How would you identify your profession/status?

- Consultant/Engineer/Process Designer: 53%
- End User: 7%
- Salesperson/Vendor: 27%
- Student: 13%

Other (here for the food, between jobs, etc.):
ISA Toledo Section

How To Choose Level Instrumentation

A vendor perspective on how we can work better together to improve level instrumentation selection.

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This presentation is intended for educational purposes for ISA Toledo Section. This material is from Jeff Blair, unless I specifically cite or quote a source. This presentation does not necessarily represent the thoughts and views of Schneider Electric. There are no warranties or other offers implied by this presentation. Process equipment and instrumentation should be installed, operated, serviced and maintained by qualified personnel. No responsibility is assumed by Schneider Electric for any consequences arising from the use of this material.
Which geography best describes Toledo?

- Great Lakes: 25%
- Midwest: 25%
- Northeast: 25%
- Ohio: 25%
What the Experts Say

“Level can either be one of the easiest processes to control, or one of the most difficult…”
Why Level

- End user level related mishaps:
  - 2005 Buncefield
  - 2005 BP Texas City
  - 2009 CAPECO Puerto Rico
Why Level

- Storage Efficiency
- Flow in and out of tank
- Interface
- Level
- Volume
- Leak Detection
- Overflow/Safety
- Inventory

Image from: https://www.predig.com/whitepaper/level-measurement-technologies-process-control-industry
Why Level

- Sales perspective

2016 MCAA Products Market
All Industries by Product, by Cumulative Market Gain
5 Year CAGR = 3.6%, 5-Year Cumulative Market Gain = $2,282M
2016 Market Value = $11.7B
Bubble Size is 2016 Market Value

Why Level

- EPC
- Consultant
- Engineer/Owner’s Engineer
- CSI

Images from: https://www.aveva.com/-/media/Aveva/English/Products/Literature/Instrumentation/AVEVA_Instrumentation.pdf
Nearly every device will work; use the least costly

Many devices will work; check application parameters carefully

Few devices will work; check application parameters carefully... cost is a significant issue

The application may not be measurable or the cost of making the measurement is prohibitive

$  $  $  $  $  $

Mechanical Devices

Capacitance and RF Admittance

Ultrasonic

Differential Pressure

Radar Level

Laser Level

Nuclear Level

1 Atmosphere

PRESSURE

High

Very Easy

Somewhat Difficult

Much More Difficult

Nearly Impossible

Water

Water-Based Liquids, Acids and Bases

Slurries

Stationary Granulars

Oils and Emulsions

Interface Measurement

Agitated Tanks

Moving or Vibrating Granulars

Very Hot or Cryogenic Liquids

Vessels with Internal Structures

Thick-Walled Vessels

Image from: https://www.controlglobal.com/articles/2012/boyes-lowdown-radar-level-measurement/
What is PIP?

PIP - Process Industry Practices - is a member consortium of process industry owners and engineering construction contractors.

Members collaborate to harmonize internal company standards and “best practices” around design, procurement, construction, and maintenance into industry-wide PIP Practices for member use.

PIP Practices are on a 5-year revision cycle and are written and maintained by members on discipline teams.

Images from: https://pip.org/practices
13. What size flange connection is required for the heating jacket?

- B1 / DN15 PN40
- B1 / DN25 PN40
- B2 / DN15 PN40
- B2 / DN25 PN40
- ¾” ANSI 300 RF
- 1” ANSI 300 RF
- ½” ANSI 300 RFJ
- 1” ANSI 300 RFJ

14. Is a displacer element required? (Yes or No)

- YES (If yes proceed to question 15)
- NO (If no, proceed to question 17)

15. What is the required displacer material? (check one)

- 316 SS
- Hastelloy C276
- Inconel
- Monel
- Titanium
- PTFE

16. What is the required displacer length? (Available lengths are 12” – 591” [300 – 15000 mm])

Length =

17. Is a displacer chamber required? (Yes or No)

- YES (If yes proceed to question 18)
- NO (If no proceed to question 24)

18. What mounting type of vessel connections are required? (check one)

- Side – Side
- Side – Bottom
- Side – Top
- Top – Bottom

19. What is the required measurement length? (Available lengths are 12” – 236” [300mm – 6000mm])

Length =

20. What is the required chamber material? (check one)

- Carbon Steel
- 316 SS
- Hastelloy C276
- Inconel
- Other =

21. What size are the flange connections to the vessel? (check one)

- ¾”
- 1”
- 1 ½”
- 2”
- DN15
- DN25
- DN40
- DN50

22. What is the flange contact face? (check one)

- RF
- RJF/RJF
- RTJ
- E
- F
- LM
- LF
- LT
- LG
- ST
- SG
- B1
- B2
- C
- D
- LL

23. What type of drain is required on the chamber? (check one)

- No Drain
- ¾” Flange
- ½” Flange
- 1” Flange
- 1 ½” Flange
- 2” Flange
- ¾” NPTF
- DN15 Flange
- DN20 Flange
- DN25 Flange
- DN40 Flange
- DN50 Flange
- G ¾ Female Thread

Image from: http://www.Schneider-electric.com
Simple Seven

- Is the tank open, vented or closed?
- What’s the temperature of the process liquid?
- What’s the process pressure?
- What are the fluid properties?
- Is the material compatible with the process liquid?
- What are the available tank connections?
- What is your economic situation?
What continuous level instrument type do you use most often in new installations?

- Capacitance
- d/p (Hydrostatic)
- Displacer/Buoyancy
- Free Space Radar
- Guided Wave Radar
- Magnetic Level Indicator
- Magnetostrictive
- Ultrasonic Txmtr
• What else can we do?
• Don’t shoehorn
• Open the communication – be available and helpful
• Remote tools can save the day
• Techs – speak up!

• Design tanks for level devices

• Try new devices / update the AVL
  – Test lab
  – Pilot plant

Image from: Author's Personal Collection
- Back to school
- Join a club!
• Cause of accidents – poor maintenance/misapplication

• Do vendors need to step up their game and offer routine services

• Culture of safety instead of “keep it running!”
• Smart instruments are wonderful

• No substitute for physical inspection of instruments

• Case study of 60 months between calibrations
“…Vendors were chosen based on product technical quality, support, and lifecycle cost. An additional selection criterion was that the vendor be willing to devote special attention to the company to educate users about its products, address sales and support issues, and provide home-office backup assistance to resolve technical problems. This provided a readily accessible level of support in addition to the local sales representatives in the territory of each plant.”

Vernon Trevathan, ISA Fellow and St. Louis Section member from article
Level - What Are We Measuring?

- See the position of liquid/height of surface
- Infer level from head pressure
- This presentation concentrates on continuous liquid measurement (not bulk solids or gases)
Level – How We Measure

- Guided Wave Radar: 12
- Free Space Radar: 11
- d/p / Hydrostatic & Ultrasonic (tie): 10
- Capacitance & Buoyancy/Displacer & Magnetic Level Indicator (tie): 6
Guided Wave Radar

- Low energy electromagnetic pulses emitted and guided along a probe
- Pulses are reflected back at the product surface
- Distance calculated by measuring transit time
- Suitable for applications with foam, dust, vapour, agitated or boiling surfaces

Image from: http://www.schneider-electric.com/
**Guided Wave Radar**

**Level measurement principle (direct mode)**

![Diagram of level measurement principle](image)

**Figure 1-1: Level measurement principle**

1. Time 0: The electromagnetic (EM) pulse is transmitted by the converter
2. Time 1: The pulse goes down the probe at the speed of light in air, V1
3. Time 2: The pulse is reflected
4. Time 3: The pulse goes up the probe at speed, V1
5. Time 4: The converter receives the pulse and records the signal
6. The EM pulse moves at speed, V1
7. Transmitted EM pulse
8. Half of this time is equivalent to the distance from the reference point of the device (the flange facing) to the surface of the product
9. Received EM pulse
Guided Wave Radar

Typical choices you have to make:

• Process seal (Viton, EPDM, etc.), Probe type and length (cable, rod, coax, doubles), Process connection (NPT, flange, communication protocol)

• Typical Options: SIL2, Remote converter-electronics, secondary seal systems, removeable electronics, interface capability, Turck style connectors

• Typical max range: 130 ft.

Image from: http://www.schneider-electric.com/
Guided Wave Radar

• +++: unaffected by changes in liquid density, conductivity, pressure, temperature or by gas movement above the product; no tubing required; fewer leak points; works well in foam; generally better performing than free space radar – tradeoff is contact with the liquid

• -- -: dielectric constant (dk) of liquid must be high enough 1.1 dK absolute minimum (1.5 preferred); maybe tough to install – must have clearance on top of tank; viscous liquids may coat the probe; can’t be used with an agitator

• !!!: tank “shot” to blank out obstacles; install away from sidewalls; stilling wells, chambers and coax probes work well with turbulent surfaces
Free Space Radar

- Electromagnetic pulses emitted through an antenna
- Pulses reflected back at the product surface
- Distance calculated by measuring frequency shift or time of flight of pulse
- Easy & fast installation (no probe)
- Suitable for applications that are corrosive, high viscous, sticky or media with a heavy deposition

Image from: http://www.schneider-electric.com/
Free Space Radar

Typical choices you have to make:

• Process seal (Viton, EPDM, etc.), Antenna type (horn, cone, seal, parabolic, rod), Process connection (NPT, flange, communication protocol)

• Typical Options: SIL2, Remote converter-electronics; secondary seal systems; removeable electronics, Turck style connectors

• Typical max range: 98 ft. – 300 ft. (depends on frequency)
Free Space Radar

• +++: unaffected by changes in liquid density, conductivity, pressure, temperature or by gas movement above the product; no tubing required; fewer leak points; does not contact the liquid; easy to install

• ---: dielectric constant (dk) of liquid must be high enough 1.1 dK absolute minimum (1.5 preferred); may have difficulty with foam

• !!!: tank “shot” to blank out obstacles; watch the beam angle (bigger antenna diameter = smaller beam angle) to avoid obstacles in measurement area
All Radar Types

• Work with manufacturer who will allow a 90-day trial of a unit if the conditions aren’t ideal (e.g. free space radar with foam)

• Be careful when installing - you may have to connect a GWR probe to the bottom of the tank

• Fill out manufacturer application data and sketch of application

• Try to find a good installation location or make one

• As radars get less expensive they are displacing ultrasonics
“Perhaps the most frequently used device for the measurement of level is a differential pressure transmitter.” – https://goo.gl/1GMEEu

“There are many different technologies available, but, the most widely employed is differential pressure.” – https://goo.gl/wQCTCe

“...hydrostatic pressure measurement has been the most important measuring principle in continuous level measurement.” – https://goo.gl/EECpX6

“The most common measuring principles include absolute and gauge pressure measurement, differential pressure measurement, and hydrostatic pressure measurement.” - https://goo.gl/ZYKT8R
d/p / Hydrostatic

+++  - - -

• Inexpensive
• Simple
• Suitable in Many Conditions
• Interface
• Easy to Check in Field
• Suitable for Most

• Must know SG for true height
• SG changes-compensation is required
• Winterization is required

Source: http://www.pip.org/default.asp
Hydrostatic Principle

- $H = (GL) \times (x)$

- $H =$ hydrostatic head (pressure measurement) measured in inches of water (inH2O)

- $GL =$ specific gravity of the liquid

- $x =$ Height of liquid in inches
d/p / Hydrostatic

- d/p Min Level = (Y) (GL)
- d/p Max Level = (X+Y) (GL)
- Range = d/p Min Level to d/p Max Level
- Span = (X) (GL)
d/p / Hydrostatic

(Specific Gravity) GL = 0.8

X = 200”
Y = 20”

Image from: http://www.schneider-electric.com/
d/p / Hydrostatic

(Specific Gravity) GL = 0.8

- d/p Min Level = (Y) (GL)
- d/p Max Level = (X+Y) (GL)
- Range = d/p Min Level to d/p Max Level
- Span = (X) (GL)

- d/p Min Level = (20”) (0.8) = 16”H2O
- d/p Max Level = (200” + 20”) (0.8) = 176”H2O
- Range = 16” to 176” H2O
- Span = (X) (GL) = (200”) (0.8) = 160” H2O
**d/p / Hydrostatic**

\[
\text{Span} = (X)(G_L) \\
\text{LRV} = (Y)(G_L) - (d)(G_S) \\
\text{URV} = (Y + X)(G_L) - (d)(G_S) \\
\text{Range} = \text{LRV} \text{ to } \text{URV}
\]

where:

\[X, Y, \text{ and } d \text{ are in the same units}\]
\[\text{LRV} = \text{Lower Range Value at minimum level}\]
\[\text{URV} = \text{Upper Range Value at maximum level}\]
\[\text{LRV and URV are in units of Equivalent Head of Water, such as inH}_2\text{O or mmH}_2\text{O}\]
\[G_L = \text{Specific gravity of tank liquid}\]
\[G_S = \text{Specific Gravity of capillary fill fluid}\]

- Silicone (DC200, 10 cSt): 0.94
- Fluorinert (FC77): 1.76
- Silicone (DC200, 3 cSt): 0.89
- Silicone (DC704): 1.07
- Neobee: 0.92
- Halocarbon 4.2: 1.85
- Syltherm XLT: 0.85
Span = (X)(G_L) = 50"H2O

LRV = (Y)(G_L) - (d)(G_S) = (20 * 0.8) - (100 * 0.93) = -77"H2O

URV = ((Y+X)(G_L) - (d)(G_S)) = ((20+50) * 0.8) - (100 * 0.93) = -37"H2O
**d/p / Hydrostatic**

<table>
<thead>
<tr>
<th>X</th>
<th>50”H2O</th>
</tr>
</thead>
<tbody>
<tr>
<td>Y</td>
<td>20”H2O</td>
</tr>
<tr>
<td>D</td>
<td>100”H2O</td>
</tr>
<tr>
<td>GI</td>
<td>0.8</td>
</tr>
<tr>
<td>Gs</td>
<td>0.93</td>
</tr>
</tbody>
</table>

Span = 50 * 0.8 = 40”H2O

LRV = (20 * 0.8) – (100 * 0.93) = -77”H2O

URV = ((20+50) * 0.8) – (100 * 0.93) = -37”H2O
d/p / Hydrostatic

- Keep the minimum level ABOVE the bottom process seal
- Specify the proper span code (i.e. 0-200)
- Watch for sunlight on capillaries
- d/p - low vented to atmosphere - use bug screens
Ultrasonic

- Sounds waves bounce off surface
- Unaffected by fluid density or dielectric
- Difficulty with foam

Image from: https://www.coulton.com/beginners_guide_to_ultrasonic_level_transmitters.html
Magnetic Level Indicator

- Magnetic float “trips” panels to indicate level
- May be redundant measurement with 4-20mA Txmtr
- Watch for plugging or interfering fluids

Capacitance

- Measuring capacitance (C) between two conductors or plates
- Level inferred by knowing C at 0%/4mA and 100%/20mA
- Dielectric constant changes cause error
- Conductive = coated probe  
  Non cond. = metal rod or cable

**NON-CONDUCTIVE MATERIAL:** Vessel wall acts as ground plate

**CONDUCTIVE MATERIAL:** Material acts as ground plate
Displacer/Buoyancy

- Level inferred by buoyant force of displacer
- As the liquid level in the vessel changes, the buoyancy force on the displacer changes, resulting in a change to the “apparent” weight of the displacer.
- Ability to handle very high temps and pressures
- Affected by changes in liquid density
"We often forget that the performance of equipment is in the care of the automation system that is the window into the process and the means of affecting the process. It starts with the measurement. You can only do as good as what the measurement tells you. Despite the process being in the critical care of the measurement, we may obsess over project budgets losing sight of the bigger picture. The instrumentation is typically less than 10% of the cost of the equipment and piping yet we see projects cut corners from misguided goals based purely on hardware cost. Using the best sensor technology and redundancy can greatly reduce the lifecycle costs by adding intelligence and reducing maintenance. If you include the benefits from increased process efficiency and capacity, the decision is simple."

Source: Greg McMillan – conversation March 2019

Underlines are emphasis by author
Recommended Reading

- Walt Boyes
- N.E. Battikha
- Robert Heider
- Béla Lipták
- Peter Martin
- Greg McMillan
- Greg Shinskey
- David Spitzer
FAQ

- How often do you calibrate radar?
- Can you isolate a radar from the vessel?
- Are microwaves from radar safe?
References

References

- Boyes, Walt. "The Lowdown on Radar Level Measurement - Free-Air or Guided-Wave -- Which Do You Use When?" Control Feb 2012
- Spitzer, David. “Beginner’s guide to differential pressure level transmitters." Control Feb 2009