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Level gauges. Application features

G. Narodnytskyi, E. Suhomlinov, S. Tiupa, A. Marchenko

National Scientific Centre "Institute of Metrology", Myronosytska Str., 42, 61002, Kharkiv, Ukraine
Gennadiy.narodnitsky@metrology.kharkov.ua; narodnitsky@gmail.com

Abstract

This paper considers various aspects of application of the most common types of level gauges – magnetostrictive, servo-driven, radar and reflex. Much attention is paid to accuracy of level gauges, expressed in error and uncertainty, including those referred to the legally regulated measuring instruments. Due to the fact that the most of the level gauges are installed on tanks, the requirements for them, given in the standards, and possible ways to improve the accuracy of level gauges installed on tanks have been analyzed. Methods of verification and calibration of level gauges are considered, including both verification on standard units using water, and carried out by the simulation method.

The requirements for the metrological control of level gauges with moving parts are stated. It is shown that for verification of such level gauges, it is necessary to carry out measurements when the water moves both up and down. However, there is no need to take measurements, as in determining the variation, at the same points when the water moves up and when the water moves down.

Some known caution is needed when using the results of the verification of level gauges by the simulation method. Especially big differences in the results of verification on the standard unit with water and the simulation method are observed for magnetostrictive level gauges.

This difference is due to the fact that in these level gauges, the float slides along the pipe with a certain friction, and in the simulation method, the float moves by hand and its movement does not depend on friction.

Keywords: variation; range; test; error; level gauge.

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Introduction

Level gauges are measuring instruments with a very wide range of applications. This requires a careful analysis of all the features of their work and, first of all, the influence of the conditions of level measurement in tanks should be analyzed, where high measurement accuracy is very important. It is equally important to correctly take into account the change in the ambient temperature and to give an additional error due to the influence of temperatures in the operating documents. In addition, the requirements for the stability of the position of the level gauge on the tank should be formulated.

Research results

Level gauges are measuring instruments for level measurement – the distance from bottom to top from any base (surface of the earth, bottom of a water, etc.) vertically to the boundaries between two environments, for example, water and air, free flowing medium and air. In many cases, level gauges do not measure from bottom to top, but from top to bottom. The level gauge apparatus easily converts distances to level if necessary.

Level gauges are divided into non-contact and contact, in contact level gauges, the sensor (probe) touches the medium, the distance to which is measured; in non-contact level gauges, it does not touch. Example of contact level gauges – magnetostrictive, servo-driven, example of non-contact level gauges: radar (microwave), reflex.

Let's dwell in more detail on the characteristics of level gauges. In the first place among them is the accuracy, expressed in error or uncertainty. As a rule, the error or uncertainty (hereinafter – error) of level gauges is from ± 1 to ± 10 mm. Due to the fact that for government accounting and commercial operations level gauges are mainly used, installed on tanks, it is these level gauges that are classified in Ukraine as legally regulated measuring instruments (MIs) in accordance with the Technical Regulations on legally regulated MIs [1]. The corresponding standard for this Resolution of the said Regulations is DSTU OIML R 85 [2]. This standard specifies that the accuracy of level gauges intended for installation on tanks should be ± 1 mm in laboratory conditions. Level gauges not installed on tanks are not subject to this limitation. A very essential characteristic of level gauges

Table 1

Error when lowering the water level

Level, mm	1780.1	1572.8	1374.2	1172.8	974.4	824.6	683.3	515.7	367.6	220.2
Error, mm	0.2	0.3	-0.1	0.3	0.3	0.1	-0.2	-0.2	-0.3	-0.4

Table 2

Error when increasing the water level

Level, mm	465.2	671.4	863.6	1063.5	1211.7	1364.7	1511.8	1665.0	1810.9	1960.9
Error, mm	-0.6	-0.4	-0.6	-0.2	-0.4	0	-0.1	0.2	0.7	0.8

is the component of their error caused by the ambient temperature, or the range of ambient temperature in which the error does not exceed the standardized value. The uncertainty of level gauges in operating conditions is a very important and thoroughly verified characteristic. Usually, such a check is carried out not on a standard unit, designed to verify metrological characteristics, but in heat chambers with parallel fixation of the change in the level gauge readings in a simulation mode (with a reflector, a bridge or other devices). In this case, the level gauge error Δ equals:

$$\Delta = \sqrt{\Delta_1^2 + \Delta_2^2},$$

where Δ_1 – absolute error of the level gauge under normal conditions, mm; Δ_2 – maximum change in level gauge readings when exposed to high and low temperatures, mm.

This result is somewhat different from that which would be obtained if the temperature change was carried out directly during the verification of the metrological characteristics on the standard unit. In such a difficult-to-implement approach, the result must correspond to [2].

In those cases where level gauges contain moving parts (such as a float), level gauges must be tested with upward and downward movement of water, often referred to as variation tests [3–5] (hysteresis).

These are widely used level gauges servo-driven, magnetostrictive and some others. The purpose of these tests – identify the difference in readings during the movement of liquid up and down and also find the maximum error for these two modes of water movement. As a rule, when assessing the conformity of level gauges with moving part to the requirements of Technical Regulations on legally regulated MIs [1], module F, in accordance with [2], the error of level gauges is checked at 10 points when the water moves up and at 10 points when the water moves down. Tables 1 and 2 and Figures 1 and 2 show examples of the results of such measurements for level gauges with maximum permissible error ±1 mm carried out on the national primary standard of the unit of length for the liquid level DETU 03-02-15 with measurement range from 0 to 20 m and expanded uncertainty 0.3 mm [6]. Since the level gauges are legally regulated MIs, they are characterized by an error, and as a result of such tests, the maximum error is found from the

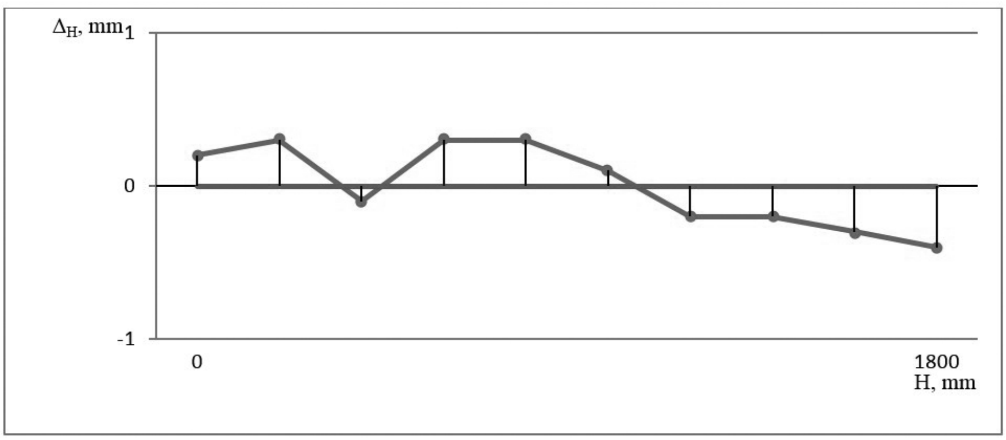

Fig. 1. Absolute error (Δ) when lowering the water level (H)

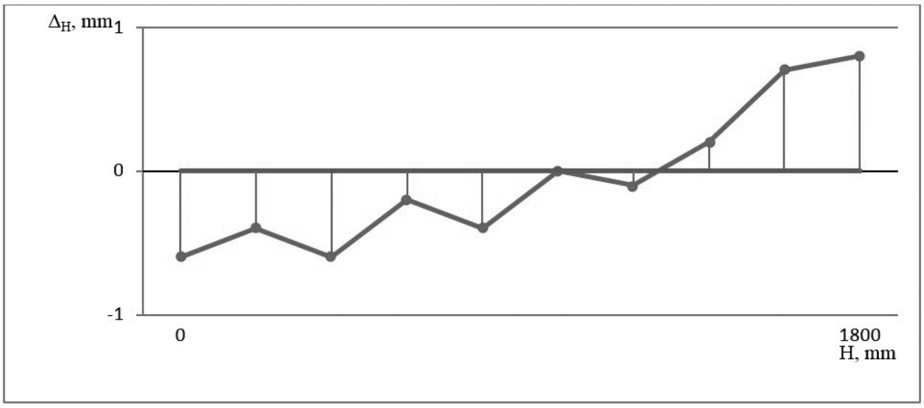

Fig. 2. Absolute error (Δ) when increasing the water level (H)

data array when water moves in the tank of standard unit both up and down. In this case, the 10 points at which measurements are taken are approximately evenly spaced over the range.

In cases where level gauges are not used in a legally regulated area, they are calibrated, in which the standard uncertainties of types A and B [7] are experimentally found separately for the same field of points as during verification, the maximum values of standard uncertainties are found and the expanded uncertainty is calculated – one value for the movement of water up and down. Separate measurements of variation are needed when calibrating of level gauges are not used in legislatively regulated metrology, if the type B standard uncertainty is not found experimentally, but by calculation and the variation is taken into account in the uncertainty budget.

However, to determine the variation, it is necessary not only to find the error or uncertainty when the water moves both up and down, but also to measure exactly at one point when the water moves up and down. Only in this case can not only the maximum error and uncertainty be found, but also the variation. In connection with this, in [2] a separate paragraph provides tests to determine the variation. And, although, with the understanding of the great difficulties in ensuring measurements strictly at one point, in [2] it is recommended to carry out these measurements not in the entire range (at 10 points), but at 3 points, these measurements are quite laborious. But the most important thing, apart from research purposes, these tests do not give anything new for determining the metrological characteristics of level gauges and it is advisable for the manufacturer to carry out them in order to find reserves for increasing the accuracy of level gauges based on reducing one of the components of errors – the magnitude of variation.

The instability of the position of the installation site can make a significant contribution to the level gauge error, in particular, when the level gauge is installed on a swinging roof of a vertical tank. In [2] it is recommended to take the level gauge error equal to ± 4 mm after installing the level gauge on the tank. Note that we are not talking about the level gauge error during operation (the effect of temperature, pressure, humidity), but only about the effect of a swinging roof. To significantly reduce this component of the level gauge error, according to the recommendations in [8], the level gauge should be installed not on the roof, but on a rigid crossbar fixed at the ends of the tank walls. However, the error of the level gauges installed on the tank shouldn't be taken equal to ± 4 mm without taking measures for correct installation, because a level gauge error of ± 4 mm leads, for typical operating conditions, to an error in measuring the volume of liquid in a tank of about ± 10% [8].

As a rule, in level gauges installed in tanks, a tank calibration table is entered to calculate the volume of liquid in the tank, and if the level gauge has a density measurement channel, then calculate the mass of liquid or the volume of liquid reduced to a temperature of 15 °C (for petroleum products – according to [9]).

Gauges that have been verified or calibrated by a simulation method should be used with great care. Some types of level gauges show fairly close verification results on water and with the use of imitation reflectors (for example, radar). Slightly more difficult to carry out a verification by a simulation method of reflex level gauges. Much greater differences in the results of verification on water and by the simulation method of magnetostrictive level gauges. This is apparently due to the fact that in these level gauges the float slides along the pipe and it is very important that the friction of the float in water is minimal. At the same time, in the simulation method, the float is moved by hand and is set at a certain distance, regardless of friction.

Conclusion

The features of the application of the most common types of level gauges are considered. Main focus is placed on level gauges installed on tanks. The errors of level gauges containing moving parts are analyzed in detail. Such level gauges must be tested with water movement up and down. In cases where level gauges are not used in a legislatively regulated area, in the process of calibrating such level gauges, it is advisable to find one, the largest, value of expanded uncertainty for the movement of water up and down.

Рівнеміри. Особливості застосування

Г.Ю. Народницький, Є.Ф. Сухомлінов, С.Ю. Тюпа, О.Ю. Марченко

Національний науковий центр "Інститут метрології", вул. Мироносицька, 42, 61002, Харків, Україна
Gennadiy.narodnitsky@metrology.kharkov.ua; narodnitsky@gmail.com

Анотація

Розглянуто різноманітні аспекти застосування найбільш розповсюджених типів рівнемірів – магнітострикційних, сервоприводних, радарних та рефлексних. Велику увагу приділено точності рівнемірів, яка виражається похибкою та невизначеністю, у тому числі віднесених до законодавчо регульованих засобів вимірювальної техніки. У зв'язку з тим, що більша частина рівнемірів встановлюється на резервуарах, проаналізовано вимоги до них, наведені у стандартах, та можливі шляхи підвищення точності рівнемірів, які встановлюються на резервуарах. Розглянуто методи повірки та калібрування рівнемірів, які включають як повірку на еталонах із застосуванням води, так і ті, що проводяться імітаційним методом.

Викладено вимоги до метрологічного контролю рівнемірів, які мають рухомі частини. Показано, що при повірці таких рівнемірів необхідно проводити вимірювання при русі води як угору, так і вниз. Проте немає необхідності проводити вимірювання, як при визначенні варіації, в одних і тих же точках при русі води вгору та при русі води вниз.

Необхідна певна обережність при використанні результатів повірки рівнемірів імітаційним методом. Особливо великі відмінності у результатах повірки на еталоні з водою та імітаційним методом спостерігаються для магнітострикційних рівнемірів.

Така відмінність викликана тим, що у цих рівнемірів поплавок ковзає по трубі з певним тертям, а при імітаційному методі поплавок переміщується рукою і його рух не залежить від тертя.

Ключові слова: варіація; діапазон; випробування; похибка; рівнемір.

Уровнемеры. Особенности применения

Г.Ю. Народницкий, Е.Ф. Сухомлинов, С.Ю. Тюпа, А.Ю. Марченко

Национальный научный центр "Институт метрологии", ул. Мироносицкая, 42, 61002, Харьков, Украина
Gennadiy.narodnitsky@metrology.kharkov.ua; narodnitsky@gmail.com

Аннотация

Рассмотрены различные аспекты применения наиболее распространённых типов уровнемеров – магнитострикционных, сервоприводных, радарных и рефлексных. Большое внимание уделено точности уровнемеров, выражаемой погрешностью и неопределённостью, в том числе отнесенных к законодательно регулируемым средствам измерительной техники. В связи с тем, что большая часть уровнемеров устанавливается на резервуарах, проанализированы требования к ним, приведенные в стандартах, и возможные пути повышения точности уровнемеров, устанавливаемых на резервуарах. Рассмотрены методы поверки и калибровки уровнемеров, включающие как поверку на эталонах с применением воды, так и проводимые имитационным методом.

Изложены требования к метрологическому контролю уровнемеров, имеющих подвижные части. Показано, что при поверке таких уровнемеров необходимо проводить измерения при движении воды как вверх, так и вниз. Однако нет необходимости проводить измерения, как при определении вариации, в одних и тех же точках при движении воды вверх и при движении воды вниз.

Ключевые слова: вариация; диапазон; испытание; погрешность; уровнемер.

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