The Status Quo and Development Direction of Liquid Level Meter in Industrial Sector

Siyuan Lu

Shanghai Jinhua Private Middle School- SAINT MARYS, Shanghai 200333, China.

492002824@qq.com

Abstract

The industrial liquid level meters have been nowadays widely used in various industrial sectors such as pharmaceutical industry, petrochemical industry, food industry and environmental protection industry in order to ensure the safety of production lines as well as improving the production efficiency. Currently speaking, liquid level meters could be divided into two categories: the in-situ liquid level meter and the signal remote liquid level meter. The former one measures media based on physical and mechanical principles, which is generally used as the reference standard of the signal remote liquid level meter. The latter one enables the detected media to realize the real-time track record, remote control and other intelligent measurement functions by utilizing electronic component, conversion module and transmitter. Comparatively speaking, the signal remote liquid level meter has higher precision and more comprehensive functions. Yet as there are some electronic components that involve in its manufacturing process, some uncertain factors still remain. Based on the objective limitations and the overall shareability of utilizing liquid level meters during production process, the combining application of the in-situ liquid level meter and the signal remote liquid level meter is definitely imperative. Moreover, the design concept and final products of liquid level meters will highlight some significant features such as portability, intelligence, reliability, durability and simplicity.

Keywords

Liquid level meter; he in-situ liquid level meter; he signal remote liquid level meter.

1. Introduction

Liquid level meter is a very significant measuring instrument in modern industrial production process, which is mainly used for the measurement, demonstration and control of the liquid level in pot, kettle, tower and pressure vessel.[1] It has been widely applied in oil industry, chemical industry, sewage treatment, pharmaceutical production and a series of other research areas, where the high measurement precision and the special environmental adaptability of the meter in industry sites are both required. The application of medium with high temperature, high pressure, strong causticity and deep refrigeration, as well as remote transmission and the measurement in a closed pressure vessel should all be under serious consideration.

With the rapid development of high technology such as microelectronic computer, optical fiber and ultrasonic wave, various measurement methods have been sprung up in the field of the auto-measurement of liquid level since the 1980s. The requirement towards the measurement precision, stability and security of liquid level meter is higher along with the improvement of modern industrial automation. In the field of the auto-measurement of liquid level, much more measurement methods have been applied with more comprehensive functions and more adaptable performance indices that easily meet the demands of industrial production, which have become more automatic and more intelligent. 2]

This essay aims at introducing the typical instruments of two main kinds of liquid level meters (the in-situ liquid level meter and the signal remote liquid level meter) and the relevant detection methods during industrial production process. It will then comparatively analyze the characteristics of those tested instruments and finally make further discussion on the development tendency of the liquid level detection technology.

2. Common Liquid Level Meters

When the products have been actually put into industrial use, two kinds of liquid level meters with different principles of measurement need to be applied for real-time monitoring, that is, the in-situ liquid level meter and the signal remote liquid level meter.

The in-situ liquid level meter with simple structure and direct-view appearance utilizes physical and mechanical methods and applies the measurement principle of communicating vessels, which to a great extent avoids obvious errors and the influence of electronic component failure. Therefore, the liquid level parameters shown on the in-situ liquid level meter could be used as the correct measuring standard and the reference base of the remote liquid level meter, while the remote liquid level meter realizes its long-distance demonstration, configuration and control by making good use of its sensor, electronic component and modular operation mode, which makes the whole production chain safe and reliable.

The in-situ liquid level meter could roughly be divided into four categories: the glass level meter, the magnetic level meter, the two color quartz glass tube liquid level meter and the float ball liquid level meter; The signal remote liquid level meter could mainly be classified as the float pontoon liquid level meter, the magnetostrictive liquid level meter, the static pressure level meter, the radar level meter and the ultrasonic liquid level meter. The selection of different types of liquid level meters needs to adapt to the current temperature, pressure, corrosion resistance and other requirements according to different working conditions. [3]

2.1 The In-situ Liquid Level Meter

The in-situ liquid level meter is one of the indispensable instrument during modern industrial production process. By using "the law of connected vessels" in Physics, the vessel opens its holes from both the top and the bottom and connects itself with the in-situ liquid level meter through flange. Then the media in the vessel need to be injected inside the chamber of the liquid level meter, so that the actual height of liquid level would be directly shown on the liquid level meter. Common in-situ liquid level meters include the glass level meter, the magnetic level meter and the two color quartz glass tube liquid level meter.

Comparative analyses of the above three kinds of in-situ liquid level meters are shown in the Table 1.

Table 1 The Summary Table of Comparative Analyses on Common In-situ Liquid Level Meters

Name of the In-situ Liquid Level Meter	Advantages	Disadvantages
Glass level meter	Clearness; direct-view appearance	Heaviness; inconvenience of installation
Magnetic level meter	Little linkage; good sealing	Lack of high precision
Two color quartz glass tube liquid level meter	Wide visual surface; adaptability of night check	Maladjustment of thick and high-pressure medium

2.1.1 Level Meter

Based on "the law of connected vessels", the glass level meter could help researchers view the real-time liquid level inside the vessel, which makes the whole measurement process simple and clear [4]. By changing the pitch numbers of the glass boards, glass level meters with different lengths could be manufactured for various field demands. As most parts of the glass level meter are made of the carbon steel and stainless steel, the glass level meter has relatively high cost performance with low cost.

However, its joint structure leads to much more leaking points compared with that of other types of liquid level meters, which greatly reduces its sealing property. Additionally, its materials make the glass level meter much heavier and more inconvenience, so that it is generally not suitable for the remote measurement. Thirdly, due to the joint structures of the glass boards, there are some blind areas that exist on certain liquid levels between two boards.

This kind of liquid level meter general realizes the connectivity by mating two flanges for installation. Because of the special structure of glass level meter, the chamber is relatively narrow and small, which causes limitations for the viscosity of the tested media. In other words, media with much impurity are not suitable for the application of this kind of meter. In addition, the cumbersome glass level meter is not applied to the measurement of vessel which is longer than two meters. Common glass level meters on the market include transparent glass level meter (HG5-1364-80), reflective glass level meter (HG5-1366-80), anti-frost glass level meter (HG5-1365-80) and illuminated glass level meter (UB-6).

2.1.2 The Magnetic Level Meter

The magnetic level meter is composed of primary conduit, magnetic float and display panel. Turning plates with two colors are set within the panel, in which white color represents the no-liquid state while the red color represents the liquid state. According to the principle of buoyancy, the level of float ball in the primary conduit would rise up along with the increasing of liquid level within the vessel under the magnetic coupling effect. Then the magnetic transmission would take effect towards the external magnetic turning plate, which makes the turning plate show the red side. The other white side would be shown as the liquid level decreases. Therefore, researchers may directly view the liquid level of the media within the vessel according to the color of the turning plates. [5] Most of the magnetic level meters are side-mounted or top loaded, and its simple structure and measurement principle bring much more convenience to the field installation of magnetic level meter. Generally speaking, the magnetic level meter with lightness and simplicity has relatively higher cost performance.

Although working principle of the magnetic level meter is very similar to that of the glass level meter, there are less open holes for the former one, which greatly increases its safety and sealing property. Moreover, the length of its float pontoon could be customized according to the length of the measuring vessel, so that the application scope of this kind of meter is relatively wider (the length of the vessel≤10 meters). It could also add or change some components so as to deal with extreme working conditions. For instance, it may be changed into a kind of signal-output level meter by adding remote suites on it; It may also become the polytetrafluoroethylene (PTFE) magnetic level meter in order to cope with the tested liquid with high corrosion; It could further measure the liquid level of low-temperature media by applying the vacuum anti-frost structure.

2.1.3 The Two Color Quartz Glass Tube Liquid Level Meter

The two color quartz glass tube liquid level meter is a kind of advanced in-situ liquid level meter with the cutting-edge technology. As light reflects and refracts differently in different media, the turning plates in the vessel would demonstrate different colors in different conditions: the red color represents the no-liquid state while the green color represents the liquid state. It’s worth noting that compared with the general glass level meter, the two color quartz glass tube liquid level meter has clear gas-liquid interface, and there is no blind zone during measurement process [6]. Based on the refraction principle, this kind of in-situ liquid level meter overcomes the shortcomings of traditional glass level meter and will not face the problem of inaccurate readings. Based on "the law of connected vessels", when two flanges are connected to the vessel, the change of liquid level will be timely reflected via viewing the glass tube. Researchers on the spot could easily judge the liquid level through distinguishing the red and green color of the turning plate. This kind of liquid level meter has the advantages of easy portability, installation convenience and good sealing property.

The main body of this two color quartz glass tube liquid level meter is made of carbon steel, stainless steel and quartz glass tube, which is suitable for measuring media whose pressure ranges from 1.6mpa

to 6.4mpa, and whose temperature is below 500℃. Therefore, it has been widely applied into chemical engineering, petroleum, medical science and many other industrial fields. The weakness of this kind of liquid level meter is that it is not applied to the measurement of those thick, high-pressure and low-temperature medium, because a small amount of liquid might hang on the inner walls of the vessel, which will result in measurement error as the inner glass tube is opaque to light.

2.2 The Signal Remote Liquid Level Meter

The signal remote liquid level meter is also one of a necessary measurement instrument during the modern industrial production process. This kind of liquid level meter specially applies to the liquid level measurement and could realize signal output. Its development and manufacture are highly related to sensor, electronic components and software programming technology. Common signal liquid level meters include magnetostrictive liquid level meter, guided wave radar level meter and ultrasonic liquid level meter.

Comparative analyses of the above three kinds of signal remote liquid level meters are shown in the Table 2.

Table 2 The Summary Table of Comparative Analyses on Common Signal Remote Liquid Level Meters

Name of the Signal Remote Liquid Level Meter	Advantages	Disadvantages
Magnetostrictive liquid level meter	High precision	Poor anti-interference ability
Guided wave radar level meter	Signal stability and centralization	Necessity of periodic cleaning
Ultrasonic liquid level meter	Convenience for installation and maintenance	Tendency to be influenced by temperature variation

2.2.1 The Magnetostrictive liquid level meter

The magnetostrictive liquid level meter is a new-generation liquid level meter with quite high measurement precision based on the magnetostrictive principle [7]. The relevant magnetostrictive effect is a kind of physical phenomenon because of which the ferromagnetic material would change its form in the magnetic filed. In other words, the magnetic domain in random orientations within ferromagnetic materials will go in the same direction as that of the external magnetic field, so that the ferromagnetic material will then undergo extension or contraction aligned with the external magnetic field in geometry.

The magnetostrictive liquid level meter measures the liquid level by its inner magnetic float which moves along with the fluctuation of the liquid level, but its working principle is totally different from the float ball liquid level meter. The sensor of the magnetostrictive liquid level meter may transmit the current impulse (also called the initial impulse) through the waveguide line, which may create a magnetic filed. This filed will meet the loop's magnetic filed and thus combine into a superposition. The instantaneous twisting force caused by magnetostrictive effect will then twist the waveguide line and create the pulse of tensile force, which finally goes back to the original zone at a constant speed via the waveguide line (here the pulse will be called as termination pulse). Through this process, the liquid level of tested medium could be accurately measured by calculating the time difference between initial impulse and the termination impulse. The appearance and structure of magnetostrictive liquid level meter is similar to that of float ball liquid level meter.

Advantages of magnetostrictive liquid level meter include: high precision, good stability, long working life, multi-signal output, the ability of anti-polarity protection, anti-lightning and anti-RF interference, smart structure, strong environmental adaptation and wide range of application. This kind of liquid level meter also has its unique functions of liquid level measurement for multi parameter, self-correcting and maintenance free, which is especially suitable for the liquid level measurement with large range, multi parameter and high precision. The maximum measurement

range could reach 18m and the measurement precision could accurate to 0.1-0.5mm. It is not very sensitive to the temperature variation and may simultaneously do the multi-point detection. However, the magnetostrictive liquid level meter also has some shortcomings. The production cost is relatively high, and it could not withstand high working pressures. Additionally, different density of liquid causes different level of the float, so that the measurement data should be acquired based on the actual medium.

The magnetostrictive effect develops rapidly in the application of liquid level measurement, and the SF, MS, SFMS and UPM100 are all common series of magnetostrictive liquid level meter. The mentioned advantages of it help magnetostrictive liquid level meter become very popular in the industrial field of modern liquid level measurement. Soon it will be widely used in the high-precision and multi-parameter liquid level measurement.

2.2.2 The Guided Wave Radar Level Meter

The guided wave radar level meter is a new-type liquid level meter, which transmits pulse signal through wire rope based on the reflection principle. When the pulse signal meets the tested liquid, it reflects back to the top unit via the same wire rope, so that researchers could judge the whole measurement range and liquid level through calculating the transmission time [8]. The guided wave radar level meter has relatively high requirement on the dielectric constant of the tested media. As low dielectric constant could hardly catch the reflecting signal which might cause measurement error, the guided wave radar level meter could not be used to measure media with the dielectric constant underε1.4. Moreover, because guided wave rod and guide wire are contained within the structure of the guided wave radar level meter, it is relatively hard for the installation and measurement of high-length vessels. Generally speaking, this kind of liquid level meter has many obvious advantages. For instance, it sends centralized pulse signal; its measurement is very precise without being influenced by the external high temperature, high pressure, foam, steam and noise; it sends stable and continuous electronic pulse which guarantees the continuity of scientific measurement. Besides, the measurement of guided wave radar level meter could be accurate to 5mm, and its maximum measurement range reaches 30m. It could also be manufactured as anti-explosive liquid level meter in order to protect the security of the whole spot. The high pressure resisting guided wave radar level meter is able to withstand the high pressure within 40MPa, and the high temperature resisting guided wave radar level meter could bear 400℃ at most. For these above reasons, this kind of liquid level meter has always been widely used in various industrial fields, including the measurement control area.

2.3 The Ultrasonic Liquid Level Meter

The ultrasonic liquid level meter is a kind of non-contact liquid level meter. The structure and working principle of this liquid level meter are very simple and clear, which imitates the physiological predation mechanism of spider. In other words, the sensor of the ultrasonic liquid meter sends ultrasonic wave, which then passes to the surface of liquid level, and next reflects back to the top receiver [9]. This kind of liquid level meter may cause some measurement errors when it is used in the measurement of medium with foam or when dewing phenomenon occur on the surface of the receiver. In addition, different tested conditions with different temperature may cause different sound speed, so that the ultrasonic liquid level meter is not suitable for some certain working conditions which may influence the propagation of sound waves, where the temperature changes greatly and where there is much dust in the air. After the ultrasonic pulse is sent, the reflected pulse could not be instantly received, so that the blind distance of measurement is generally from 4cm to 15cm. Moreover, the ultrasonic liquid level meter could be manufactured into the polytetrafluoroethylene-type liquid level meter so as to effectively measure high corrosion media.

One of the obvious shortcomings of this liquid level meter is that the length of tested object should be shorter than 20m. It is also not applied to the high temperature and high pressure working conditions, as the ultrasonic liquid level meter strictly controls the temperature range from -20℃ to 60℃. So far, the ultrasonic liquid level meter in the market could hardly be explosion-proof, which means that for safety considerations it is not suitable for the high pressure (higher than 1.5MPa)

working condition. Furthermore, a signal isolation amplifier is needed for the areas with electromagnetic interference, which may help deal with this kind of external disturbance so as to ensure the accuracy of the measurement.

3. The Optimum Type of Liquid Level Meter

3.1 A Brief Analysis of Different Types of Liquid Level Meter

Various types of liquid level meter spring up in the market for meeting the large demands of liquid level instrument. All of the products are for the same purpose: to precisely measure the liquid level [10]. I believe that every client may face choice questions when tending to buy a liquid level meter, as you don't know which one is really suitable for your own special requirement. Actually each of the liquid level meters has its own advantages to cope with different working conditions.

The glass level meter, glass tube level meter and quartz glass tube liquid level meter are all belong to direct-reading liquid level meter. Based on "the law of connected vessels", when the main tube and the vessel have synchronous motions, we could directly look through the transparent tube and view the changes of the liquid level with the naked eyes. This kind of liquid level meter is not affected by the fast changes of liquid level in the vessel which may bring mistakes to the measurement, because the liquid level we see in the instrument is actually the real level within the vessel. However, this type of liquid level meter also has many shortcomings, such as low visibility at night. We could hardly distinguish the liquid level under the dark or long-distance circumstances, which is a fatal flaw for this type of products. Similar types of liquid level meter, such as the two color quartz glass tube liquid level meter, successfully deal with the visibility problem. This kind of liquid level meter has large viewing angles and extended visual surface. It could also detect the liquid level from a long distance via cameras. Based on the refraction principle, the refraction of light within the tube would be changed if the liquid was added into the tube, so that the turning plate would show its different side with a certain color for researchers' recognition. However, this kind of direct-reading liquid level meter generally has many disadvantages such as poor sealing property and relatively large number of leaking points. The glass level meter, for instance, is very cumbersome and inconvenience for installation and could not be manufactured in wider measurement range. Recently, the most popular liquid level meter in the market is the magnetic level meter with good sealing property, high temperature resistance and high pressure resistance. It can be manufactured into the polytetrafluoroethylene-type liquid level meter in order to resist strong corrosion, and may realize its remote transmission function if its usage is combined with a sensor. In brief, the magnetic level meter has high cost performance.

The magnetic level meter can be used to measure the liquid level lines of two different materials. Researchers adjust the buoyancy force of the float until it demonstrate different states in different conditions: the float remains afloat on the surface of one kind of liquid, while changes into precipitation state in the other kind of liquid. In this way the magnetic level meter could measure the dividing line of different liquid levels. This type of liquid level meter has advantages of versatile application, long working lifetime and few special restriction on working conditions. It is generally a good choice for most of clients.

In terms of the measurement precision, the radar level meter is definitely worth mentioning, with small measurement error ranges (less than 1mm), smart structure and convenient installation procedures. However, its cost performance is not very high, and clients rarely select this type of liquid level meter unless they intend to measure liquid with extremely high accuracy.

The input-type liquid level meter occupies a large amount of signal remote liquid level meters, which measures the liquid level through a module with a cable. This module could induct the pressure of the liquid media and then converse the pressure into liquid level via a transmitter. This type of liquid level meter has both high cost performance and high measurement precision.

The ultrasonic liquid level meter and radar level meter belong to non-contact liquid level meter, that is, these liquid level meters could measure the real-time liquid level in the vessel without touching

tested materials. This type of liquid level meter has great advantages when measuring liquid with high thickness. As it does not touch the tested materials, accurate measurement could still be realized even if less liquid sticks to the wall of vessel. Moreover, the non-contact liquid level meter is not influenced by high temperature and high pressure. Its measurable temperature ranges from -196℃ to 350℃, and its maximum measurable pressure reaches 400bar. The instrument is also operational in the vacuum environment. Yet when using this type of liquid level meter, it is worth noting that the dielectric constant of the tested media cannot be lower than ε1.2.

3.2 The integrated measurement method of different types of liquid lever meters

In order to ensure the security of the whole production process, sometimes only one liquid level meter is not enough. In the application of modern industrial production, random errors or other uncertain factors may easily appear when using liquid level meter. Factories generally select two or more different liquid level meters with different working principles, so that these instruments could mutually help check data during their working procedures. Generally speaking, the in-situ liquid level meter is used for references, as this kind of liquid level meter is manufactured totally based on the principle of physics and mechanics, while the signal remote liquid level meter usually applies some parts such as electronic components, transmitter and sensor, which are always uncontrollable with relatively high error rate. During the actual operation, the remote liquid level meter is also of great importance with many advantages. It highly improves the production efficiency in industry and provides human beings with great convenience. We could know small or big changes of the liquid level in the vessel just in our office instead of going outside, and detect the whole trend of the measurement process via remote control. Above all, the remote liquid level meter could help improve the measurement security. It has the function of liquid level warning when the level is too high or too low, helping researchers know the real-time liquid level. Then researchers could make appropriate adjustments for the current condition. Therefore, remote liquid level meter plays a great role during our production, making the process much more intelligent. In the industrial application, the combination of one in-situ liquid level meter and one signal remote liquid level meter is very necessary and reasonable, as they could check data for each other and ensure the safety of equipment operation, which greatly improve the working efficiency.

4. Future Development Tendency of Liquid Level Meter

With the rapid development of science and technology, in the future liquid level meter will surely become much more intelligent with smaller volume. Some types of liquid level meters such as the contact liquid level meter will be gradually driven out of the market, because they are easily influenced by the tested media, which for instance might be the high corrosion or high temperature liquid. They are thus not applied to certain industrial fields like food processing.[11] In terms of instrument installation, the future liquid level meter will be installed and debugged without too many human-power resources. In addition, the development space of signal remote liquid level meter will be relatively larger. As each current remote liquid level meter more or less has its own shortcomings that could not meet all the working conditions, many world' top manufactures of liquid level meter, such as Fisher, E+H, Emerson, FOX and Vega, have made great efforts to overcome various difficulties in regard to the remote liquid level meter. They have prepared to research and develop more advanced measurement instruments for the modern industries in the future. At the same time, three preconditions are definitely necessary during the development process of liquid level meter: product quality, security coefficient and precision. Modernized factories help cut down the human cost greatly, so that we could see obviously the reduction of the volume of many cutting-edge products. For instance, the external liquid level switch in which the high intensity ultrasonic sound waves may pass into the wall of vessel and then reflect back. Based on different reflection characteristics of the ultrasonic sound waves we could know whether the liquid level in the vessel has reached the known height and decide whether we need to raise the alarm. Moreover, the gamma ray liquid level meter also belongs to the advanced technological product. In one side of the vessel, radiation source is needed to be installed in order to let the gamma ray covers the whole measurement

range in a geometrically angled way. In the other side of the vessel a detector is used for the reception of gamma ray from the other side. As the intensity of this kind of ray would be greatly weakened during the process of the ray's passing through materials or liquid, the detector could easily detect the real-time liquid level in the vessel. The volume of radiation source is small with great portability and long useful life. It is applied to the extreme working conditions with high temperature, high pressure or high corrosion without directly touching media. It could be referred to as a typical advanced remote liquid level meter, and we believe in the future there will be more and more intelligent liquid level meters in the market that provide industrial convenience and improve production efficiency. Even though the most advanced remote liquid level meter is developed, in-situ liquid level meter is still indispensable. Based on its physical and mechanical principles, this type of liquid level meter does not have wide developing prospect. Generally speaking, the magnetic level meter is a reliable one with comprehensive functions and high security coefficient. Therefore, I believe this type of liquid level meter, as a kind of in-situ liquid level meter, will be widely applied in production lines in the future that provides a dependable reference for the future design of remote liquid level meters.

References

[1] Zhang Weiliang. Applications of the Liquid Level Meter in Chemical Industries[J]. Shandong Chemical Industry, 2014, 43(4):76-77.
[2] Wang Yuan & Xu Fei. A Brief Introduction of the R&D of Liquid Level Meter[J]. Engineering Technology: Unabridged Version, 2017(3):00245-00245.
[3] Zhang Xinjuan. Selections of General Liquid Level Meters[J]. Scientific and Technological Information, 2012(27):53-54.
[4] Wei Bo. Error Discussion on the Measurement of Glass Level Meter[J]. Shanghai Gas, 2008(6):6-8.
[5] Yuan Ming. Analyses of on-spot Calibrating Methods of Magnetic Liquid Level Meter[J]. Industrial Measurement, 2011, 21(3):63-63.
[6] Zhang Lei, Shan Sufang & Fan Chu. Measurement Principle of Two Color Glass Level Meter[C]// Annual Meeting of Chinese Petrochemical Automation. 2011.
[7] Li Changchun. Characteristics and Applications of Magnetostrictive Liquid Level Meter[J]. Chinese Advanced Technology and Products, 2011(8):112-112.
[8] Lv Qinmei. Applications of Guided Wave Radar Level Meter in Liquid Level Measurement[J]. Academic Journal of Shanghai Electronic and Computer Engineering College, 2011, 14(5):347-350.
[9] Gong Yuanjiu & Wang Jiang. Ultrasonic Liquid Level Meter[J]. Electronic Measurement Technology, 2004(5):70-71.
[10] Deng Huixian. Selection and Application of Petrochemical Tank Liquid Level Meter[J]. Chinese Science and Technology Review, 2012(22):450-451.
[11] Yang Zhaohong & Li Huan. Developing Situation and Trend of New Measurement Technology of Liquid Level Meter[J]. Industry and Mine Automation, 2009, 35(6):61-64.