Water Flow Meters - Meeting the Requirements In Use and Subsequent Metrological Control of Meters.

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Abstract: *Household water meters as a subset of water flow meters, i.e. water meters that are used as designated meters, belong to one of the most numerous groups of meters. These meters are subject to requirements in accordance with the applicable EU metrological legislation in terms of their placing on the market (making available on the market or putting them into use), but also the national legislation of the Slovak Republic in use during the period of their valid verification. The subject of this paper is to analyze how water meters behave at the end of the verification interval with the evaluation of compliance with the maximum permissible errors after performing accuracy tests in the verification of these meters in the laboratory of the authorized person with reference to specifics and possible effects that may affect the accuracy of these meters when using them, or drawing conclusions that may be of a recommendatory nature in terms of the possible elimination of some effects.*

Keywords: *Water Meters, Gauges, Flow of Water, Accuracy, Verification, Validity of Verification, Conformity.*

INTRODUCTION

The subject of the analysis in this paper were water meters, which were used to measure the flow of cold and hot water as a designated meter in accordance with Directive 2004/22 / EC of the European Parliament and of the Council of 31 March 2004 on meters (EP Directive) and § 11 of Act no. 157/2018 Coll. on Metrology and on Amendments to Certain Acts, as amended by Act no. 198/2020 Coll., (Hereinafter referred to as the Metrology Act).

The aim is to evaluate compliance with the permissible error in the subsequent verification of water meters in connection with the maximum permissible error in use in accordance with § 16 of the Metrology Act [5] and draw conclusions related to the duration of verification of these meters, or draw conclusions pointing to their accuracy at the end of their use.

To measure the flow of water in closed pipes (water supply networks), meters belonging to the group of speed meters of the flowed amount of water are used and we most often refer to them as water meters [1, 7].

In the conditions of Slovakia, the history of the use of water meters as specified meters or gauges intended for calibration or calibrating (note: in this context the word „calibration“ used as a synonym for the Slovak colloquial „ciachovanie“ or „cajchovanie“), dates back to the period of 1909, when the verification of water meters in the period of Austria-Hungary was carried out by employees of state calibration authorities. Legislation relating to water meters in the intentions of the Austro-Hungarian legal system survived until the mid-1930s, when the existing legislation was replaced by Government Decree no. 107/1934 Sb. from. a n. on the official calibration of water meters [2].

After the year 2000, the requirements for these measuring instruments were regulated by the Decree of the Office for Standardization, Metrology and Testing of the Slovak Republic No. 210/2000 Coll. on metrological control meters, as amended, which separately in two annexes specified the technical metrological requirements for cold water meters and especially for hot water meters.

With the accession of the Slovak Republic to the EU, there was a gradual approximation of the legal regulations of the Member States, which also apply to measuring instruments, which resulted in the issuance of the Regulation of the Government of the Slovak Republic no. 294/2005 Coll. on meters, which specified the requirements and procedures for meters that are subject to its adjustment when they are placed on the market in the EU Member

States, which also affected water meters [8].

In the transitional period bounded by the years 2006 to 2016, water meters could be placed on the market in the Slovak Republic in two ways [8].

At present, water meters are covered by two legal regulations governing their placing on the market (making available on the market or putting them into use) and their use and metrological control during their use, which transposes the EP Directive [7] in the Slovak Republic into Government Regulation no. 145/2006 Coll. on making measuring instruments available on the market, as amended by Government Regulation of the Slovak Republic no. 328/2019 Coll. [11] and Decree of the Office for Standardization, Metrology and Testing of the Slovak Republic no. 161/2019 Coll. on measuring instruments and metrological control [9].

Water meters for measuring clean cold and hot water according to their use and from the point of putting them on the market are divided into:

a) water meters for measuring in households, for commercial purposes or in light industry,

(b) water meters for measuring in heavy industry [4].

This division according to the Decree of the Office for Standardization, Metrology and Testing of the Slovak Republic no. 161/2019 Coll. is given by how these meters are made available on the market or put into use in accordance with the applicable legislative requirements.

Water meters for measuring in households, for commercial purposes or in light industry are available on the market or put into use in accordance with harmonized EU legislation [4] the so-called "new approach" legislation represented in the Slovak Republic Act no. 56/2018 Coll. on the conformity assessment of a product, making a specified product available on the market and on the amendment of certain laws and, subsequently, for the field of measuring instruments, it is the Regulation of the Government of the Slovak Republic no. 145/2006 Coll. on making measuring instruments available on the market, as amended by Government Regulation of the Slovak Republic no. 328/2019 Coll [10].

Conformity assessment procedures for water meters (MI-001) are specified in Annex no. 3 of the EP Directive [10], whereby the manufacturer may use the B + F or B + D or H1 procedure for the purposes of conformity assessment under this Directive. We also refer to these procedures as conformity assessment modules.

MODULE B: The EU-type examination is the part of the conformity assessment procedure whereby a notified body examines the technical design of a measuring instrument and verifies and confirms that the technical design of the measuring instrument meets the requirements of this Government Regulation applicable to that technical design of the measuring instrument [7].

MODULE D: Conformity to type based on quality assurance of the manufacturing process is the part of the conformity assessment procedure by which the manufacturer fulfills the obligations and ensures on his own responsibility that the relevant instrument conforms to the type described in the EU-type examination certificate and meets the requirements of this Regulation that applies to the relevant measure [7].

MODULE F: Conformity to type based on instrument verification is the part of the conformity assessment procedure whereby the manufacturer fulfills the obligations and ensures and declares on his own responsibility that the instrument concerned is in conformity with the type as described in the EU-type examination certificate, and meets the requirements of this Government Decree that apply to the relevant instrument [7].

MODULE H1: Conformity based on full quality assurance and design examination is a conformity assessment procedure whereby the manufacturer fulfills the obligations set out in the second and sixth paragraphs and ensures and declares on his own responsibility that the

instrument meets the requirements of this Government Regulation applicable to the instrument it applies to [7].

Water meters for measuring in heavy industry are placed on the market by performing a pre-market metrological inspection, which includes national type approval and initial verification in accordance with the Metrology Act [4], a procedure carried out in accordance with national legislation, which we refer to as legislation The "old approach".

If a water meter is used as a specified gauge, i. in accordance with § 11 of the Metrology Act, must be used in accordance with the provisions of § 16 of the Metrology Act.

Water meters used in the Slovak Republic as designated meters are subject to subsequent metrological control - subsequent verification in accordance with Section 16 of the Act on Metrology. According to the law, the user of this measuring instrument is obliged to submit the used specified measuring instruments for subsequent metrological control.

By using a designated meter we mean measurement by a specified meter by the user [5] (eg. using the results read from a specified meter for the purpose of billing the price of the amount of water consumed in the household - apartment).

Water meter user as a designated meter in means of a public authority or entrepreneur who uses a specified meter or a value indicated by a specified meter in a measurement related to payments, where there may be a conflicting interest in the measurement result or where an incorrect measurement result may harm the interest of a natural person, legal entity or persons of the wide public, is provided by special regulations [5] (eg the Public Water Supply Act).

Subsequent verification of water meters in the Slovak Republic is carried out in accordance with § 25 of the Metrology Act, when a water meter test is performed, during which the water meter error(s) is detected and conformity with the specification for the maximum permissible error is evaluated in accordance with Annex no. 10 Decree of the Office for Standardization, Metrology and Testing of the Slovak Republic no. 161/2019 Coll. on measuring instruments and metrological control [10] or special regulations in force at the time of conformity assessment of a water meter, e.g. Regulation of the Government of the Slovak Republic no. 145/2006 Coll. on making measuring instruments available on the market, as amended by Government Regulation of the Slovak Republic no. 328/2019 Coll [6,7].

The instrument must be in conformity with the approved type during verification and must meet the technical and metrological requirements, in particular the permissible error, as already mentioned above.

Verification of water meters can be performed by the Slovak Institute of Metrology (SMÚ), Slovak Legal Metrology n.o. (SLM), or persons (entrepreneurs or other legal entities) authorized in accordance with § 31 of the Metrology Act [5].

If a natural or legal person suspects that the water meter does not meet the metrological parameters when using a water meter, they have the right to ask the user of the specified meter to detect the error of the specified meter in accordance with § 16 of the Metrology Act. at SMÚ or SLM in means of a written request of the user of the specified meter (water meter). [5] The meter is considered satisfactory if it does not exceed the maximum permissible error in use set for water meters by Annex no. 10 Decree of the Office for Standardization, Metrology and Testing of the Slovak Republic no. 161/2019 Coll., which is determined as twice the maximum permissible error during verification.

From a legislative point of view, the maximum permissible error in use can be assessed no later than the last day of validity of the verification of the specified meter. [5] The validation interval of the verification of selected water meters is shown in Table 1.

***Table 1** Validity period of verification for water meters according to Annex No.1. Decree of the Office for Standardization, Metrology and Testing of the Slovak Republic no. 161/2019 Coll*

item	Type of determined gauge	Verification validity period (in years)
1.3.1	Household water meter a) cold water b) hot water	 5 5
1.3.2	Water meter a) cold water b) hot water	 6 4

MATERIAL AND METHODS

Subsequent verification of water meters used as designated meters is one of the standard obligations of users of designated meters as mentioned above.

The Act on Metrology [5] in the Slovak Republic specifies who is authorized to perform subsequent verification of specified measuring instruments. In the case of water meters, these are to a large extent (estimated at about 80% to 90% of water meters of the total number of water meters used as distribution meters) authorized persons to perform the verification of specified meters according to the Act on Metrology [5].

The procedure used in the Slovak Republic prior to the actual verification of water meters is such that the water meters are cleaned and adjusted, or repaired and then delivered for verification to an authorized person to perform the verification.

In accordance with the Metrology Act [5], an authorized repairer, ie a person registered under the Metrology Act [5], is required to carry out repairs and repairs to specified meters, namely those specified in the registration decision.

Repair and cleaning of household water meters is primarily performed only in Slovakia and the Czech Republic, in other EU countries this is not a trend and water meters are discarded after the first verification interval (ie after their first placing on the market or putting into use) and do not verify.

The user is always obliged to order the verification of specified meters in writing.

In this paper, we want to examine the metrological characteristics of water meters at the end of the validity period (after its expiration) in terms of meeting the requirements for the permissible error during verification and the permissible error in use.

An authorized person (metrological laboratory) was selected for the implementation of the experiments, who also performs the verification of water meters.

For the purpose of performing the experiment, the usual procedure before the actual testing (verification) was omitted and the gauges after disassembly were immediately tested as if the tests were performed to determine the water meter error in use, ie. the gauges were not cleaned, adjusted or repaired.

The purpose of this experiment was to find out how the sample of selected water meters will behave, while the evaluation was aimed at evaluating the compliance of metrological requirements, ie permissible error in verification and permissible error in use and quantification of compliant and non-compliant water meters in the sample.

For the purposes of the experiment, a sample of household mechanical water meters of dimension DN 15 in the number of 815 pieces was used.

A household water meter is a water meter located in household and non-household premises behind a joint water meter, which is used to determine the price for the supply of water to an apartment building [5].

These are meters of cold water flow (cold water meters). They are mechanical meters

with mechanical counters based on direct mechanical action when using measuring chambers with movable walls, or when the speed (flow) of water affects the speed of rotation of the moving part (turbine, a wheel, etc.) with a counter that works on the mechanical principle by means of rotating gears or other rotating components, [3] shown in Fig. 1.

Fig. 1 Household water meter

This sample of water meters was delivered to the laboratory of the authorized person as standard, while the verification of these water meters was ordered by their user in order to perform their subsequent metrological control, ie subsequent verification in accordance with the Act on Metrology.

The basis of the experiment was an accuracy test, which analyzes (determines) the error of the water meter δ in%.

This accuracy test was performed on a Standard device (water meter line) connected to the flow standards of the Slovak Institute of Metrology.

The accuracy test for the subsequent verification was performed at three flow rates in the order *Qmax; Qt; Qmin.*

Maximum flow (*Qmax,*) - the highest flow at which the meter can operate for a limited time without damage and without exceeding the maximum permissible errors and the maximum allowable pressure loss.

Nominal flow (*Qn*) - is equal to half the maximum flow *Qmax* and is used to identify the meter; at nominal flow *Qn*, the meter must be able to operate in normal use, meaning under constant and intermittent working conditions without exceeding the maximum permissible errors.

Transient flow (*Qt,*) - the flow that divides the upper and lower sections of the flow range and is the flow at which the limits of the maximum permissible errors occur.

Minimum flowrate (*Qmin,*) - flowrate above which the maximum permissible accuracy errors must not be exceeded.

The fixed start mass method according to [3] was used to perform the accuracy test.

It is a method in which the conventional true value of the flow rate is carried out by reference weights and the liquid is at rest at the beginning and end of the test on the test scale, this method being considered static because the liquid is at rest at the beginning and end of the test in the standard [3].

The test equipment used (water meter track) for the mass method with scales is a device that is mechanically operated - the fixed start method. This device can be used for one meter under test or for several meters connected in series.

The basic parts of the test equipment are:

a) flow source with storage tank,

b) measuring part for mounting gauges,

c) flow control branches with flow meters and weighing system,

(d) evaluation equipment.

The used test equipment (water meter line) is supplemented by software for automation

of the testing process with the possibility of controlling the whole process, flow setting for the test, automatic measurement of test time, weight reading, control of valves (control branches, start stop valves), pump control, control of line input valves and archiving of measured values into the database.

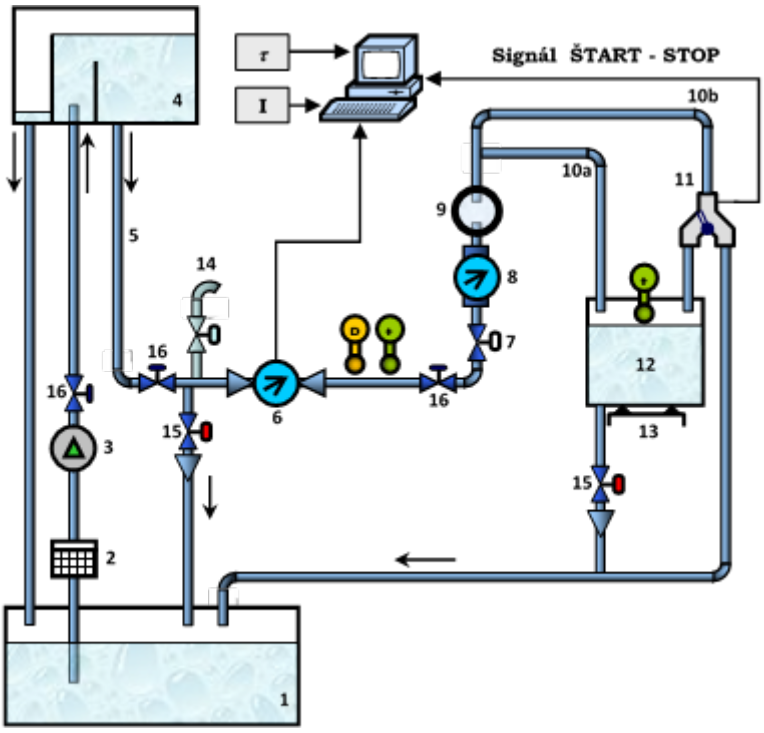

Fig. 2 Principle of a test rig operating by the mass balance method [3]
1 - storage tank, 2 – filter, 3 – pump, 4 - height tank, 5 - supply line, 6 - calibrated gauge, 7 - control valve, 8 - flow meter, 9 - sight glass, 10a - control branch, 10b - control branch, 11 - switching flap, 12 - metering tank, 13 – scales, 14 - vent valve, 15 - drain valve, 16 - shut-off valve

RESULTS AND CONCLUSIONS

815 water meters were tested (verified) at three flows according to the established approved work procedure, while data on the detected error of the tested water meters were collected, with the result being presented as an expression of compliance with the maximum permissible error verbally as "Pass" or "Fail" and the numbers of water meters are determined for these categories. At the same time, these numbers of water meters are also determined for individual test flows.

Evaluation of compliance with the maximum permissible error as follows:

1. confirmation of the conformity of the specified measuring instrument with the metrological requirements for the type of the verified specified measuring instrument in accordance with § 25 para. 1 of the Metrology Act [5] as follows: % and in the lower section (Qt to Qmax,) + 2% for cold water [4] shown in fig. No.4,

2. determination of the number of compliant specified measuring instruments according to par. 6 and 7 §16 of the Metrology Act, the error of which does not exceed the maximum permissible error in use, which is equal to twice the maximum permissible error determined during the verification of water meters [5,9] shown in Fig. 4.

It must be said that a water meter is considered unsatisfactory if its error exceeds the maximum permissible error, even with just one flow.

The Fig. 3 graphically shows the numbers of compliant and non-compliant meters with

respect to the permissible error in verification after the expiration of the validity period (i.e. without repair and cleaning). Fig. 3 testifies to the error of the meter without repair and cleaning and indicates the need for repair and cleaning, or deployment in the use of new meters.

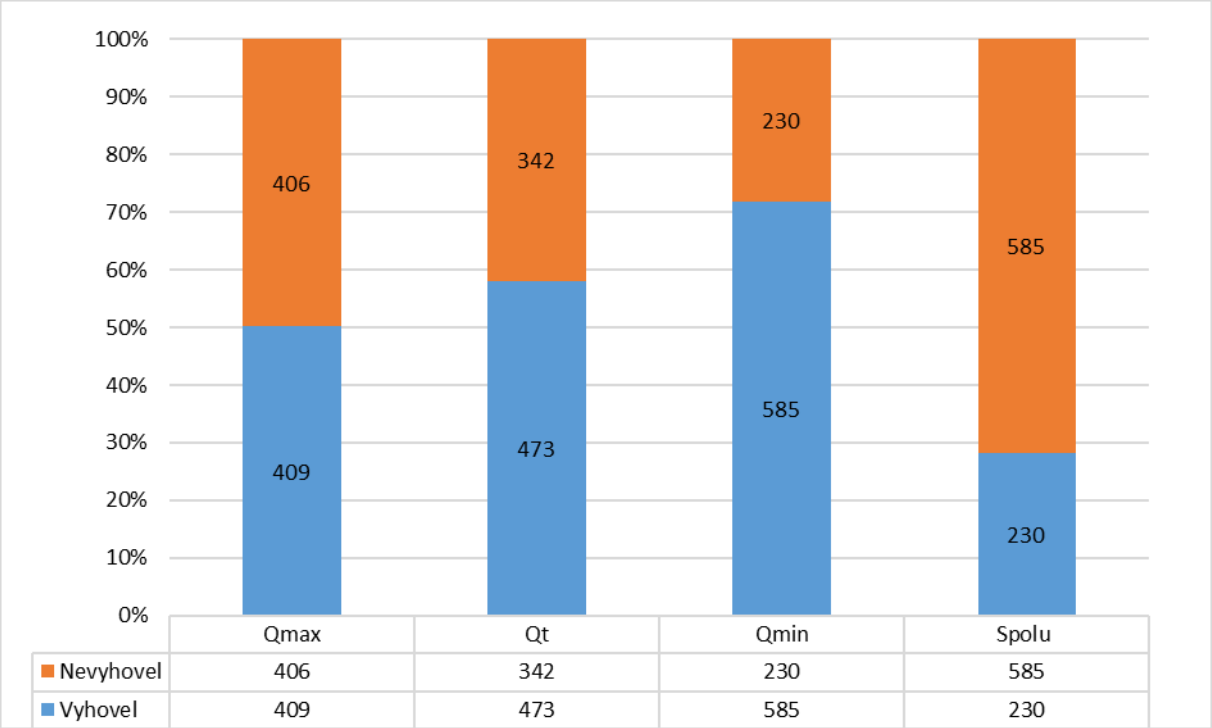

Fig. 3 Quantification of the number of water meters that passed / failed the accuracy test after the expiration of the validity period with the evaluation of compliance with the permissible error in the verification of the meter

From Fig. 3, it is clear that, applying the requirement for compliance with the maximum permissible error in verification, 585 of the total number of water meters 815 would not satisfy, which represents approximately 72% of the water meters in the sample.

If we select a group from non-compliant water meters that did not comply with *Qmin* when applying the requirement for compliance with the maximum permissible verification error and look at how these water meters in this group behaved at other flows, we would find that about 2/3 of this group did not comply with other test flows t. j. at *Qt* and *Qmax*, as documented in Fig. 4. There appears to be a strong correlation of the magnitude of the error of the meter at different flow rates.

If the criterion of double permissible error, ie. permissible error in use, were taken into account in the conformity assessment, the results of this analysis would be as shown in Fig. 5, which means that out of the total number of tested water meters in the number of 815 pieces, 134 pieces did not meet this criterion, which represents approximately 16.5%.

At present, in the Slovak Republic, the period of validity of the verification is set for household water meters as for specified meters in the length of 5 years [9]. The sample of household water meters that were analyzed should meet the required metrological characteristics during this period of validity. It is clear from the results that this is not the case. However, it must be said that in the usual procedure, testing of uncleaned and unadjusted meters is not performed during the subsequent verification after the expiration of the verification, and this testing was performed as a "model". From the above results, it can be deduced that the water meters are affected during use mainly by the measured medium itself,

meaning water, which can cause them to become clogged and thus affect their accuracy, especially in the case of water of a higher degree of hardness.

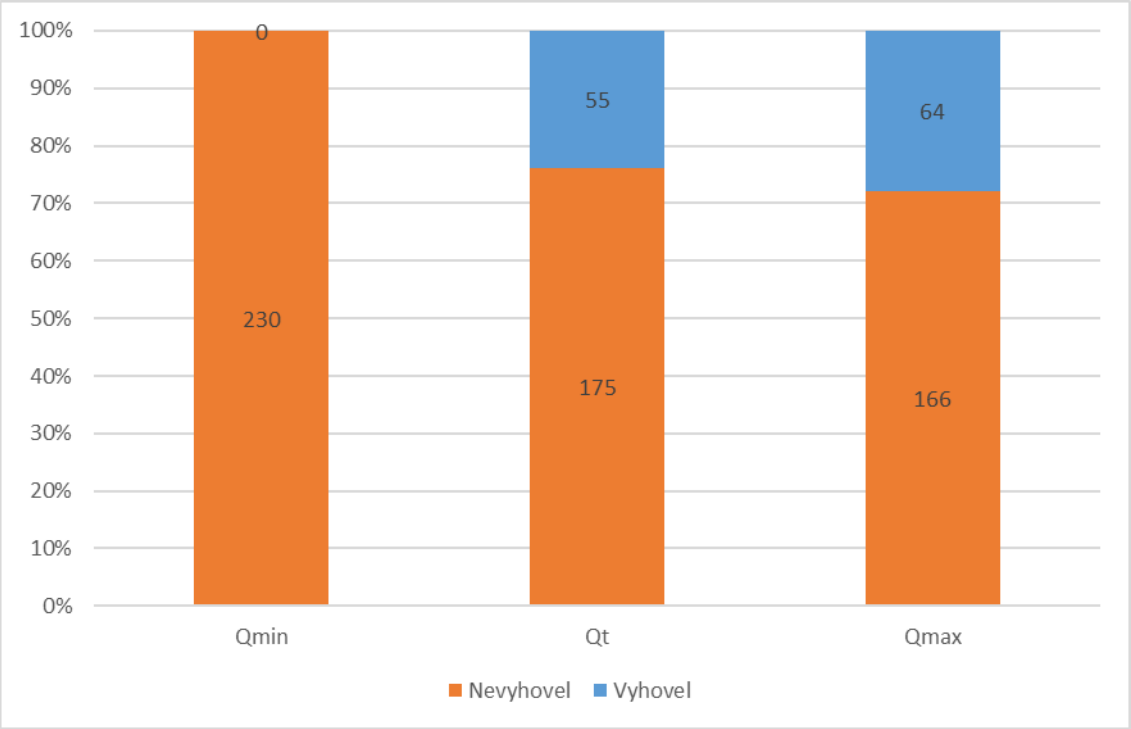

Fig. 4 Quantification of the number of non-compliant water meters at Qt and Qmax from a sample of non-compliant water meters at Qmin under conditions as in Fig. 3

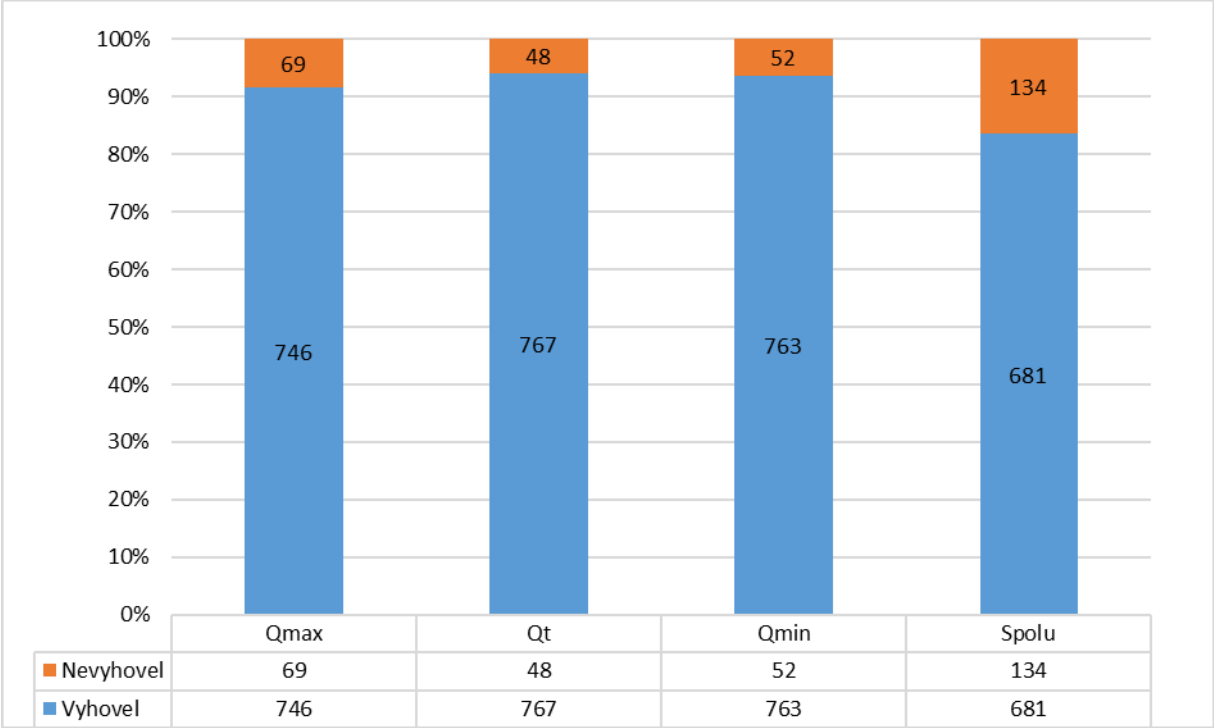

Fig. 5 Quantification of the number of water meters that passed / failed in the accuracy test with the evaluation of compliance with the permissible error when using the meter

In practice, however, in cases of dispute, the double permissible error is taken into account when assessing instruments in use, testing uncleaned and unadjusted instruments and

the requirement that the verification of these instruments should not expire must be complied with. From the results evaluated in this way, it is clear that even the % of unsatisfactory water meters is significantly lower, but even so, 1/6 (16.5%) of water meters will not ensure compliance with satisfactory metrological characteristics.

The question is whether the interval of validity of the verification of this type of meters in the Slovak Republic is sufficient, even taking into account that these meters are mostly not verified abroad for the most part. It is worth mentioning that in the past the length of validity of the verification of these meters has also changed in the Slovak Republic, in the older stages it was 4 years and in the recent past it was 6 years.

REFERENCES

[1] Chudý, V., Palenčár R., Kureková E., Halaj M., (1999) Meranie technických veličín.1.vyd. BRATISLAVA: STU Bratislava 688 s. ISBN 80-227-1275-2
[2] Časopis METROLOGIE., Tematická príloha č.4/2016 Metologie prutoku a protečeného množství kapalin a vodní páry v ČR, ÚNMZ Praha 40s. ISSN 1210-3543
[3] Mikulecký, I., Benková M., Drozda F., (2016) Príručka pre používateľov meradiel prietoku a pretečeného množstva kvapalín Kalibračné združenie SR.2016
[4] Príloha č. 10 k vyhláške č. 161/2019 Z. z. VODOMERY, Dostupné na: https://www.slov-lex.sk/pravne-predpisy/SK/ZZ/2019/161/20190801
[5] Zákon č. 157/2018 Z. z. o metrológii a o zmene a doplnení niektorých zákonov v znení zákona č. 198/2020 Z. z.
[6] Dostupné na: https://www.slov-lex.sk/pravne-predpisy/SK/ZZ/2019/161/20190801
[7] Nariadenie vlády Slovenskej republiky č. 145/2016 Z. z. o sprístupňovaní meradiel na trhu v znení nariadenia vlády Slovenskej republiky č. 328/2019 Z. z.
[8] Directive 2004/22/EC of the European Parliament and of the Council of 31 March 2004 on measuring instruments (Smernica Európskeho parlamentu a Rady 2004/22/ES z 31. marca 2004 o meradlách),
[9] Filo, R., Drozda F., (2016) Požiadavky na starostlivosť o meranie vyplývajúce z platnej legislatívy, starý a nový prístup, Zborník KZ SR, Kurz „Abeceda firemného metrológa“ november 2016, Bratislava
[10] Vyhláška Úradu pre normalizáciu, metrológiu a skúšobníctvo Slovenskej republiky č. 161/2019 Z. z. o meradlách a metrologickej kontrole
[11] Nariadenia vlády Slovenskej republiky č. 145/2006 Z. z. o sprístupňovaní meradiel na trhu v znení nariadenia vlády Slovenskej republiky č. 328/2019 Z. z.

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