Light Evenly on the Back of the Gauge
- When Used In Cold Service They Can Be Provided With A Frost Extension



Level Instrumentation Types – Float / Displacer

Magnetic Level Gauge

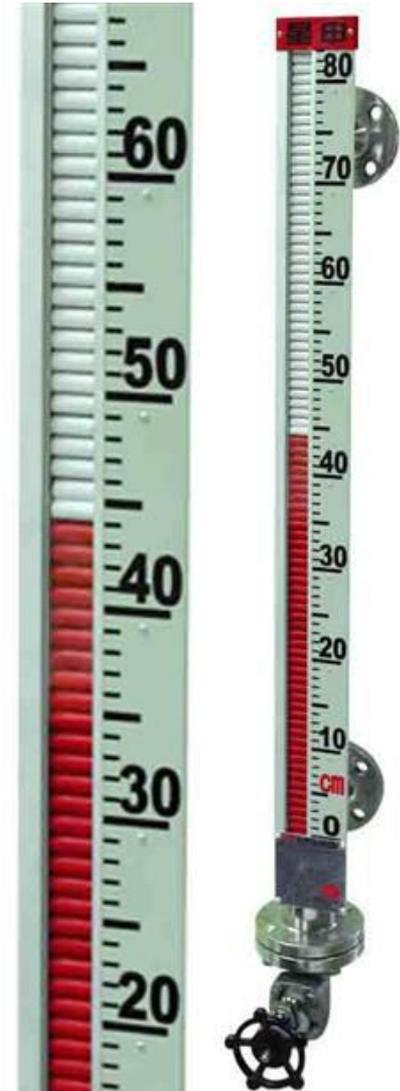
- Consists of a Non-Magnetic Chamber
- Internal Float with Magnet and Bi-Colored Indicator Wafers



Level Instrumentation Types – Float / Displacer

Considerations

- The Visible Length Should Cover the Full Operating Range of Interest Including any Other Level Instrumentation on the Vessel
- If More than One Gauge is Required, the Gauges Must Overlap Each Other
- Level Chamber Needs to be Installed Vertically Level to Reduce any Possible Friction with the Float
- Require Jig Set Connections
- May Require a Magnetic Trap



Level Instrumentation

Types – Float / Displacer



Advantages

- Long Visible Lengths
- Corrosive or Toxic Liquid Applications
- Adaptable to Variations in Fluid Densities
- High Pressure or Temperature Applications

Limitations

- Affected by changes in fluid density
- Coating media may seize moving parts
- Over Pressuring can Implode Float
- Long ranges may require additional support



Level Instrumentation Types – Differential Pressure

Operating Philosophy

- Measures Hydrostatic Head of Liquid in a Vessel
 - Liquid Height Multiplied by a Density



Level Instrumentation Types – Differential Pressure

Considerations

- Vessel Shape has no Impact
- Ease of Installation and Isolation
 - Inexpensive and Most Widely Used
- Variation in Fluid Density Should be Checked
 - Changes with Temperature and Composition
- Mounting at the Centerline of Bottom Nozzle or Below



Level Instrumentation Types – Differential Pressure



Diaphragm Seals

- Offer More Mounting Flexibility
- Not Susceptible to Plugging or Freezing
- Easier to Control than Wet Legs
- May Induce Temperature Errors
- Added Response Time with Longer Capillaries
- Small Spans Can be Difficult to Measure



Level Instrumentation Types – Differential Pressure

Atmospheric Vessels

- Only High Pressure Side Connected to Vessel
- Zero Suppression (If Mounted Below Lower Tap)

Closed Vessels with Non-Condensable Gas

- Both High and Low Pressure Sides Connected to Vessel
- Low Pressure Side is not Filled (Dry leg)
- Zero Suppression (If Mounted Below Lower Tap)

Level Instrumentation Types – Differential Pressure



Closed Vessels with Condensable or Non-Condensable Gas

- Both High and Low Pressure Sides Connected to Vessel
- Both High and Low Pressure Sides are Filled (Wet Leg)
- Fill Fluid is Typically Glycerin / Glycol Sometime even the Process
- Zero Elevation (Due to Filled Low Pressure Side)

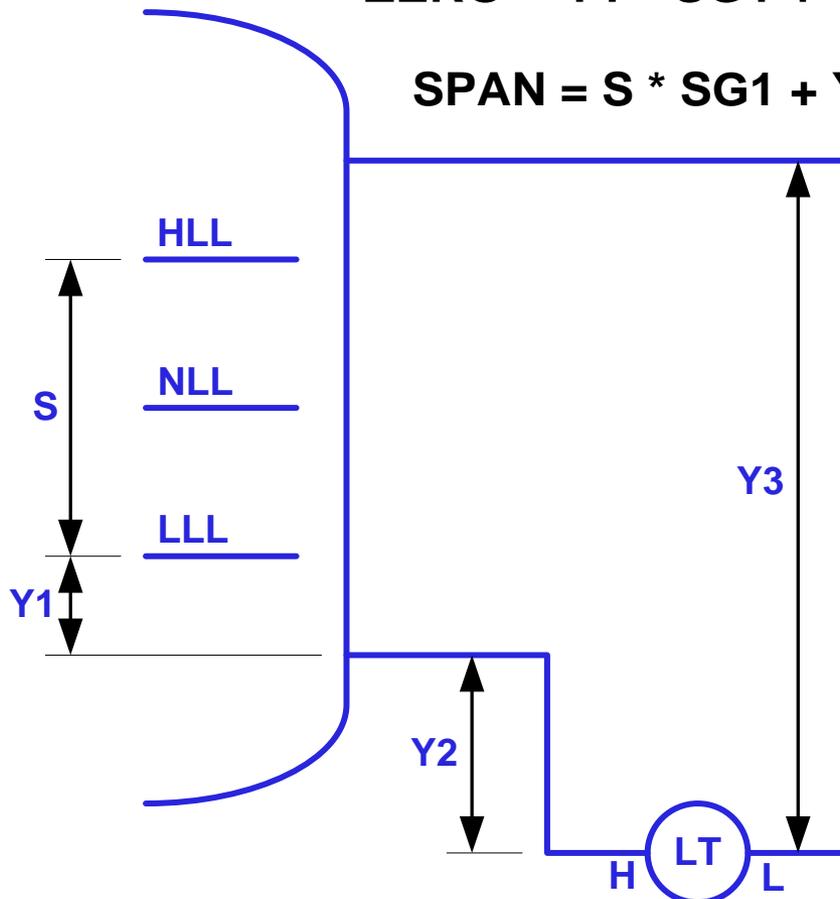
Level Instrumentation

Types – Differential Pressure

Differential Pressure Calculation – Pressurized Vessel With Sealed Legs

$$\text{ZERO} = Y1 * \text{SG1} + Y2 * \text{SG2} - Y3 * \text{SG3}$$

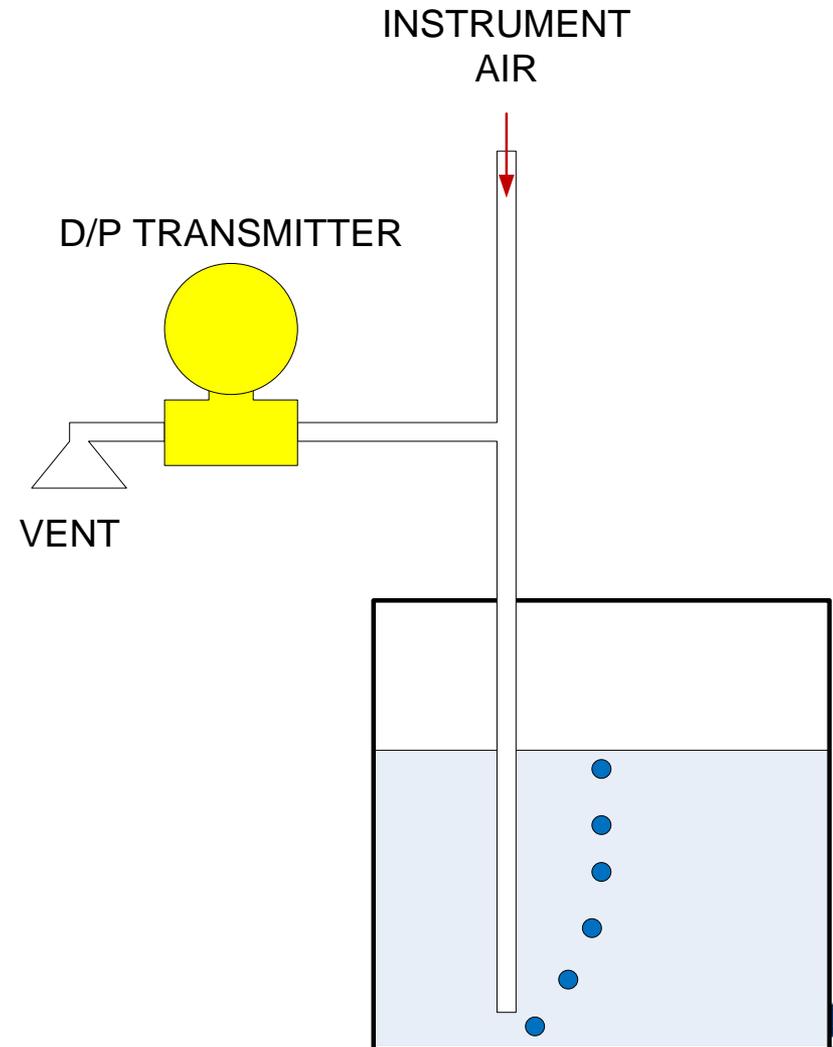
$$\text{SPAN} = S * \text{SG1} + Y1 * \text{SG1} + Y2 * \text{SG2} - Y3 * \text{SG3}$$



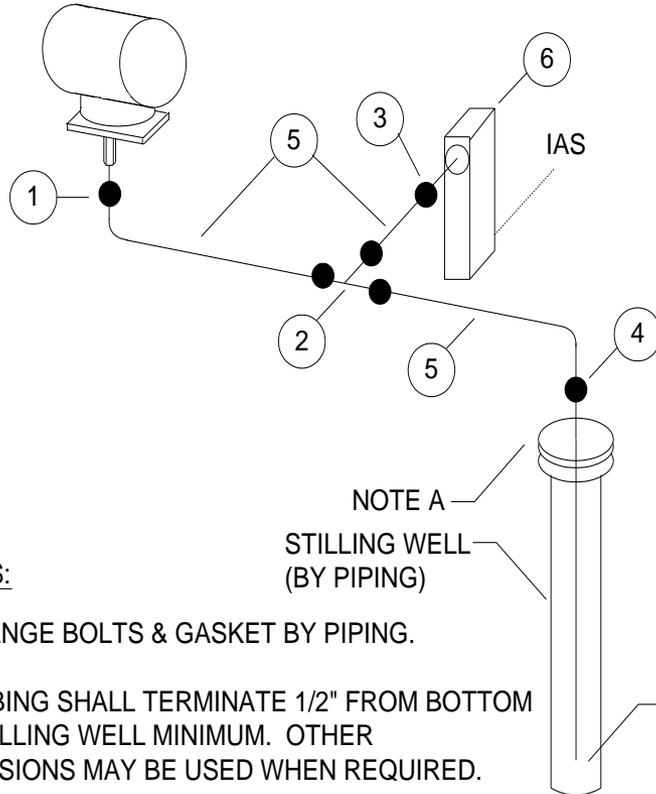
Level Instrumentation Types – Bubbler

Bubbler

- When Air Pressure Enters a Dip Pipe with a Pressure Greater Than the Hydrostatic Head of the Process Fluid, the Air will Bubble out the Bottom of the Dip Pipe
- As the Liquid Level Changes, the Air Pressure in the Dip Pipe also Changes
- Consists of Pressure Regulator, Rotameter and Pressure Gauge Along with a Stilling Well



Level Instrumentation Types – Bubbler



NOTES:

A. FLANGE BOLTS & GASKET BY PIPING.

B. TUBING SHALL TERMINATE 1/2" FROM BOTTOM OF STILLING WELL MINIMUM. OTHER DIMENSIONS MAY BE USED WHEN REQUIRED.

1	MALE TUBE CONN 316SS, TXMPT	1	1/2" T X 1/2" P
2	TEE ALL TUBE 316SS, TXTXT	1	1/2" T
3	MALE TUBE CONN 316SS, TXMPT	1	1/2" T x 1/4" P
4	MALE THERMOCOUPLE CONN 316SS	1	1/2"
5	TUBING SMLS 316SS 0.049 WALL A213	20'	1/2"
6	ROTAMETER 6.0 SCFH 1 1/2" SCALE	1	1/4"

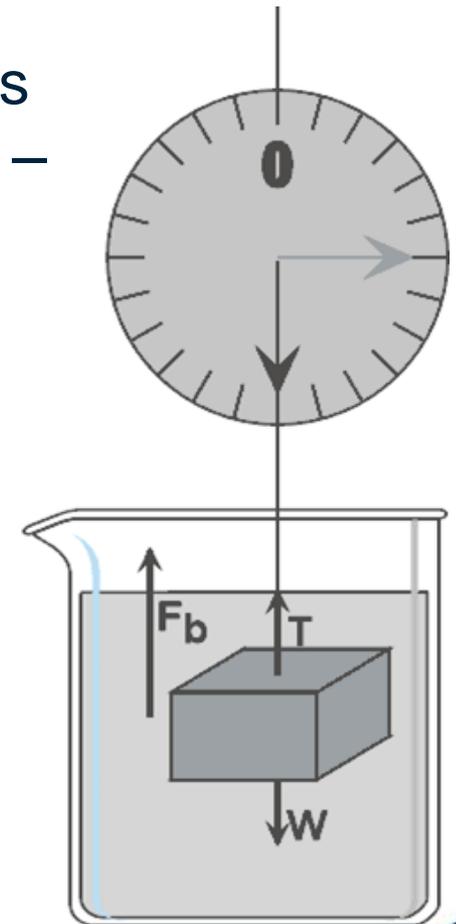


Level Instrumentation

Types – Float / Displacer

Operating Philosophy – Displacer

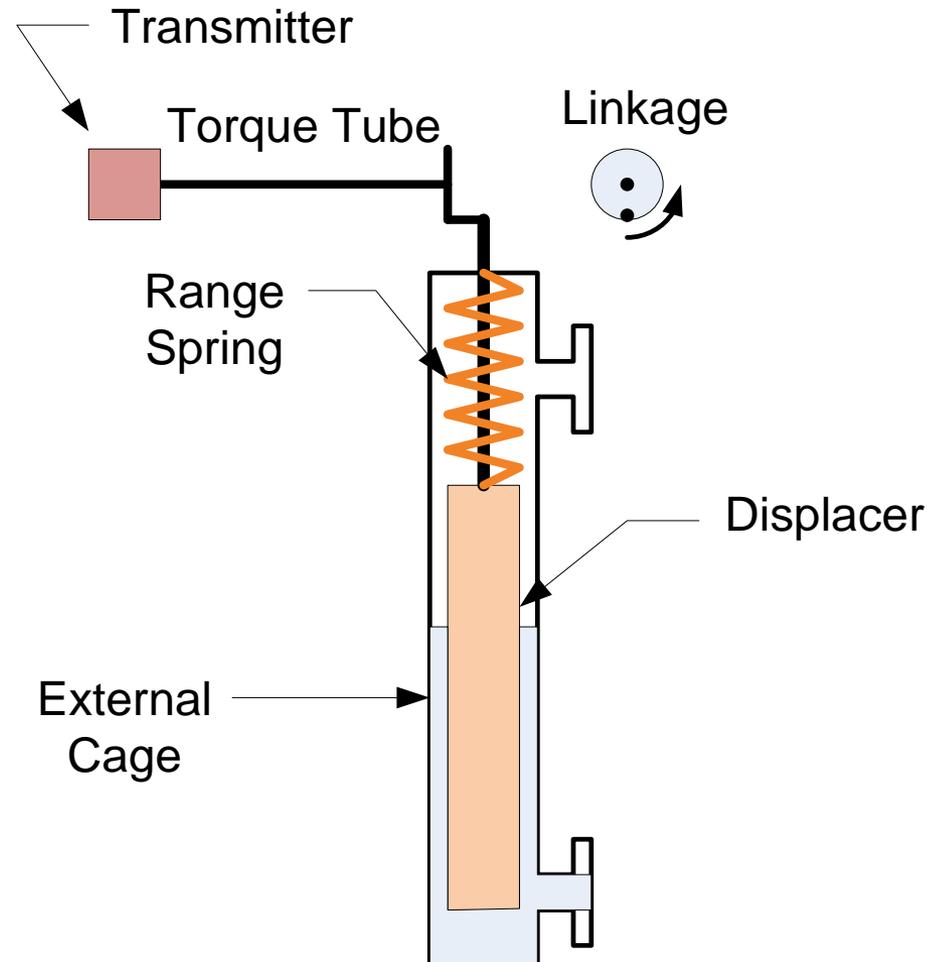
- When a Body is Immersed in a Fluid it Loses Weight Equal to That of the Fluid Displaced – Archimedes Law
- By Detection of the Apparent Weight of the Immersed Displacer, a Level Measurement can be Inferred



Level Instrumentation Types – Float / Displacer

Torque Tube Displacers

- External Cage
- Displacer
- Range Spring
- Linkage
- Torque Tube
- Transmitter
- Vertical Force Movement of Displacer and Rod is Converted to Angular Rotation of Torque Tube



Level Instrumentation

Types – Float / Displacer

Torque Tube Displacers Considerations

- Typical Measuring Range is 14” to 72”
- Mounting Orientation for Torque Tube Arm
- Fluid Density
- Vent and Drain Connections
- Require Jig Set Connections



Level Instrumentation Types – Guided Wave Radar

Dielectric Constant

- A Measure of a Material's Ability to Conduct Electricity



Level Instrumentation Types – Guided Wave Radar



Operating Philosophy

- Based on Time Domain Reflectometry (TDR)
- A Pulse of Electromagnetic Energy is Transmitted Down a Guide
- When the Pulse Reaches a Surface that has a Higher Dielectric than the Vapor Space it is Travelling in, then the Pulse is Reflected
- The Time Difference between the Transmitted and Reflected Pulse is Converted into a Distance from Which the Total Level or Interface Level is Calculated

Level Instrumentation Types – Guided Wave Radar



Guide Types

- Coaxial
 - Rigid Twin Lead
 - Flexible Twin Lead
 - Rigid Single Lead
 - Flexible Single Lead
-
- Each Guide Type has a Maximum Measuring Range and Minimum Dielectric Constant



Level Instrumentation

Types – Guided Wave Radar



Considerations

- Dielectric Constants between 1.4 and 100
- The Higher the Dielectric Constant the Greater the Reflected Pulse
- Transition Zones – Vary with Dielectric Constant
- To Stabilize the Guide Side Forces Either Install in a Stilling Well or Fix the Guide to the Tank Bottom
- Centering Discs which prevent the Guide from Contacting the Side of the Stilling Well
- Weights Should be used when Installing Flexible Guides
- Inlets should be kept at a Distance to Avoid Splashing on the Guide
- Select Guide Length According to the Required Measuring Range. Some Guides can be Cut in the Field, Others cannot

Level Instrumentation Types – Radar



Operating Philosophy

- Radar Signals are Transmitted from an Antenna at the Top of the Tank
- The Signal is Reflected by the Measured Surface and the Echo is Detected by the Antenna
- The Echo has a Slightly Different Frequency Compared to the Transmitted Signal
- The Frequency Difference is Proportional to the Distance to the Measured Surface



Level Instrumentation Types – Radar



Considerations

- Transmitter Should be Installed in Locations with a Clear and Unobstructed View of the Level Surface
 - **Keep Away from Agitator Horizontal Blades, Filling Inlets, Center of the Tank**
- Minimum Distance that the Transmitter can be Mounted from the Tank Wall
- A Stilling Well can be Used to Avoid Disturbing Objects, Turbulence and Foam
- Choose the Largest Possible Antenna Diameter for Installation
- Tank Nozzle Height can Affect Performance

Level Instrumentation Types – Radar



Antenna Types

- Rod – Suitable for Tanks with Small Openings
- Cone – Suitable for Free Propagation and Pipe Mounted Installations
- Parabolic – Suitable for Solids and Can withstand Heavy Contamination
- Each Antenna Type has a Maximum Measuring Range and Minimum Dielectric Constant

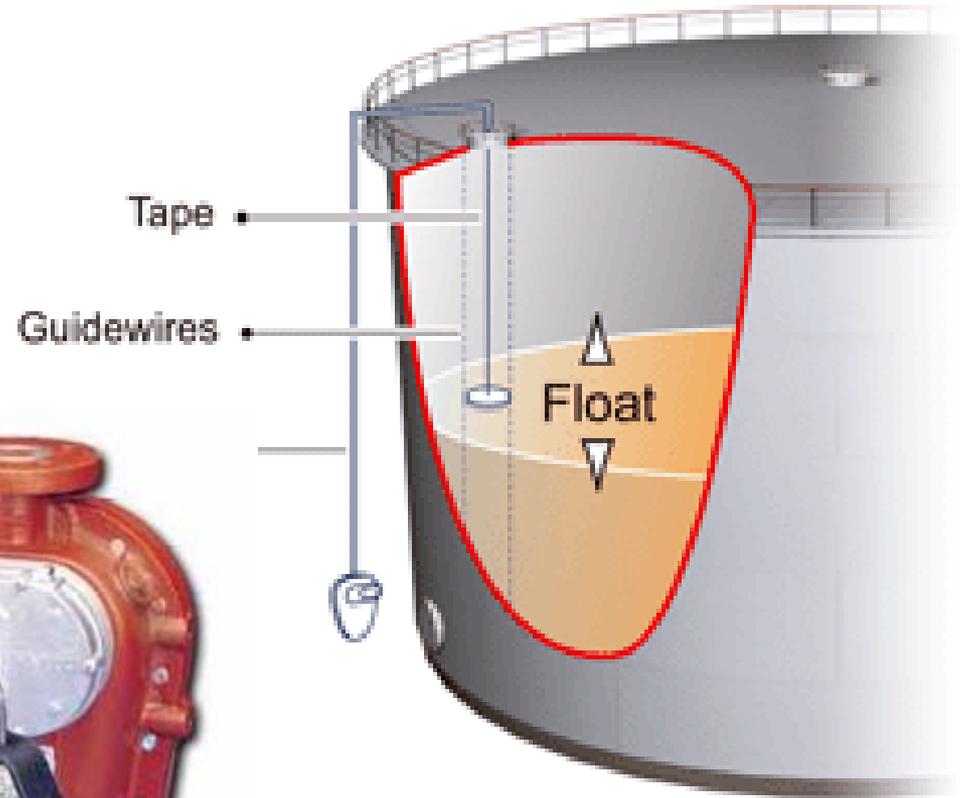
Level Instrumentation Types – Float & Tape



Float and Tape

- A Large Stainless Steel Float is Attached to a Spring by a Perforated Tape
- The Spring Provides Constant Tension, which Balances the Float on the Liquid
- The Perforated Tape Engages Pins on a Sprocket Wheel that Drive the Counter Assembly

Level Instrumentation Types – Float & Tape



Level Instrumentation Types – Float & Tape



Considerations

- Fluid Density
- Tank Roof Configuration
- Availability of 120 VAC Power

Level Instrumentation Types – Float Switch

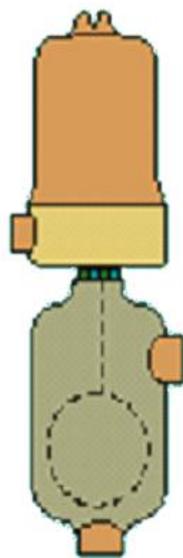


Float Switch

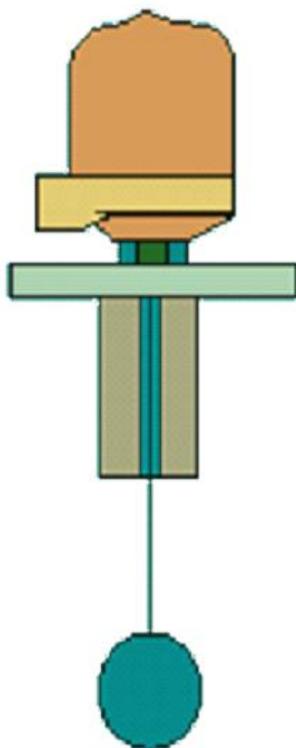
- Float Level Switches use a Float and Magnetic Coupling Action
- As the Float Rises or Falls with a Liquid, it Moves a Sleeve into or out of a Magnetic Field, Causing Switch Operation
- A Non-Magnetic Barrier Isolates the Switch Mechanisms from the Liquid

Level Instrumentation Types – Float Switch

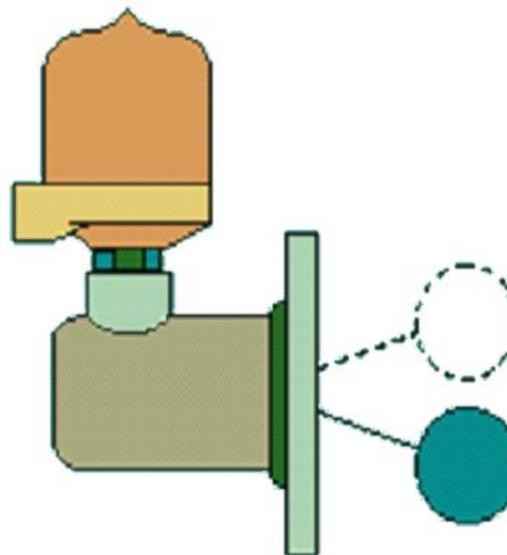
- **Float Switch Configurations**
 - Vertical
 - Horizontal
 - Top Mounted
 - Side Mounted



FLOAT CAGE



TOP MOUNTED

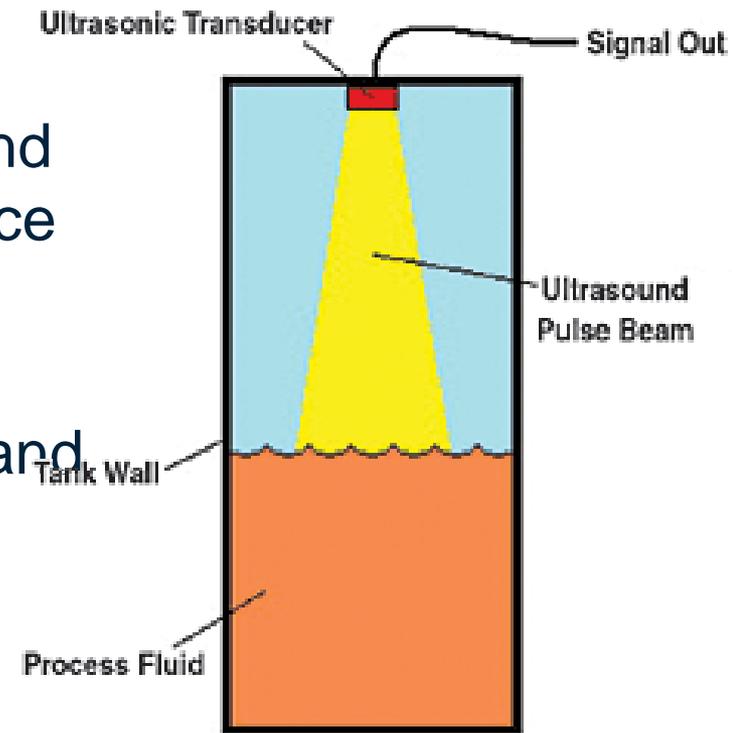


SIDE MOUNTED

Level Instrumentation Types – Ultrasonic

Operating Philosophy

- Based on Time Domain Reflectometry (TDR)
- Ultrasonic Pulse Signals are Transmitted from the Transmitter and are Reflected from the Liquid Surface
- The Transmitter Receives the Reflected Signal and Measures the Time-Delay Between Transmitting and Receiving



Level Instrumentation Types – Ultrasonic



Considerations

- Mount Transmitter as Near to Vertical as Possible
- Avoid Obstructions in the Ultrasonic Beam Path
- Minimum Tank Nozzle Height
- Foam can Reduce Echo Returns
- Do not Mount Over an Inlet Stream
- Stilling Wells can be Used to Minimize the Effects of Turbulence and Foaming

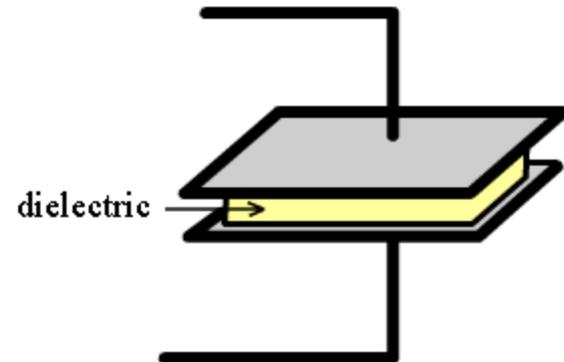
Level Instrumentation Types – Capacitance

Capacitance

- A Measure of the Amount of Energy that can be Stored

Capacitance is Influenced by Three Factors:

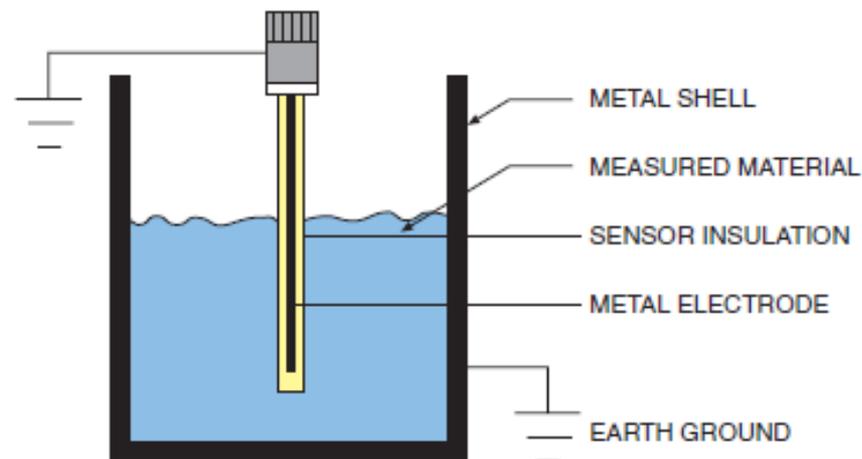
- Distance between the Electrode Plates
- Size of the Electrode Plates
- Dielectric Value of Material between the Electrodes



Level Instrumentation Types – Capacitance

Operating Philosophy

- As Level Covers the Sensing Probe, the Capacitance Between the Probe and Conductive Media or the Probe and the Vessel Wall Increases
- A Bridge Misbalance is Created which is Amplified and Converted to an Output that Corresponds to the Level the Vessel
- This Technology does not Measure the Amount of Energy Stored, but Rather the Amount of Energy that can be Stored



Level Instrumentation Types – Capacitance



Considerations

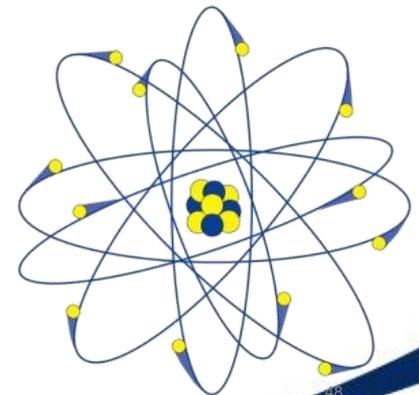
- Do not Mount in an Inlet Stream
- Stilling Wells
- Use Brackets and Supports in Agitated Vessels
- Ground the Probe when Installed in Non-Metallic Vessels
- Nozzle Diameter
- Probe Coating



Level Instrumentation Types – Nuclear

Operating Philosophy

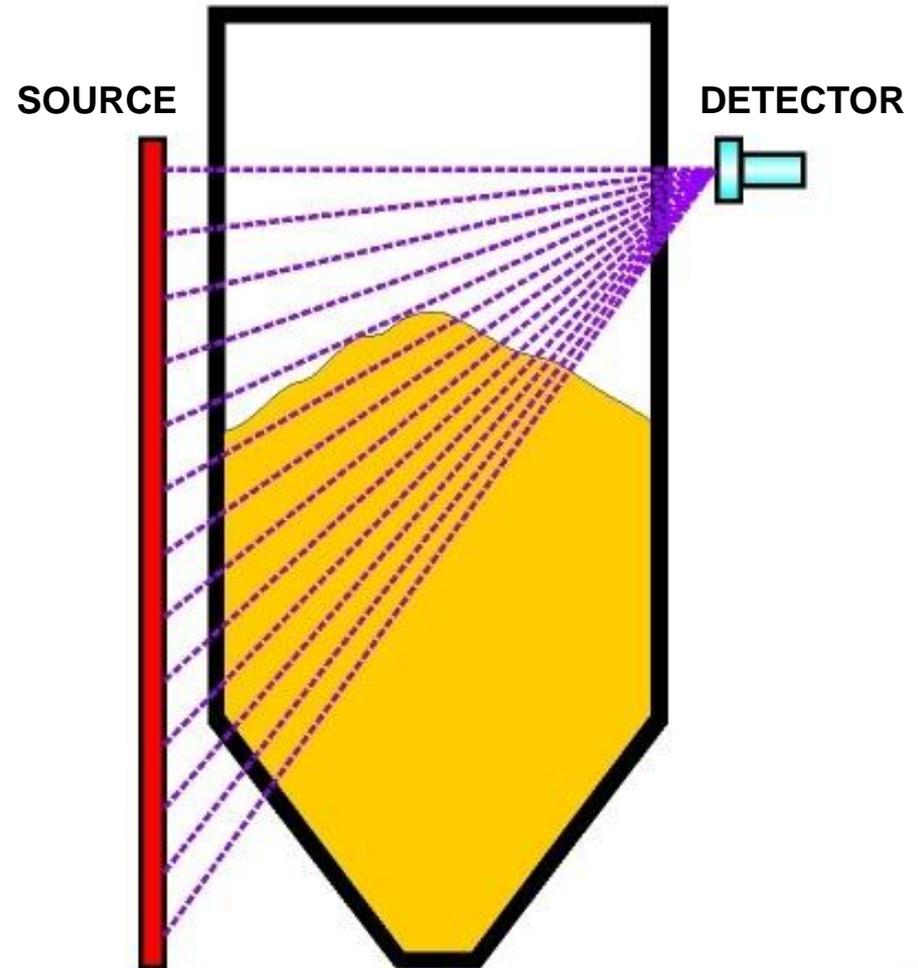
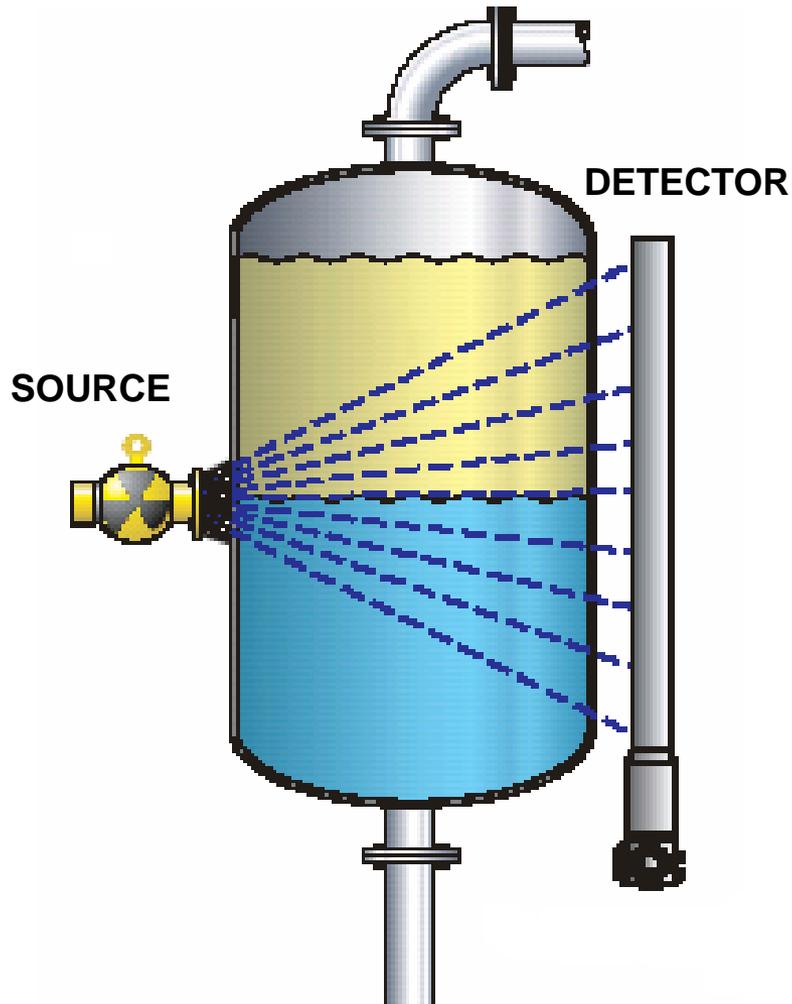
- Source Radioisotopes used for Level Measurement Emit Gamma Radiation that Penetrates the Vessel Wall and Process Media
- A Target Detector on the Opposite side Measures the Radiation Field Strength and Infers a Level in the Vessel
- The Radiometric or Nucleonic Principle is Based on the Fact that Gamma Radiation is Attenuated when it Penetrates a Material
- Cesium 137 (Half Life 30 Years) and Cobalt 60 (Half Life 5.26 Years) are the Most Commonly Used Industrial Isotopes



Level Instrumentation Types – Nuclear

- Geiger Tube Detectors are Used to Measure the Amount of Radiation Received and Hence the Level in the Vessel
- Lead Lined Source Holders Contain Radioactive Material with a Slit to Send a Narrow (in Horizontal Plane) Fan Beam Across the Vessel
- Source Strength has to Consider Vessel Wall Thickness
- Nucleonic Level is Considered for the Most Difficult Applications such as High Temperatures and Pressures, Toxic, Sticky/Blocking Materials. It is Used as a Last Resort.

Level Instrumentation Types – Nuclear



Level Instrumentation Concepts – Tank Gauging

- Tank Gauging is associated with Large Volumes of High Value Product
- Additional Measures are Taken to Achieve the Highest Possible Measurement of Level and Volume Correction



Level Instrumentation Concepts – Tank Gauging

This is Essential for:

- Stock Control for Production and Gains/Losses
- Asset Reporting for Tax Purposes
- Emissions Monitoring Via Tank Level Changes for Leakages
- Blending between Tanks of Out-of-Spec Product with In-Spec Product
- Cross Checks on Ship Loading/Off Loading Flow Meters and Ship Dips



Level Instrumentation Concepts – Tank Gauging

Tank Farm Level Configuration



Level Instrumentation Overview - Summary



- There is no single level measurement technique that will work in all applications.
- Proper installation is important for level not just for accuracy but for getting a measurement reading at all.

Any Questions???



Thanks for your attendance

