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CLASSIFICATION AND ANALYSIS OF LEVEL MEASUREMENT METHODS

MAKHMUDJONOV MIROLIM

Associate Professor, Tashkent State Technical University, Tashkent, Uzbekistan
Phone.: (0890) 128-7443, E-mail.: mirolim.muhammad.92@gmail.com
*Corresponding author

MUMINOV KHOLMURODJON

Assistant, Tashkent State Technical University, Tashkent, Uzbekistan
Phone.: (0891) 106-9887, E-mail.: xolmurodmominov2@gmail.com

TILAVKHANOVA LINDA

Master student, Tashkent State Technical University, Tashkent, Uzbekistan
Phone.: (0890) 420-1727, E-mail.: lindatilavxanova@gmail.com

Abstract: This article presents the classification of level measuring instruments and level sensors used as their sensitive elements. It describes the operating principles of electromechanical, electrical, optoelectronic, radio wave, acoustic and ultrasonic, hydrostatic, and radioisotope level sensors, providing examples of these devices. The advantages and disadvantages of using these sensors are also discussed. Additionally, the article analyzes the accuracy indicators of level measuring instruments and the factors influencing the results obtained from them.

Keywords: Level measurement, level sensors, radio wave level sensors, acoustic and ultrasonic level sensors, hydrostatic level sensors, radioisotope level sensors, factors affecting level sensor accuracy.

Introduction. Currently, various measuring instruments based on numerous level measurement methods are used in industry. According to the classification, they are categorized by their physical principles, which allows them to be grouped based on a general theory describing their structure and operation process (Fig. 1). Transducers based on these methods are divided into electromechanical level sensors, electrical level sensors, optoelectronic level sensors, radio wave level sensors, acoustic and ultrasonic level sensors, hydrostatic level sensors, and radioisotope level sensors [1,2,3].

Electromechanical level sensors

Figure 2. Float Switch (FLS) and Magnetostrictive Level Sensor (MTS)

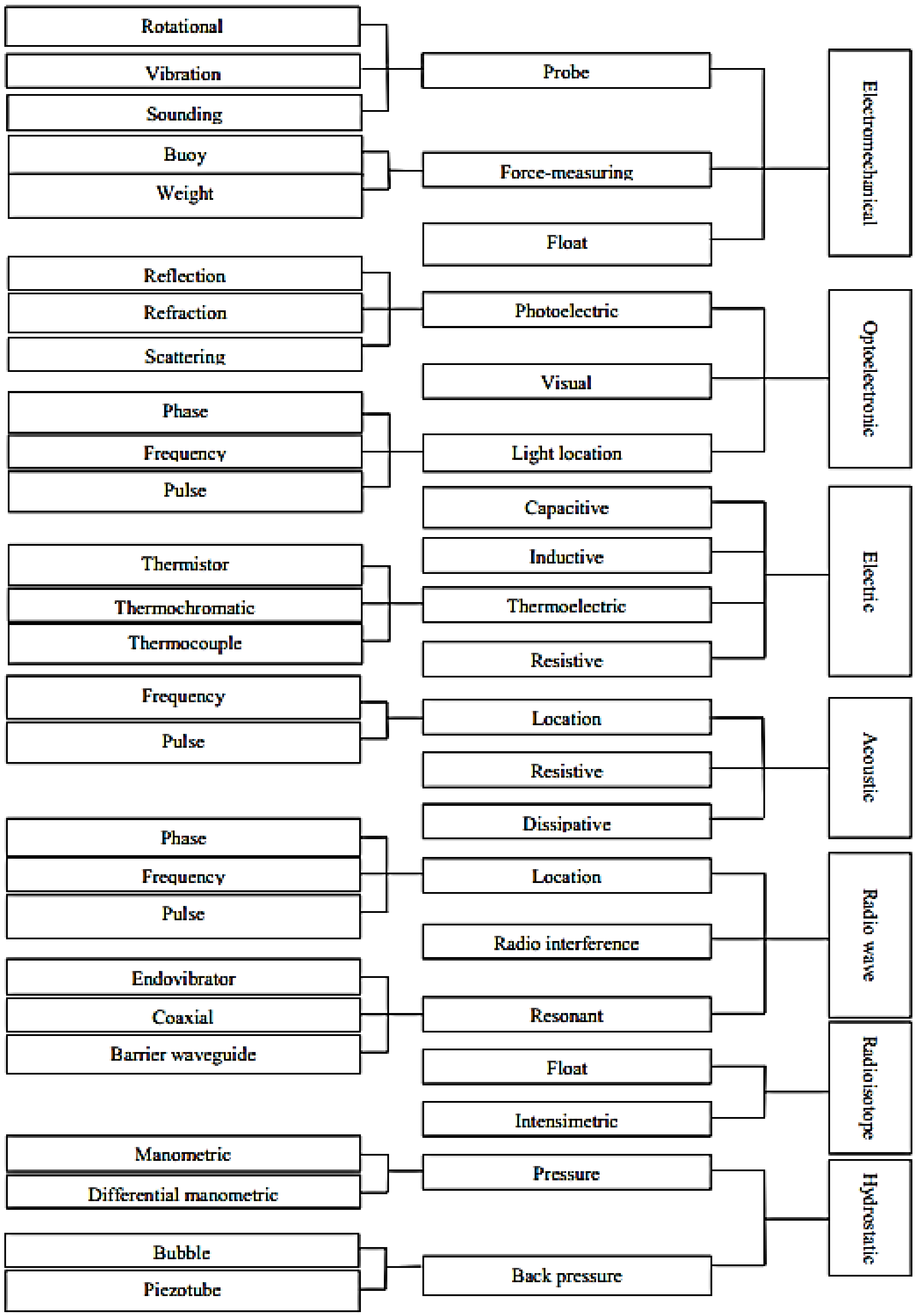

Figure 1. Classification of level gauges

With an electromechanical sensor, the level is determined by the angular or linear displacement of the sensitive element. The connection with the measuring transducer can be magnetic or mechanical. This method is considered a contact level measurement. These sensors are used both for signaling critical level values and for accurate and continuous level measurement [4,5]. Electromechanical level sensors have the following advantages: simple design, low cost, high reliability (durability of moving parts), and operation in a wide temperature range. Disadvantages: risk of malfunction during long-term mechanical use, suitable only for liquids (does not work with solid materials), potential for malfunctions and measurement errors in unclean environments.

Electric level sensors

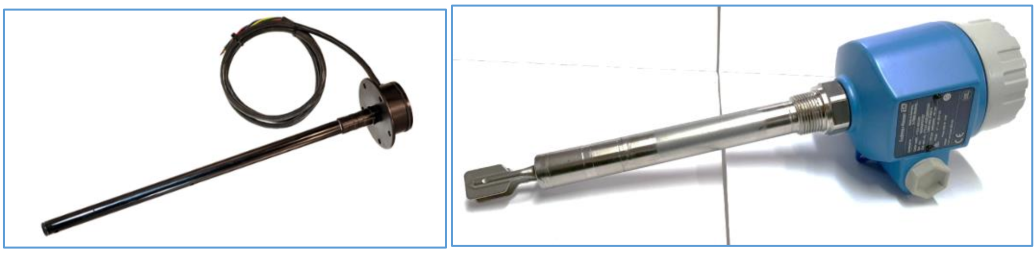

Figure 3. CLS Series Capacitive Level Sensor and Liquiphant M Point Level Switch

These level sensors operate based on the difference in electrical properties between the liquid and the vapor-gas mixture above it. Typically, electrical conductivity and dielectric permittivity are utilized. The sensitive element is constructed in the form of electrodes, which determine the level state when immersed in a substance [4,5,6]. Electric level sensors advantages: the absence of moving parts ensures long-term service life of the device, works with a wide range of liquids including oils, achieves high accuracy due to high sensitivity and stability of results. Disadvantages: dependence on the liquid's dielectric constant, decreased sensitivity in environments with variable operating conditions, calibration required after any maintenance.

Optoelectronic level sensors

Figure 4. KOBOLD OPT optic and Optical level sensor O1D300 level sensor

Such sensors utilize the properties of substances to absorb, refract, and reflect light waves. Systems using laser location principles operate on the basis of reflection [4,5]. In discrete level gauges, the principle of absorption is usually applied: the light ray directed to the photodetector is blocked by the surface of the substance. Advantages of optoelectronic level sensors: high measurement speed, availability of compact models, and resistance to chemicals. Disadvantages: decreased measurement accuracy in unclean or turbid liquids, higher cost compared to others, and sensitivity to external light sources.

Radio wave level sensors

Figure 5. Micropilot M FMR250 and Rosemount 5400 Level Sensors

This method is based on the phenomenon of electromagnetic wave reflection from the interface of media with different electrical and magnetic properties [4,5]. Advantages of radio wave (radar) level sensors: contactless measurement (operates in highly corrosive environments), suitable for any environment (dusty, high pressure), and capability for long-range measurement (up to 30 meters). Disadvantages: high cost, potential signal interruption by obstacles (for example, devices in containers), complex setup requirements.

Acoustic and ultrasonic level sensors

Figure 6. ULS 200 Ultrasonic Level Sensor 7ML1510-3JE02 and Echomax XPS-15 level sensors

Acoustic level sensors are based on the principle of measuring the time it takes for an ultrasonic pulse to travel from the emitter to the liquid surface and back. When receiving the reflected pulse, the emitter itself functions as a sensor [4,5]. If the emitter is located above the liquid, such a level gauge is called acoustic; if it is placed inside the liquid, it is called ultrasonic. In the first case, the lower the liquid level, the longer the measured time, while in the second case, it's the opposite. Advantages of acoustic and ultrasonic level sensors: they work with any type of liquid (including turbid ones), have no mechanical contact (ensuring long service life), and are easy to install. Disadvantages: sound speed depends on temperature (requiring additional calculations), foamy liquids reduce accuracy, and they are suitable only for short distances (up to 10-12 meters).

Hydrostatic level sensors

Figure 7. Deltapilot FMB53 and LMK 307 Level Sensors

This method of level measurement is based on the presence of hydrostatic pressure in the liquid, which is proportional to the depth, i.e., the distance from the liquid surface. When measuring the level using the hydrostatic method, pressure differential or pressure measuring instruments are used. Advantages of hydrostatic level sensors: simple and reliable design, operate under high pressure and temperature conditions, suitable for clean and turbid fluids. Disadvantages: changes in fluid density cause errors, installation location is crucial (measures pressure in the lower part), has a mechanical sensor (subject to long-term wear).

Radioisotope level sensors

Figure 8. LB 470 level meter and VEGASOURCE 81 level sensors

Radioisotope level gauges are used for precise non-contact measurement of level and volume in complex technological process conditions. This method allows for monitoring the levels of various solid and liquid substances [4,5,7]. Since all elements of the level gauge are located outside the vessel and do not have direct contact with the monitored substance, the radioisotope level gauge is not affected by parameters such as temperature, corrosion, vacuum, viscosity, and pressure. Advantages of radioisotope level sensors: ideal for extreme conditions (high temperature, chemical corrosion), works with any material (solid, liquid, powder), non-contact method. Disadvantages: radioactive hazard (special permission and protection requirements), expensive and complex maintenance, potential environmental hazard.

If we compare the advantages and disadvantages of the primary sensitive elements of the 7 types of level measuring instruments mentioned above, we can see the comparison results as shown in Table 1.

Table 1. General comparative table of level sensors

No	Sensor Type	Advantages	Disadvantages
1	Electromechanical level sensors	Affordable, reliable	Not resistant to mechanical corrosion, can only work with liquids
2	Electrical level sensors	Stationary, wide range	High sensitivity to the environment, frequent need for calibration
3	Optoelectronic level sensors	Fast, chemically resistant	Does not work in turbid environments
4	Radar level sensors	Contactless, able to operate in extreme conditions	Expensive, signal interference
5	Ultrasonic level sensors	Suitable for turbid liquids	Affected by foam and temperature
6	Hydrostatic level sensors	Simple, resistant to high pressure	Density changes cause errors
7	Radioisotope	For the most challenging conditions	Radioactive hazard, legal restrictions

When using a level gauge, it is necessary to consider external interfering factors and various physical and chemical properties of the reservoir's working environment (temperature, viscosity, pressure, vacuum, chemical reactivity, etc.). These properties vary within wide ranges and affect level gauges. In sensors whose operating principle is based on interaction with the substance, the properties of the medium are of crucial importance. Due to the variability of these properties, they can have a strong and unacceptable impact on the accuracy of the obtained results. Furthermore, when measuring the level by contact method, if the substance is chemically active, it can react with the material of the sensitive element, leading to damage of the components [8].

When measuring the level of viscous or paste-like substances, these substances may adhere to the elements of the sensor design, which makes it impossible to use contact level gauges. When measuring the level of bulk materials, contact level gauges are subjected to adverse mechanical effects, resulting in the sensor's sensitive element becoming unusable.

To achieve the specified accuracy within established limits during operation, regular calibration of contact level gauges is required. Contactless level gauges, however, are equipped with self-correction and self-checking devices for measurement results, which eliminates this drawback. The selection of a level gauge is influenced by environmental temperature, pressure, required measurement accuracy, capacity characteristics, and other factors for various specific tasks.

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