LEVEL MEASUREMENT SYSTEMS

• Level measurements is an integral part of process control, and may be used in a variety of industries
• Level measurement may be divided into two categories:
  ➢ point level measurement
  ➢ continuous level measurement

• **Point level sensors** are used to mark a single discrete liquid height, a preset level condition (as a high alarm or a low alarm condition)
• **Continuous level sensors** provide an analog output that directly correlates to the level within the containing vessel. This analog signal may be directly linked to a visual indicator or to a process control loop, forming a level management system.

The material to be measured

• **Liquid**
  – from pure, clean water to viscous, sticky, and corrosive and abrasive fluids
• **Bulk material**
  – from free-flowing, dry crystals to moist, lumpy solids

The processing environments for level sensors extend from vacuum to high-pressure service, and from subzero to elevated temperatures.

Level sensors

• **Mechanical sensors**
  – Float methods
  – Buoyancy method
  – Vibrating level systems
• **Hydrostatic pressure methods**
  – Differential pressure level detectors
  – Bubbler systems
• **Electrical methods**
  – Conductivity probes
  – Capacitance probes
  – Optical level switches
  – Ultrasonic level detectors
  – Microwave level systems
  – Nuclear level systems
**Floats**

- The basic float arm indicator comprises very simply a float connected to a pivoted arm that drives pointer or a switch.
- The unit can be made for either side- or top- entry.
- Moving parts present a very definite disadvantage, since they are situated in the liquid and are thus prone to corrosion and seizing
- Methods of the providing indication other then by linkage to a pointer include the use of a potentiometer, or of magnetic or inductive coupling

![Image of float arm indicator](image1)

**Design of floats**

**Floats with transmission linkage:**

![Image of floats with transmission linkage](image2)

**Floats with magnetic switches:**

![Image of floats with magnetic switches](image3)

**Buoyancy method**

- These devices use Archimede's principle
- The mechanical level indicator consists of the immersion body with calibrated measuring spring which transmits the change of level to the mechanical or electrical indicator

$$\pi r^2 (\Delta h - \Delta l) \rho g = k \cdot \Delta l$$

![Image of buoyancy method](image4)
**Vibrating level switches**

**Principle:** A vibrating fork or blade

- An electronic circuit excites the blade of probe to its resonant frequency, and when material comes into contact with the blade, vibration is damped causing switching of the relay
- This device is suitable for control maximum levels of solids and liquids in many types of applications (e.g., foods, grains, granules, pellets, cement, powder)

**Principle:**

**Design:**

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**Hydrostatic pressure methods**

- The hydrostatic pressure at the bottom of a container is directly proportional to the liquid height

**Measurement in an open vessel:**

\[ p = h \rho g \]

**Measurement in an enclosed vessel:**

\[ \Delta p = h \rho g \]

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**Bubbler systems**

- Clean air from a compressor is forced through a restriction into a tube that leads to the bottom of the tank
- The air pressure after the restriction is equal to the hydrostatic pressure at the bottom of the tank

**Measurement in an open tank:**

\[ p = h \rho g \]

**Measurement in an enclosed tank:**

\[ p_n > h_{\text{max}} \rho g \]

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**Conductivity level probes**

- only for electrically conductive liquids

**Continuous level sensing:**

![Continuous level sensing diagram]

Advantages:
- low costs
- simple electronic circuits
- no moving parts

**Capacitance level probes**

for nonconductive liquids:

**Principle:**

\[ C = \varepsilon_0 \varepsilon_r \frac{S}{d} \]

- \( \varepsilon_0 \) - permittivity of free space
- \( \varepsilon_r \) - relative permittivity
- \( S \) - area of electrodes
- \( d \) - electrode distance

**Cylindrical type sensor:**

- An insulated electrode is used (e.g. an insulated rod)
- The insulator may be polytetrafluorethylene or polyethylene
- The conductive liquid forms the second electrode
- With increasing liquid level increases the area of the second electrode as well as capacitance
- An electronic transducer converted capacitance changes into a voltage or current signal

**Conductance level probes**

for conductive liquids:

- Only for electrically conductive liquids

**Discrete level indications:**

![Discrete level indications diagram]
Capacitance level probes design

Applications:
- Suitable for measuring of liquids and bulk (loose) materials
- Suitable for wide temperature ranges (from -40 to +200) °C and high pressures
- Unsuitable for measuring foaming liquids

Optical level switches
- Light must be transmitted and then received
- Optical level sensors consist of:
  - Light source (bulb, LED)
  - Photoelectric detector (photodiode, phototransistor, photoresistor)
- Devices works with infrared or visible radiation

Design of level switches:

Ultrasonic level measurement
The measuring equipment consists:
- A transmitter that periodically sends a sound pulse to the surface of the liquid
- A receiver that amplifies the returning pulse
- A time interval counter that measures the time elapsing between the transmission of a pulse and receipt of the corresponding pulse echo

\[
L = c \cdot \frac{t}{2} \\
h = L_{\text{max}} - c \cdot \frac{t}{2}
\]

Influencing, interaction:
- gas density
- temperature
- mixing device
- foaming liquid
**Ultrasonic level-meter with compensation**

- Compensation of the influence of the gas density changes
- Cyclical measurement of the sonar pulse velocity in the environment
- Automatic compensation

![Ultrasonic level-meter diagram](diagram.jpg)

The sonar pulse velocity is calculated:
\[ c = \frac{2L_1}{t_1} \]
where \( t_1 \) is the time for the reference element distance.

**Ultrasonic level-meter design**

**Smart sensor for level measurement**
- Ultrasonic transmitter and receiver (piezoelectric principle)
- Microprocessor controlled electronic circuits
- Analog and digital output signal

![Smart transducer](smart_transducer.jpg)

**Microwave level systems**

- They are parallels in the operating principles of ultrasonic systems with microwave radar level systems
- Much higher frequencies (around 10 GHz) are used in radar system
- The radar beam is not affected by density changes

**Pulse method:**
- Microwave pulses are transmitted in short cycles
- The time is measured (ps)
- Demanding at the time measuring accuracy

\[ L = c \cdot \frac{t}{2} \]
\[ h = L_{\text{max}} - c \cdot \frac{t}{2} \]

- \( c \) - microwave velocity [m.s\(^{-1}\)]
- \( t \) - time [s]
- \( L \) - distance [m]
**Frequency Modulated Continuous Wave method**

- When the reflected signal $f_0$ returns to the receiver, it is mixed with the outgoing signal $f_1$.
- There will be a difference in frequency between the transmitted and the reflected signals $\Delta f = f_1 - f_0$.
- The difference in frequency is proportional to the time difference $\Delta t = t_1 - t_0$ and also to the distance to the liquid surface.
- The frequency difference can be measured very accurately.

**Radar level gauge design**

**Radar antennas:**

**Radar sensors on the tank cover:**

**Smart level sensor**
- uses Fast Fourier Transformation
- microprocessor controlled circuits
- analog and digital output signal
- high accuracy (± 5 mm)

**Nuclear level systems**
- Nuclear radiation from a selected source can be related to liquid or solids levels in a vessel
- Cobalt-60, cesium-137 or radium-226 is used as the gamma radiation source
- The radioactive source is capable of transmitting through the container wall
- As a detector for converting nuclear gamma ray radiation into electrical quantities related to level, some systems use Geiger counters

**Discrete level indication:**

**Continuous level measurement:**
- Intensity of radiation depends on the liquid level

**Applications:**
- liquid and solids level
- liquid/liquid interface
- high temperature and pressure
- high viscosity
- aggressive medias
Some guidelines for selecting instruments to be used for the indication or control of level

- The material to be measured must be looked at to determine its compatibility with the instrumentation. For instance: Is the liquid hot, cold, under pressure, viscous, corrosive, abrasive, hygienic?
- Is the area hazardous, requiring intrinsically safe or flameproof products?
- Can the sensor contact the material being measured?
- Can the sensor be inserted into an existing entry or does it require new "hole"?
- Does the instrument have to be top-enter or can be mounted in the side?
- Is point or continuous measurement desirable?
- Is remote control or indication desirable?
- Are there objection to the mechanical moving parts?
- The question must be asked whether or not the equipment need be compatible with data loggers microprocessor or computers.
- What is the required accuracy of the measurement?
- What are costs?

References


All texts for lectures Measurement technique are on web-sides:
http://www.vscht.cz/ufmt/kadleck.html