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Application of proficiency testing scheme at determining the tank capacity on the results of laser 3D scanning

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Abstract

A three-level proficiency testing scheme is proposed in the form of the interlaboratory comparisons for the determination of the tank capacity of all possible types calculated by the laboratories' own software. The proficiency testing scheme will be available to any accredited or non-accredited laboratory worldwide. Each laboratory chooses from the proposed computational tasks what it needs. To protect the confidentiality of the information within the framework of this scheme, all the Participants generate their individual codes, which they indicate in the file name with the results of their calculations.

The laboratories are suggested to pass successfully three levels of operation characteristics testing ranked by the increase of the set tasks:

1) calculation of the tanks' interval capacities without introducing any corrections by their 3D models prepared by the Provider;

2) calculation of the tanks' interval capacities by introducing all necessary corrections by their 3D models prepared by the Provider;

3) calculation of the tanks' interval capacities by scans that have not been subjected to preliminary preparation by the Provider.

To participate in the first level of the proficiency testing, it is necessary to:

- download the program of proficiency testing of the first level from the site SE «Ukrmetrteststandart» https://metrology.kiev.ua/ru/mezhlaboratornye-sravneniya;
- download files with point coordinates on the tank wall from Google disk Comparison: http://bit.ly/vgsucsm;
- calculate interval capacities of the tanks without the introduction of any corrections;
- send files with calibration tables of the tanks to the Provider's e-mail: vgsucsm@gmail.com;
- if the submitted data is suitable for analysis, then register and pay for the service;
- receive the results of the proficiency testing via your e-mail;
- read the publication of the proficiency testing results in the journal «Measurement infrastructure» https://mi-journal-online.org.

At the first level of the proficiency testing, the payment is fulfilled only for the registration of the Participant and the execution of the documents on the completion of this level.

Keywords: liquids volume measurement, laser scanner, vertical and horizontal cylindrical tanks, spherical tanks, ship tanks, interlaboratory comparisons, proficiency testing.

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1. Introduction

The proficiency testing organization through the interlaboratory comparisons at the determination of the tank capacity is extremely complicated since it involves gathering the Participants in one place for tank laser scanning. That is why taking into account a considerable experience in tank calibrations and verifications, SE «Ukrmetrteststandart» offers an interpretive proficiency testing scheme. It is based on processing the data sets given by the Provider. Moreover, each Participant uses their own software. Definitely, tank calibration requires serious professional skills. The experience shows that it is harder to calculate tank capacity correctly than to carry out these measurements. Thus, the proposed proficiency testing scheme will be extremely useful to both the beginning laboratories and experienced ones.

The proposed proficiency testing scheme is not a consulting service; however, the Provider is ready to settle these questions with any Participant as a separate work.

The measurement results performed by the scanner or other data will be allowed to download on the Google Disk Comparison in the International unit system SI. SI is the main system that is used to compile calibration tables. By agreement with the Provider, any other system of units required by the Participant can be used.

2. About the Provider

SE «Ukrmetrteststandart», as the National Institute responsible for the Legal Metrology of Ukraine, took the initiative to conduct such interlaboratory comparisons considering their importance and complexity. The reason for this is more than 45 years of experience in tank calibration by volumetric and geometric methods.

The scientific and production laboratory of the angle and geodetic measurements of SE «Ukrmetrteststandart» has been developing and improving tank calibration and verification methods using geodetic instruments for the last 25 years. Since 1997 the tank verification has been fulfilled by theodolite, since 2004 – by electronic scanning total station, and since 2013 – by laser scanners. Currently, the laboratory is performing measurement with four scanners and two total stations. During this period the laboratory, with the help of these instruments, has verified or calibrated more than 20 000 tanks of all possible constructions and sizes.

Coordinators of the proficiency testing have developed four National Standards that have been valid in Ukraine since 2013 and provide appliance electronic total stations and laser scanners for verification or calibration of different tank types. In 2016, a second, more advanced version of these National Standards was released. They were adopted as Interstate Standards (GOST) [1-3], which were joined by Azerbaijan, Belarus, Kazakhstan, Uzbekistan, Armenia, and Kyrgyzstan.

For more than 20 years Provider has been developing the special software «VGS» [4]. The last version of «VGS» corresponds to standards [1-3] and will be used to calculate the interval capacities of the tanks. «VGS» is software for everyday fluent work. Years of use, research and testing provide confidence in the correct capacity calculations.

3. The goal of the comparisons

The path from the «raw» scanning data to the calibration table comprises several important stages. Errors made by the laboratory at each stage can lead to unacceptable errors in the interval capacities of the tanks. Laboratories do not include unnoticed blunders in the estimated uncertainty. This leads to significantly overestimated uncertainty estimates (better than it actually is).

The goal of the proficiency testing is calculation accuracy increase by the laboratories of the interval capacities of the tanks by the results of 3D scanning.

To achieve the goal, the laboratories are proposed to search for their mistakes or approve their absence by comparison of the interval capacities processed by their own software and the Provider's software. The proficiency testing results will provide the National

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Accreditation Bodies with evidence of the professional competence of the Participants' personnel.

Choosing the criteria for evaluating the operational characteristics of the Participants Provider will be guided, first of all, by the requirements of [5] and [1–3]. Mentioned documents are more informative than the standards of the series [6–12].

Software developers have to solve all complicated questions concerning the calculation of the tank interval capacities with the required accuracy. The authors of this publication are sure that small calibration laboratories cannot independently solve this problem. Harmonization of the requirements for methods and algorithms and accuracy of the capacity calculation at the international level is necessary for increasing the equivalence level of tank capacities calculation results.

Modern publications include not much information about metrological tests of tank laser scanning technology in general and software tests in particular concerning the uncertainty of the calculated interval capacities. The first mention of such tests is given in [13]. Test results of the software for calculation of the interval capacities of the vertical cylindrical tanks are given in [14]. Information about metrological tests of laser scanning technology of the horizontal tanks is not described in [15] and [16], as well as about tests of the used software.

The proposed proficiency testing scheme is also supported by the fact that evidence in the EPTIS database about the conduction of such schemes is absent. So, the proficiency testing scheme [17] is proposed for the first time.

4. Pattern for proficiency testing

The 3D models of the main tank types are proposed as a pattern for proficiency testing at the first level:

- vertical cylindrical tanks;
- horizontal cylindrical tanks;
- spherical tanks;
- tanks of arbitrary geometrical shape and ship tanks.

Vertical cylindrical tanks have many modifications that differ in:

- the nominal capacity – from 3 to 200 000 m^3;
- the use – for storage of petroleum, petroleum products, oils, chemical matters, for example, liquefied ammonia, foodstuffs;
- the wall material – steel or reinforced concrete as well as with external insulation;
- with a pontoon or floating roof.

In the first level, the modifications of all tank types differ only in nominal capacity

The 3D model of the typical vertical cylindrical tank is shown in Fig. 1.

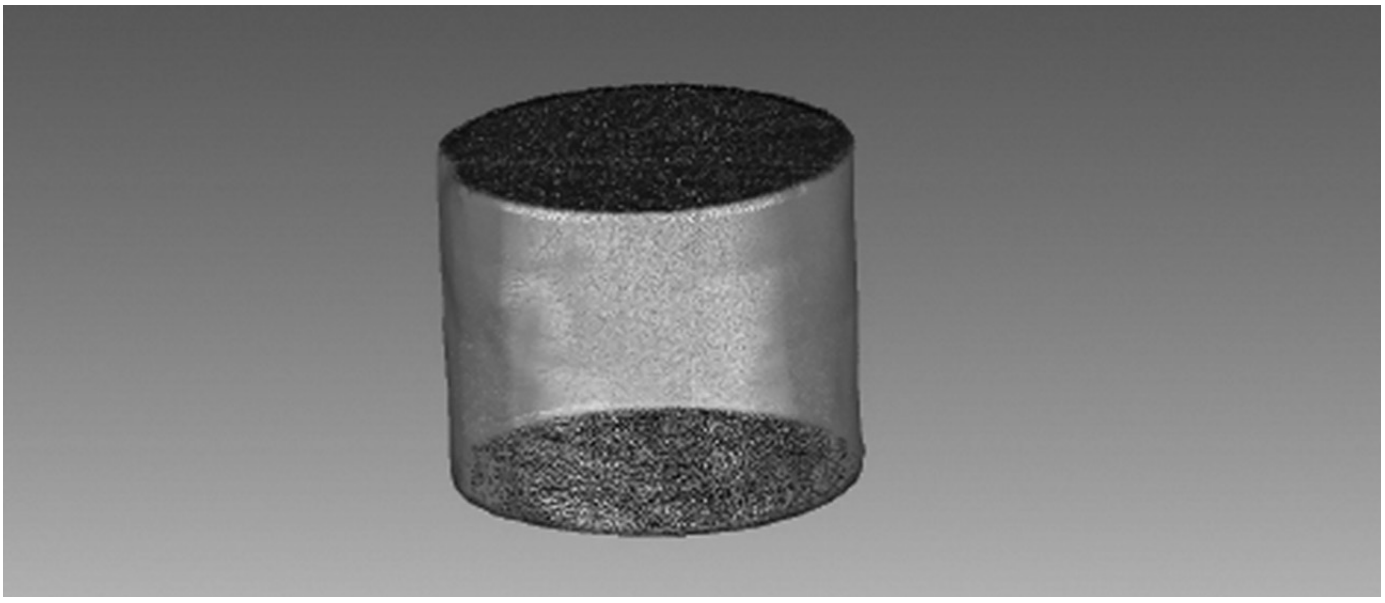

Fig. 1. *Visualization of the vertical cylindrical tank*

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The Participant can divide the vertical cylindrical tank into two parts, which can include bottom and bottom of the cylindrical part, and internal cylindrical part, because their capacity can be calculated by different software. The results of such calculations the Participant combines into one calibration table. The maximum absolute filling height, as a rule, is equal to absolute height of the cylindrical part (the lowest point on the border of the cylindrical part and roof).

The horizontal cylindrical tanks have many modifications that differ in:

- the nominal capacity – from 3 to 600 m^3;
- the use – for storage of petroleum products, liquefied gas, oils, chemical matters, and foodstuffs;
- the shape of the bottoms – flat, conic (including in the form of a truncated cone), elliptical (including spherical), spherical segment, torispherical;
- the direction of the bottoms – convexly directed outwards or inwards;
- multi-section.

The 3D model of the typical horizontal cylindrical tank is shown in Fig. 2.

The maximum absolute filling height is set equal to the absolute height of the upper point on the tank wall.

The spherical tanks are used for the storage of liquefied gas. The modifications vary only in nominal capacity – from 400 to 5000 m^3.

The 3D model of the typical spherical tank is shown in Fig. 3.

The null of the calibration table of the spherical tank is aligned by the Provider with the lowest point on its wall. The maximum absolute height filling height is set equal to the absolute height of the upper point on its wall.

The tanks of the arbitrary geometrical shape and ship tanks have many modifications that differ in:

- the nominal capacity – from 3 to 5000 m^3 and more;
- the geometrical shape – parallelepiped and arbitrary geometric shape;
- the use – for storage of petroleum, petroleum products, liquefied gas (tanks) and their transportation (ship tanks), as well as power supply (fuel tanks).

The calibration of the ship tanks and their fuel tanks is a particular complexity. Their capacity must

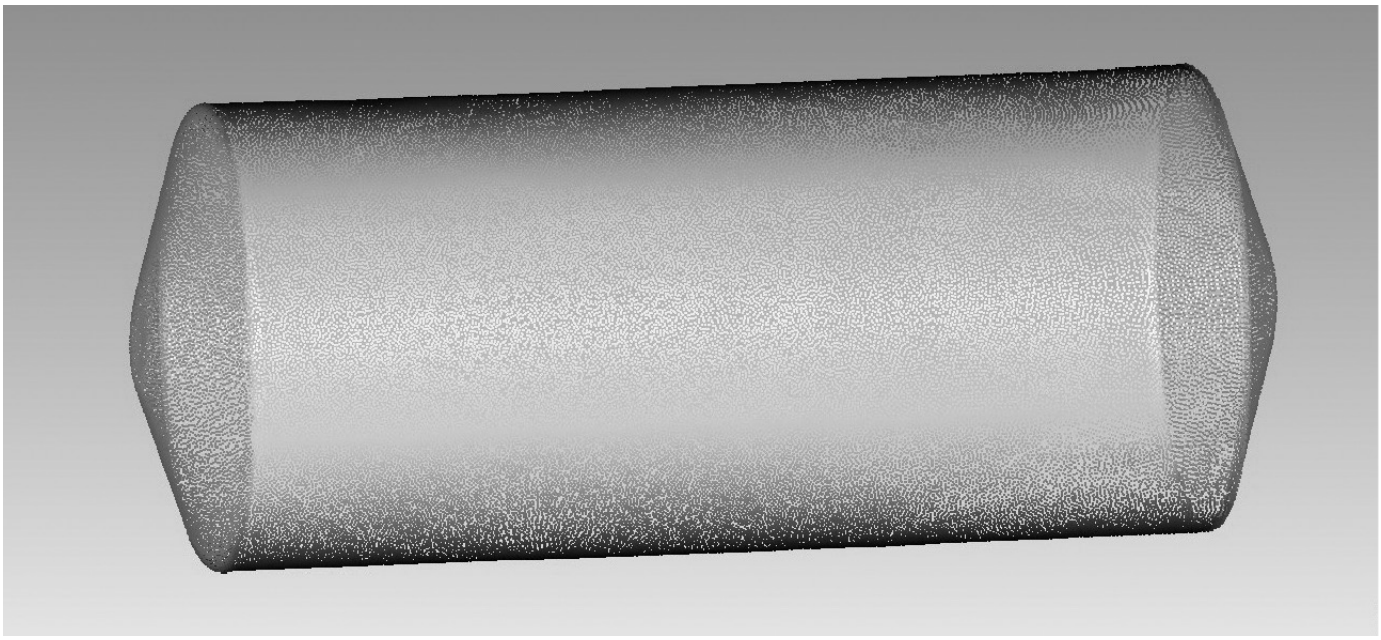

Fig. 2. *Visualization of the horizontal cylindrical tank with conic bottoms*

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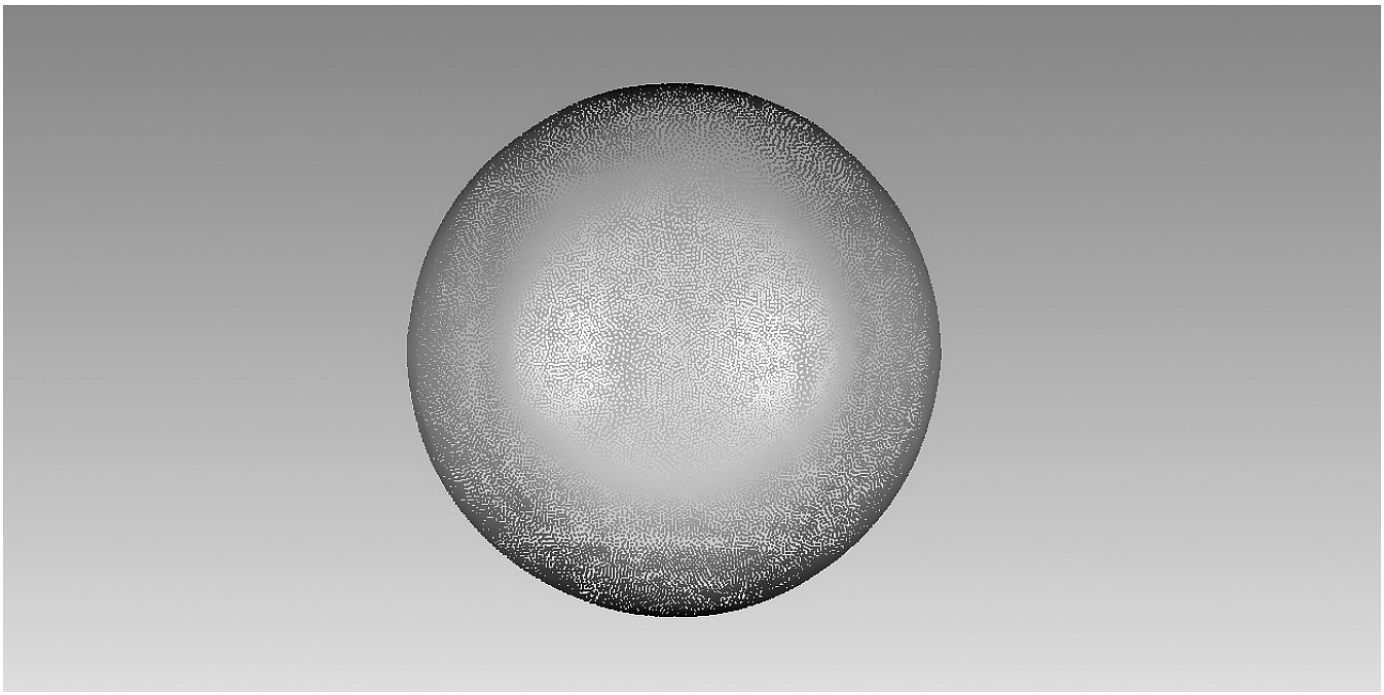

Fig. 3. *Visualization of the spherical tank*

be calculated for different heels and trims of the ship. Such calculations will be proposed to the Participants after successfully completing the first level. 3D model of the typical tank of the arbitrary geometrical shape is shown in Fig. 4.

The maximum absolute filling height is set equal to the absolute height of the highest point on the tank wall.

Since every tank type has modifications, the Provider plans to provide as many modifications as possible for calculation. The Provider will add files with coordinates on the tank walls at Google disk Comparison from time to time. The Participant can simultaneously perform capacity calculations of different tank types. Proficiency testing for each tank type (modification) is considered a separate work and is evaluated separately by the Provider.

The real tanks proposed for capacity calculation have significant deformations of bottoms and walls. The cylindrical tanks have significant axis tilts

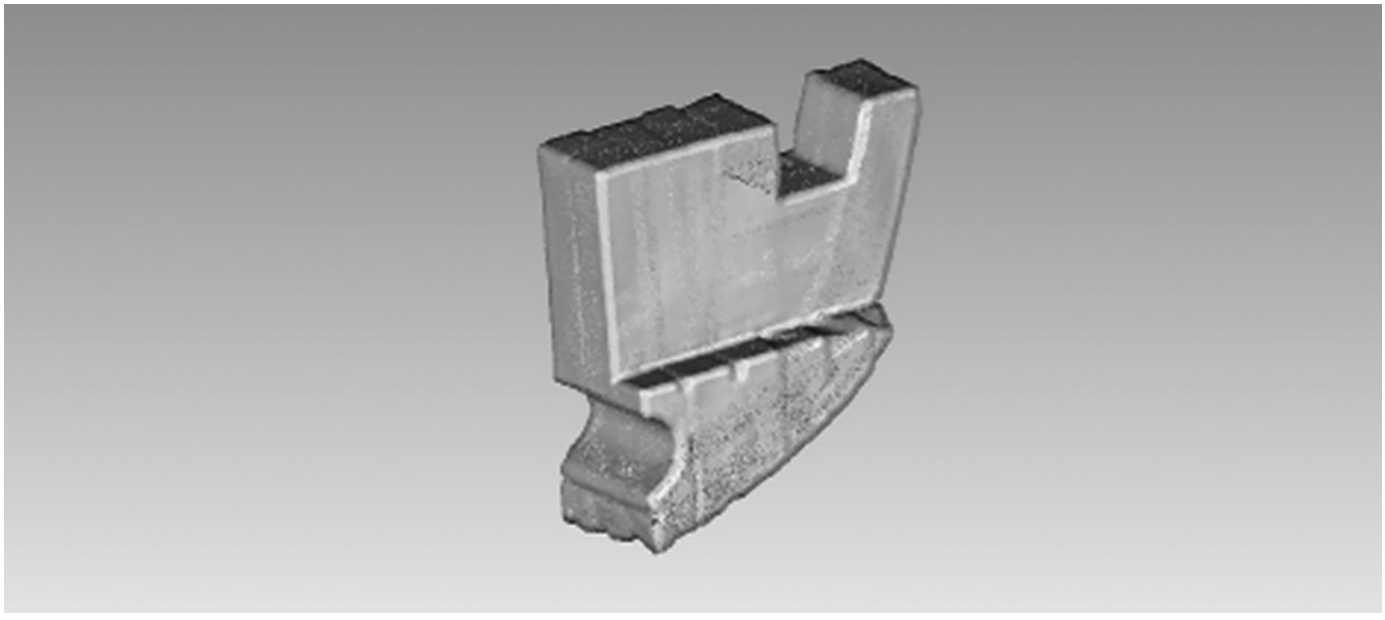

Fig. 4. *Visualization of the arbitrary geometrical shape tank (fuel tank of the ship)*

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of their cylindrical part. The bottoms of the vertical cylindrical tanks can have an arbitrary geometrical shape close to a plane, cone, spherical or elliptical segment, etc. The tank bottom axis, as a rule, is not linked with axis of their cylindrical parts. That is why the real interval capacities of the tanks may differ significantly from the capacity of tanks with regular geometric shapes with similar dimensions.

For all tanks, where it was possible, the Provider has performed calculations of the interval capacities by the rigorous methods [1-3, 14, 18-20]. The comparative analysis of methods and various software that implement these methods is described in [14, 18]. Further analysis of accuracy methods and software will be carried out in the published proficiency testing reports.

5. Levels of operation characteristics testing

The Participants are proposed to pass three levels of proficiency testing through participation in the interlaboratory comparisons in the determination of the tank capacities calculated by own software of the laboratories from simple to more complicated tasks. These three levels are described below. Only successful completing the first level makes sense to begin the second one and then the third. The third level is the most complicated. The Participant may stop at any of the proposed levels of the proficiency testing, which each Participant may find the most appropriate for him.

The authors of this publication hope that while passing these three levels of proficiency testing, a partnership will be formed between them and the Participants, allowing them to implement the proficiency testing scheme. This scheme comprises tank scanning by laboratories' own scanners with further self-processing of the scanning results and presentation of the calibration table.

Level 1. Calculation of the tanks' interval capacities without introducing any corrections by their 3D models prepared by the Provider

At the first level of the proficiency testing, the ability of the laboratory to calculate interval capacities of the geometrically integral completed 3D models is checked, i.e. models in which points are equally spaced over the tank surface and there are no coordinated points that do not belong to the tank walls. These 3D models are generated by points on the tank surface, which have coordinates measured by the scanner. The Provider has performed measurements and all primary operations for scan processing that are described in [14, 18]. All types of tanks at this level are presented in the form of a file with 3D coordinates on the tank surface. The Provider has eliminated from the file all defective points that do not belong to the tank walls and bottoms. They are the result of the dual reflection of the laser beam. The points that belong to the internal constructions and equipment have been eliminated too.

Scanning in a few minutes gives from 20 to 500 million points on the tank walls. Such an amount is not needed for precise and fast capacity calculation. The number of points on the walls has been reduced significantly to a sufficient number for precise capacity calculations. It is from 10 to 300 thousand points. The number of the remained points is worked out in such a way that, on the one hand, the reduction in their number does not affect the accuracy of the capacity calculations and on the other hand, the time for capacity calculation is not too large due to the big number of points that are being processed.

«Shadows» on the walls from the internal constructions and equipment are filled in with points. Besides, the extra points on the walls are eliminated so that the remained ones can be equally spaced on the tank walls.

The beginning of the absolute height of the 3D model (null of the Z coordinate) is inserted at the point from which the calibration table should begin.

The calculation uncertainty of the interval capacities at the first level of the proficiency testing is evaluated neither by the Participants nor the Provider, as these shifts are the components of the uncertainties of the tank interval capacities.

Some details of the proficiency testing scheme [17] for determining tank capacity for the first level is available at the site EPTIS www.eptis.org (ID 939040).

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Level 2. Calculation of the tanks' interval capacities with introducing all necessary corrections by their 3D models prepared by the Provider

After successful completion of the first level, the second level of the proficiency testing will have some features connected with introducing necessary corrections. As a rule, corrections are small values up to 0,5 % from tank capacity. But they are systematic. If they are introduced incorrectly or not introduced at all, this will lead to significant distortion in capacity.

Internal interval capacities should be suggested to calculate if the measurements were performed outwards. Tank wall and coating thickness are suggested to be taken into account when calculating the interval capacities.

Introduction of corrections for the temperature of the tank wall at measurement, for tank wall deformations due to the weight of the filled liquid in the tank or corrections for internal overpressure for liquefied gas tanks, and corrections for the presence of the internal constructions and equipment will be obligatory.

Complications for the accurate account are corrections that take into account the emersion of the pontoon and the floating roof.

The preprint [21] presents the technical report draft of the proficiency testing round for calculation of the interval capacities of the vertical cylindrical tank with the nominal capacity of 400 m^3. In the preprint [21], it is proposed to introduce some of the listed corrections.

Level 3. Calculation of the tanks' interval capacities by scans that have not been subjected to preliminary preparation by the Provider

Only at the third level of the proficiency testing, in case of the successful completion of the previous two levels the Participants will be suggested to process «raw» scans with measurements made from inwards and outwards of the tanks. The measurements inwards the tanks are performed by the installation of the tripod with scanner inside the tank in direct (usual) operating position or installation through tank hatch in its inverted position. The difficult task will be to process few scans received as a result of measurement above and under pontoon of the vertical tank and outwards the tank.

At the third level of the proficiency testing the Provider may perform the scanning results processing fulfilled and processed by the Participant. The results of such cooperation may be posted for access by other Participants.

Later separate schemes will be developed for the second and third levels of proficiency testing.

6. Conclusions

1. This publication marks the beginning of major and long-lasting cooperation between the Provider and the accredited and non-accredited calibration laboratories to establish the equivalence of the procedures for processing the laser scanning results and calculation of the interval capacities of tanks for all possible types and shapes.

2. The result of the proficiency testing scheme is a planned increase in calculation accuracy of the tank interval capacities. The increase is expected to be due to the harmonization of the processing procedures of the laser scanning results and the improvement of the procedures for calculating the tank interval capacities.

3. The three-level organization of the proficiency testing, from simple to complex, will allow the Participant to test, improve or revise their own procedures at each level of the scanning results processing and calculation of the interval capacities.

4. To avoid errors overlapping that may occur at different levels, the first level of the proficiency testing includes the proficiency testing scheme at the stage of the interval capacity calculation of a closed spatial figure in the form of the vertical or horizontal cylinder with different bottom types, sphere or tanks of the arbitrary geometric shape.

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