

METHOD FOR VERIFYING A FLOWMETER AND DEVICE FOR THE IMPLEMENTATION THEREOF FIELD OF THE INVENTION

The present invention relates to the instrumentation used in the calibration, verification,
5 monitoring of the metrological characteristics of volume and mass meters of liquids inside
verification installations, mainly for petroleum and petroleum products.

BACKGROUND OF THE INVENTION

Monitoring of the metrological characteristics (MMC) of the volume and mass meters of
liquids, verification installations for petroleum and petroleum products transported through
10 pipelines (hereinafter referred to as measuring tools - MT) are carried out in accordance with the
requirements of process regulations, other technical documentation, and as deemed necessary for
maintenance and operation. Calibration and verification of MMC tools are special cases regulated
in the regulatory documentation.

Calibration - a set of operations that establishes the relationship between the value of a
15 parameter obtained using particular MT and the value of the same parameter obtained using the
reference standard (exemplary MT, verified and approved as a reference standard in the
prescribed manner). Calibration is performed at the initial setup of the device, or before its
operation for a specific purpose, under certain conditions.

Verification - determination by an authorized body of a metrological service of the suitability
20 of MT for use on the basis of experimental studies of the MT's errors. Verification is carried out, as
a rule, with a regulated frequency.

A device called a verification (calibration) installation or a prover is usually used for
calibration, verification or MMC of tools for measuring liquid flow (liquid meters).

Several types and designs of provers exist and are used: U-pipe-shaped piston provers,
25 with a straight calibrated area, scorpion-type, with a spiral-type loop, and also compact provers (a
separate class of provers). One of the most common types in the calibrating (verifying) systems for
flowmeters of quantity and quality parameters for petroleum and petroleum products during their
transportation through pipelines is an U-shaped piston installation; in English sources they are
called U-shaped prover, loop-shaped prover, etc. The flow liquid volume measured by a being
30 calibrated meter, is passed through a calibrated section of the prover.

Here, the volume of the calibrated section is restricted by cross-section flats in which the
detectors are installed; it's recognized as the volume reference standard unit.

Contact or contactless sensors are used as detectors in various designs of provers - on an electromechanical, optical or other physical basis, that detectors are able to detect a moment when the piston is passing through the cross section of the pipe section in which the detector is installed with a high accuracy. The provers of this type utilize a piston in the form of an elastic ball, which is “pumped” by a liquid filler up to a diameter that is 2-3% larger than the internal diameter of the calibrated pipe section area, to ensure a high quality fit of the ball piston to the internal surface of the pipe along the cylindrical contact belt between them.

The physical essence of verification is to compare the volume of liquid measured by a calibrated meter during the passage of the ball piston from the beginning to the end of the calibrated section with the known volume of the calibrated section, which is taken as a reference standard.

During calibration, verification and MMC of liquid mass meters incorporated in a prover (or used together with a prover), a liquid density measuring transducer is used, which allows for comparing the mass of a liquid measured by a mass meter with the mass obtained on the basis of the calibrated prover volume (reference standard) and density of the pumped liquid measured in the flow.

As the patent information search showed, the topic of calibration or verification tests for measuring the amount of petroleum produced was a fertile object of an inventive activity for more than a century (the priority of the oldest discovered patent on this topic dates back to 1910). Dozens of inventions were published; the most relevant patents and patent applications are summarized in Table 1.

Table 1.

Patent №	Title	Assignee	Priority date	Publication date
US 3288163	Wiper ring for a fluid system flow interrupting device	Grove valve & regulator Co (USA)	05.09.1963	29.11.1966
US 3423988	Meter prover apparatus	M & J valve Co (USA)	01.08.1966	28.01.1969
US 3668923	Meter proving method and apparatus	M & J valve Co (USA)	19.06.1970	13.06.1972
US 3738153	Valveless prover	Helmerlich & payne, Inc. (USA)	24.08.1971	12.06.1973
US2007/0119227	Reference volume tube	Fukuo Moriyama (Jp, inventor)	25.12.2003	31.05.2007

US2014137628	Method and apparatus for a bidirectional meter proving system	WFMS, Inc. (USA)	29.05.2008	22.05.2014
US2015027197	Method and apparatus for a bidirectional meter proving system	WFMS, Inc. (USA)	29.05.2008	29.01.2015
RU 2522118	Flow meter, flow meter calibration method and flow meter prover computer	Daniel Management and Control Inc (USA)	27.02.2009	10.07.2014
RU 2568054	Method and device for rapid calibration of the flow meter	P.N.Frantsuzov	24.06.2014	10.11.2015
RU 2603503	A method of application of the regulating device	P.N.Frantsuzov	10.06.2014	27.11.2016

A fragment of the bidirectional prover, the most common in modern practice, is schematically shown in Fig. 1 (borrowed from the patent RU 2522118).

Here 1 is a ball piston; 2, 3, 4, 5 - electromechanical detectors; 6 — a calibrated section of the prover meter tube; V1 and V2 - calibrated volumes. Volumes in the bi-directional prover can be measured by moving the ball piston in two directions: for example, using the first pair of detectors — from detector 2 to detector 3 (calibrated volume V1) and in the opposite direction, using another pair of detectors — from detector 4 to detector 5 (calibrated volume V2). A change in the direction of flow of the verification liquid and, accordingly, the piston is provided by using a 4-way valve at the inlet of the prover; periodically, when turning the 4-way valve to the proportion of turn (moving to the next fixed position), the flow of petroleum is directed along the verification loop alternately in the forward or reverse direction.

It is important to note one characteristic feature of the existing bidirectional provers of this type: the ball passage detectors are installed in pairs, at the ends of the corresponding calibrated volume. The distances between the starting / receiving chambers of the ball piston (chambers are not shown in Fig. 1) and the beginning of the nearest calibrated volume (in both directions of flow) use to accelerate the ball piston until a constant flow rate of the verification liquid in the pipe corresponding to the specified verification flowrate is established; moreover, the ball piston should enter the calibrated volume (under the detector) at the same speed in this test cycle, in order to ensure the required repeatability of measurements on the verification flowrate. The parameters of

the calibrated and acceleration sections are determined by design calculations in accordance with the requirements of regulatory documentation.

The volume and length of the calibrated section is determined depending on the characteristics of the flowrate meters, for which verification this calibrated section is assigned, for example, on the maximum verification flowrate. The speed of movement of the ball piston in a calibrated section and the cross-sectional area of the verification pipeline should ensure the possibility of verification of the flowrate meter over the entire prescribed flow range. For bidirectional provers of this type, the speed of the ball piston, as a rule, does not exceed 1.5 m / s.

The length of the acceleration sections is calculated on the basis of the maximum specified flowrate of the verification liquid, taking into account the selected cross section of the calibrated section, the switching time of the 4-way valve of the prover, the response time of the leakage monitoring system. The ball piston, picked up by the flow at the exit of the 4-way valve, must reach a given steady-state speed by the time it enters the nearest calibrated volume.

The movement of the ball piston in the acceleration area of the prover is unsteady, and the flow characteristics through the verifying flowrate meter and prover during this time period are considered as non-sensing. As follows from the above, the bidirectional prover has two similar acceleration section adjacent to the chambers for launch/receipt of the ball piston. The section of the traditional U-shaped prover between the two acceleration sections forms substantially a united calibrated volume. As for closest analogue of the prover of the above-mentioned patent RU 2522118 of the American company Daniel Management And Control, Inc. (priority of 02.27.2008; the application was published on July 10, 2014), two calibrated volumes are placed on the site - V1 and V2 (almost identical in configuration), each of which is used as a verification volume when the ball piston is moving in one of the directions. Detectors 3 and 4 are limiting the volumes from one end, detectors 2 and 5 from the other, all are placed here side by side in two cross section areas of calibrated volume - for structural and technological reasons.

This arrangement of the functional parts of the calibration pipe section and the location of the detectors are most common for provers of this type, and, according to the authors, it can be considered as a drawback: extreme sections of the calibration pipe are acceleration sections only when the ball piston moves in one of two directions, and are excluded from the intended use for both of direction.

It should be noted that the high flowrates of a pumped liquid are provided by large flow cross section areas of pipelines (respectively, dimensions and mass of the prover ball piston are to be increased) and high flow rates. With an increase in flow cross section areas and flow rate, the response time of the 4-way valve is also inevitably increased. Accordingly, large lengths of acceleration areas are required. It is known from practice that on large U-shaped prover acceleration section long may be 15 meters or more. This leads to large dimensions and high metal consumption of the prover design, and requires a large room to accommodate them. Thus, it

is impossible to use mobile calibration (verification) installations at large petroleum metering stations (with verifiable flow rates of more than 800 m³ /hour).

SUMMARY OF THE INVENTION

5 The technical task is to create a method and device that provides the desired repeatability and standard deviation of measurement results, with a significantly shorter test duration, dimensions and weight of the device.

 The technical result of the implementation of the present invention is to increase productivity during calibration, verification, monitoring of the metrological characteristics of flowrate
10 meters, while achieving the best overall mass characteristics of the device (prover) and, as a result, expanding the possibility of their mobile use, reducing material intensity structures, reducing the cost of construction and installation of petroleum metering stations.

 The technical result is achieved due to the fact that the method of control of the metrological characteristics of the flow meter of the amount of liquid using a bidirectional prover,
15 based on comparing the indicators of the amount of liquid measured by the calibrated liquid meter with the amount of liquid flowing through the calibrated portion of the prover, taken as the reference standard unit of volume, time of passage of the calibrated area by the ball piston, comprising multiple movements of the ball piston in the forward and reverse direction with the flow of a verification liquid through the measuring pipeline of the prover, connected sequentially to a
20 measuring pipeline, in which a calibrated liquid meter is installed, and wherein during each movement there is a fixation of moments using detectors when the ball piston is passing by the starting and ending points of the calibrated portion; wherein the starting area of the ball piston movement in each of the directions is an acceleration area that is required for the movement of the ball piston to reach a speed of a free flow at a given verification liquid flowrate, wherein a portion of
25 the prover, located last along the direction of movement of the ball piston and serving as an acceleration area when the ball piston is moving in an opposite direction, is used as an addition to the calibrated portion.

 A bidirectional prover for implementation of the above method comprises a measuring pipeline, with two chambers for receiving and launching a ball piston, with at least two calibrated
30 areas, in end sections of which there is one or more ball passage sensors with at least two acceleration areas preceding the calibrated areas in the direction of movement of the ball piston, wherein the portion of the measuring pipeline of the prover is located last along the direction of movement of the ball piston to ensure the use of this portion to extend or supplement the calibrated portion, and this portion is equipped with one or more detectors installed in the end cross-section
35 of the portion close to the chamber used for the ball piston receiving and launching.

 In each of the flow directions of the verification liquid and the ball piston, two calibrated volumes V1 (primary), V3 (additional, serves as an acceleration area when the ball piston is

moving in the opposite direction) and V2 (primary), V4 (additional, serves as an acceleration area when the ball piston is moving in the opposite direction) may be sequentially formed, wherein detectors are installed in the boundary areas of the measuring pipeline, which separate supplementary volumes V3 and V4 from the main calibrated volumes V1 and V2, the detectors are
5 connected in such a way that each of them has the ability to issue a signal to the information processing system when the ball piston is passing only in one of the directions.

The measuring pipeline of the prover may consist of two areas, each of which is alternately used as an acceleration area and as calibrated area (an "economy version" of the embodiment).

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 - Fragment of the pipeline loop for the closest analogue of the invention (according to the patent RU 2522118).

FIG. 2 is a plan view of the claimed prover;

FIG. 3 is a side view of the claimed prover;

FIG. 4 is a plan view of the claimed prover (as described in claim 3 of the claims);

FIG. 5 is a plan view of the claimed prover (as described in claim 4 of the claims).

DETAILED DESCRIPTION OF THE INVENTION

The basis of the claimed invention is the well-known U-shaped design of a bidirectional piston prover. Fig. 1 schematically shows a fragment of the bidirectional prover, in which: 1 - ball piston; 2, 3, 4, 5 - electromechanical detectors; 6 - calibrated area of the measuring pipeline; V1 and V2 - calibrated volumes. Volumes in the bi-directional prover are measured when the ball piston moves in two directions: using the first pair of detectors - from detector 2 to detector 3 (the calibrated volume V1) and in the opposite direction, using another pair of detectors - from detector
25 4 to detector 5 (the calibrated volume V2). The change in the direction of flow of the verification liquid and, accordingly, the piston is ensured by using the well-known 4-way valve at the inlet / outlet of the prover. Periodically, when turning the 4-way valve to the proportion of turnover (moving to the next fixed position), the flow of petroleum is directed along the verification loop alternately in the forward and reverse direction. At the same time, taking into account the results of
30 measurements, one of the flow directions is conventionally taken as the direct, and the other as the reverse.

It is important to note one characteristic feature of the existing bidirectional provers of this type: the ball passage detectors are installed in pairs, at the ends of the corresponding calibrated volume. The areas between the launching / receiving chambers of the ball piston (not shown in Fig. 1) and the beginning of the nearest calibrated volume (in both directions of flow) serve to accelerate the ball piston until a constant flow rate of the verification liquid in the pipeline corresponding to the specified verification flowrate is established; moreover, the ball piston should enter the calibrated volume (under the detector) at the same speed in this test cycle, in order to ensure the required repeatability of measurements on the verification flow. The parameters of the calibrated and acceleration areas are determined by design calculations in accordance with the requirements of regulatory documentation.

The volume and length of the calibrated area is determined depending on the characteristics of the flowrate meters, for which verification this calibrated area is assigned, for example, on the maximum verification flowrate. The speed of movement of the ball piston in a calibrated area and the cross-sectional area of the verification pipeline should ensure the possibility of verification of the flowrate meter over the entire prescribed flow range. For bidirectional provers of this type, the speed of the ball piston, as a rule, does not exceed 1.5 m / s.

The length of the acceleration areas is calculated on the basis of the maximum specified flowrate of the verification liquid, taking into account the selected cross section of the calibrated area, the switching time of the 4-way valve of the prover, the response time of the leakage monitoring system. The ball piston, picked up by the flow at the exit of the 4-way valve, must reach a given steady-state speed by the time it enters the nearest calibrated volume.

The movement of the ball piston in the acceleration area of the prover is unsteady, and the flow characteristics through the verifying flowrate meter and prover during this time period are considered as non-sensing. As follows from the above, the bidirectional prover has two similar acceleration sites adjacent to the chambers for launch/receipt of the ball piston. The portion of the traditional U-shaped measuring pipeline between the two acceleration areas forms a substantially united calibrated volume. In the closest analogue of the prover (Fig. 1) two calibrated volumes are placed on the site - V1 and V2 (almost identical in configuration), each of which is used as a verification volume when the ball piston is moving in one of the directions. Detectors 3 and 4 are limiting the volumes from one end, detectors 2 and 5 from the other, all are placed here side by side in two cross section areas of calibrated volume - for structural and technological considerations. This arrangement of the functional areas of the test pipeline and the location of the detectors are most common for provers of this type.

The main feature of the claimed invention is to increase the calibrated part of the measuring pipeline in each direction of movement of the ball piston by the size of the area that is an acceleration area when the ball moves in the oncoming direction (i.e., each acceleration area is used as an verification area during counter movement of the ball piston). FIG. 2 shows a plan view

of a prover according to one embodiment of the present invention, where: 1 is a ball piston; 2, 3, 4, 5 - detectors; V1 and V2 - the basic calibrated volumes of the measuring pipeline of the prover; 10 and 10a are additional calibrated volumes (V3 and V4) acquired as a result of the present invention; 11 - chamber for launching / receiving a ball piston; 12 (L_{p12}) - acceleration area of the ball piston (for the calibrated volume V1); 13 (L_{p13}) - the acceleration of the ball piston (for the calibrated volume V2); 14, 15 - input and output pipelines for petroleum; 16 - 4-way valve. Moreover, $V1 = V2$, $L_{V3} = L_{p12}$, $L_{V4} = L_{p13}$, $V5 = V1 + V3$, $V6 = V2 + V4$, where V5 and V6 are full (increased according to this invention) calibrated volumes - instead of basic V1 and V2. In FIG. 2, the calibrated volume V1 is increased due to area 10, and the calibrated volume V2 is increased due to area 10a. Such a change allows, without increasing the overall size of the prover, to improve the repeatability and standard deviation of measurement results, to reduce the effect of liquid flow pulsations caused by liquid transfer technology through pipelines, allows for the transfer of a unit of volume with less uncertainty of volume measurements under operating conditions. Fig. 3 shows the side view of the same prover.

The method of controlling of the metrological characteristics of a liquid flowrate meter using a bi-directional prover comprises multiple, two-way displacements of the ball piston with the flow of the verification liquid along the measuring pipeline of the prover connected sequentially with the measuring line, in which the tested flowrate meter is installed, and wherein during each displacement there is a fixation of moments using a pair of detectors when the ball piston is passing by the starting and ending points of the calibrated area. The volume of liquid measured by the tested flowrate meter during the time the ball piston passes the calibrated area of the verification pipeline is compared to the known volume of the calibrated area of the verification pipeline. In other words, the difference of the method according to the present invention is that the acceleration area of the verification pipeline, which is required for the movement of the ball piston to reach a speed close to the speed of free flow at a given flowrate of the verification liquid, is used as a calibrated area during the oncoming movement of the ball piston.

The change in the direction of flow of the testing liquid and the ball piston to the opposite that is required to create an alternate movement of the ball piston along the loop of the prover verification pipe in two directions, is provided in a known manner, for example, switching the 4-way valve to a predetermined part of the turn, which is installed on the inlet / outlet of the verification liquid flow. At the same time, taking into account the results of measurements, one of the flow directions is conventionally taken as the direct, and the other as the reverse.

The lengths of the first and last areas of the measuring pipeline of the prover are determined by calculation and / or experimental method, based on the need to perform operations during this time to change the direction of movement of the ball piston to the opposite, namely: guaranteed establishment of a constant speed of movement of the ball piston in these areas, the speed that satisfies the test conditions over the entire range of specified flow rates of the

verification liquid and switching the 4-way valve to the specified position and triggering its leakage monitoring system.

A bidirectional prover for implementing this method includes a U-shaped or a loop-shaped measuring pipeline with two chambers for receiving and launching a ball piston, with at least two calibrated areas, in the end areas of which one or more ball piston passage detectors are installed, and with at least two acceleration areas preceding the calibrated areas in the direction of movement of the ball piston. Further, the portion of the measuring pipeline of the prover is located last along the direction of movement of the ball piston to ensure the use of this portion to extend or supplement the calibrated portion, and this portion is equipped with one or more detectors installed in the end cross-section of the portion close to the chamber used for the ball piston receiving and launching.

The design of the prover according to the present invention provides a solution to the task of provide to the areas of acceleration of the ball piston with an additional function to be a calibrated (verification) area - during opposite movement of the flow. The internal surface of the pipeline in these areas must be made with the required accuracy and quality to ensure stable coupling with the ball piston in order to enable the ball piston to move at a speed as close as possible to the speed of a free flow.

The verification pipeline may contain a larger number of detector pairs and, accordingly, calibrated areas - in order to further increase the reliability and quality of the verification measurements, or - to reduce the test duration - by increasing the number of calibrated volumes taken into account during each pass. Fig. 4 shows the prover, supplemented by detectors 8 and 9, with the result that separate the calibrated volumes V1, V2, V3 and V4 are formed. In each of the flow directions, two calibrated volumes V1 (primary), V3 (additional, serves as an acceleration area when the ball piston is moving in the opposite direction) and V2 (primary), V4 (additional, serves as an acceleration area when the ball piston is moving in the opposite direction) are formed, wherein detectors are installed in the boundary areas of the measuring pipeline, which separate supplementary volumes V3 and V4 from the main calibrated volumes V1 and V2, the detectors are connected in such a way that each of them has the ability to issue a signal to the information processing system when the ball piston is passing only in one of the directions - for reasons of reliability and quality of verification measurements.

Fig. 5 shows the embodiment of the prover, made for a maximum cost reduction, in which the number of functional areas of the measuring pipeline and the number of detectors are minimized. Here, V1 and V2 are the calibrated volumes of the prover verification pipeline; 3, 5 and 17 - detectors; 12 - acceleration area of the ball piston (for the calibrated volume V1); 13 - acceleration area of the ball piston (for the calibrated volume V2). The measuring pipeline of this prover includes three detectors and two areas, each of which is alternately used as an acceleration

area and as calibrated area for multiple movements of the ball piston, which also reduces the cost of equipping the prover.

As a result of carrying out the invention, by giving the ball piston acceleration areas an additional function of a calibrated (verification) area — with a counter-flow movement, a prover having a given calibrated volume can be implemented as having significantly smaller dimensions, mass and used material. In particular, most of the provers required for verification of quantities of petroleum production and petroleum transportation can be implemented in a mobile (transported) version, which significantly reduces the cost of assembly and equipment on petroleum metering stations.

Installation of additional detectors allows for splitting the route of the measuring pipeline into a larger number of calibrated areas, thereby reducing the number of required passes during verification tests, and as result, duration of the verification work decreasing.

On the other hand, utilization of longer calibrated areas allows for higher reliability of measurement results in each pass.

We claim:

1. A method for calibration of a flowmeter using a bidirectional prover based on comparing liquid quantity data measured by the flowmeter and a quantity of liquid flowing through a calibrated section of the prover, which is taken as a standard unit of volume, during the time while a ball piston of the prover is passing the calibrated section, comprising multiple movements of the ball piston in direct and reverse directions with a flow of a verification liquid through a measuring pipe of the prover, sequentially connected to a measuring line, in which the flowmeter is installed, and wherein detectors are fixing the moments of the calibrated section start and end crossing by the ball piston during its each movement; wherein a starting section of the ball piston movement in each of the directions is an acceleration section that is required for movement of the ball piston to reach a speed of a free flow at a given verification liquid flowrate, said method is characterized in that a section of the prover, located last along the present direction of the ball piston movement and been used as an acceleration section, serves also as an addition for the calibrated section during opposite movement.

2. A bidirectional prover for implementing the method according to claim 1, comprising a measuring pipe, having two chambers for receiving and launching a ball piston, and having at least two calibrated sections, in the end areas of which one or more ball piston passage detectors are installed, and having at least two acceleration sections preceding the calibrated sections in the direction of movement of a verification liquid and the ball piston, wherein the section of the measuring pipe of the prover is located last along the direction of movement of the ball piston to allow use of this section to prolong or supplement the calibrated section, and this section is equipped with one or more detectors installed in the end cross-section of the section closed to the chamber used for the ball piston receiving and launching.

3. The bidirectional prover according to claim 2, wherein in each of the directions of flow of the verification liquid and the ball piston, are formed two calibrated volumes, primary V1, and additional for it V3, serving as an acceleration section when the ball piston is moving in the opposite direction, and primary V2 and additional for it V4, serving as an acceleration area when the ball piston is moving in the opposite direction, are formed, and detectors are installed in the boundary areas of the measuring pipe, which separate supplementary volumes V3 and V4 from the main calibrated volumes V1 and V2, and the detectors are connected in such a way that each of them has the ability to issue a signal to the information processing system when the ball piston is passing only in one of the directions.

4. The bidirectional prover according to claim 2, wherein the prover measuring pipe consists of two sections, each of which is alternately been used as an acceleration section and as an calibrated section.