ORGANISATION INTERNATIONALE
DE MÉTROLOGIE LÉGALE

INTERNATIONAL RECOMMENDATION

Pipe provers for testing measuring systems for liquids other than water

Tubes étalons pour l'essai des ensembles de mesurage de liquides autres que l'eau

OIML R 119

Edition 1996 (E)

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FOREWORD

The International Organization of Legal Metrology (OIML) is a worldwide, intergovernmental organization whose primary aim is to harmonize the regulations and metrological controls applied by the national metrological services, or related organizations, of its Member States.

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TERMINOLOGY

The general terms used in this Recommendation are in accordance with the *International Vocabulary of Basic and General Terms in Metrology* (VIM - 1993 edition), and the *Vocabulary of Legal Metrology* (VML - 1978 edition).

Other technical terms used in this text are in accordance with the International Recommendation OIML R 117 *Measuring systems for liquids other than water* (1995 edition).

PIPE PROVERS FOR TESTING MEASURING SYSTEMS FOR LIQUIDS OTHER THAN WATER

1 Scope

This Recommendation deals with pipe provers and with their use for testing measuring systems for liquids other than water (hereinafter called «measuring systems»), in order to verify that they comply with the relevant metrological requirements in the International Recommendation OIML R 117 *Measuring systems for liquids other than water.*

In clauses 2 and 3, metrological characteristics of pipe provers are summarized, including their calibration.

In clauses 4 to 8, methods are given for testing the following measuring systems:

- measuring systems on road tankers,
- measuring systems for the unloading of road and rail tankers, ships' tanks and tank containers,
- measuring systems for the loading of road and rail tankers, ships' tanks and tank containers,
- measuring systems on pipelines,
- measuring systems for liquefied petroleum gas (LPG) under pressure,
- LPG dispensers.
- fuel dispensers,

Other types of measuring systems or measuring systems for other kinds of liquids may generally be tested according to one of the above methods. However, when special methods should be used for a particular measuring system or certain liquid, they will be the subject of future amendments or separate Recommendations.

Many of the descriptions in this Recommendation are referred to in the International Standards listed below in which more detailed information is found.

- ISO 7278-1 *Liquid hydrocarbons - Dynamic measurement - Proving systems for volumetric meters* - Parts 1: *General principles,* 2: *Pipe provers,* 3: *Pulse interpolation techniques,* and 4: *Guide for operators of pipe provers* (draft)
- ISO 8222 P*etroleum measurement systems - Calibration - Temperature corrections for use with volumetric reference measuring systems*
- ISO 4267-2 *Petroleum and liquid petroleum products - Calculation of oil quantities* - Part 2: *Dynamic measurement*

Pipe provers may only be used for testing the accuracy of a meter. For testing other components of the measuring system, in particular the gas elimination device, standard capacity measures or gravimetric techniques shall be used.

2 Pipe provers employed

A pipe prover is a pipe or cylinder whose measured volume is used to calibrate or «prove» a flow meter. Proving the meter is accomplished by passing through the pipe a displacer (usually a sphere or piston) which actuates detectors delimiting the calibrated section. The known volume in this section is corrected for temperature and pressure and compared to the reading of the meter to determine the meter error.

2.1 Types of pipes provers

The following types of devices are generally used as pipe provers. Other types of pipe provers can be used provided that the metrological characteristics of the prover comply with the requirements of this Recommendation.

2.1.1 Uni-directional type

A uni-directional prover uses a displacer that travels in one direction to actuate detectors in the calibrated section of the pipe. The measured volume corresponds to one passage of the displacer.

2.1.2 Bi-directional type

A bi-directional prover uses a displacer that travels in one direction to actuate detectors in the calibrated section of the pipe and then in the opposite direction through the same calibrated section and the same detectors. The measured volume corresponds to the sum of both passages of the displacer.

2.1.3 Small volume type

A small volume or compact prover uses a displacer which travels through a very short section of the pipe or cylinder. The volume displaced in the calibrated section is usually much smaller than that of a conventional prover. For this reason high-precision detectors and pulse-interpolation are necessary to achieve repeatability and accuracy.

2.1.4 Full-stroke type

This type of pipe prover uses the standing start and stop method; its base volume is the volume displaced by a single full stroke of the reversible displacer. Full-stroke type may be used mainly for the verification of LPG dispensers.

2.2 Accuracy

The calibration of a prover base volume shall be carried out such that the expanded uncertainty of the calibration be within one-fifth of the maximum permissible error on pattern approval tests and one-third of the maximum permissible error on verification tests. The estimation of the expanded uncertainty shall be made with a coverage factor $k = 2$. Expanded uncertainty includes uncertainty of measurement standards, uncertainty of calibration operation, and uncertainty of the prover being calibrated.

When the prover is calibrated, the expanded uncertainty of the calibration shall be recorded in the calibration certificate.

2.3 Construction of pipe provers

Construction of pipe provers shall meet the provisions of ISO 7278-2.

From the legal metrology viewpoint, some particular requirements are mentioned below. Care should be taken in the control system of a small volume prover for the collection of data from the meter and the prover. Typical layouts of pipe provers are shown in Figures 1 to 4 (*).

2.3.1 Materials and fabrication

The materials of construction and the pressure rating must be compatible with the measuring systems to be tested and the fluid used. The prover should be adequately insulated for the required duty and ambient conditions. If separation of the prover is necessary for the transport, the centering of the individual parts shall be guaranteed by an appropriate construction or the base volume revalidated after reassembly.

2.3.2 Displacer

In general, provers use one or more spheres, or a piston as a displacer. Spheres are made of a resilient material which must be compatible with the test fluid, and shall be required to meet certain minimum and maximum sizes. Piston displacers shall be made of rigid material with resilient seals in contact with the pipe prover wall.

2.3.3 Valves

The valves used in pipe prover systems whose possible leakage would influence the measurement result shall not leak. Means of checking leakage in the measuring system and prover shall be provided.

2.3.4 Temperature measuring devices

Temperature measuring devices of suitable range shall be installed at the inlet and outlet of the prover. The temperature measuring device shall be immersed in the fluid to enable accurate determination of fluid temperature. The use of thermowells is normally recommended. The accuracy and range of the devices must be such that the provisions of 2.2 and 4.3 are met.

2.3.5 Pressure measuring devices

Pressure measuring devices of suitable range shall be used at appropriate locations to measure pressure in the prover. The accuracy and range of the devices must be such that the provisions of 2.2 and 4.3 are met.

2.3.6 Detectors

Except for the full-stroke type of prover, detection devices and switches for any given direction of the displacer shall respond to the displacer's position such that the prover meets the performance requirements specified in 2.2.

(*) Figures 1, 2 and 3 are extracted from ISO 7278-2:1988 and ISO DIS 7278-4, with have been reproduced with the authorization of the International Organization for Standardization, ISO, case postale 56, 1211 Genève 20, Switzerland. Copies of this standard may be obtained from ISO or from one of its member committees. Copyright remains within ISO.

2.3.7 Vent valve and related piping

Vent valves shall be installed on the topmost part of the pipe to ensure that all the gas is vented from the dead spaces not swept by the displacer; this is to ensure that the piping, the pipe prover and the meter to be tested are completely filled with the test liquid. Provisions shall be made for the disposal of the liquid and vapors drained or vented from the prover. Connections shall be provided for the calibration of the prover by the water draw method or the master meter method. Critical vent and drain valves shall be closed during operation.

3 Calibration of pipe provers

Detailed description of the calibration of the pipe prover is given in ISO 7278-2; the calibration methods summarized below are intended to serve as guidelines.

National regulations may specify that pipe provers used for testing measuring systems for liquids shall be calibrated before installation, and may be re-calibrated periodically at intervals to be fixed by these regulations. Pipe provers shall also be recalibrated when they may have been mechanically altered (e.g., change of detector, recoating, dismantling, and re-installation).

3.1 Reference conditions

The base volume of a pipe prover shall be determined on the basis of the reference conditions specified in national regulations.

3.2 Methods for calibrating a pipe prover

There are two methods for calibrating a pipe prover: the water draw method and the master meter method.

3.2.1 Water draw method

The calibration of a pipe prover by the water draw method requires standard capacity measures or a weighing instrument with a tank, against which the volume of the prover may be determined.

To allow a continuous and uniform flowrate to be produced, the complete volume of the prover between detectors may be run into a holding tank, using typical arrangements such as those shown in Figures 5 and 6. This volume is measured subsequently by weighing or by transferring to standard capacity measures.

3.2.2 Master meter method

The function of the master meter in this method is to serve as an intermediate link between the pipe prover being calibrated and the master prover which may be either a proving tank or a pipe prover. Therefore, it is necessary to check, before and after the calibration run, whether there has been any variations in the performance of the master meter by using a master prover. A typical arrangement is shown in Figure 7.

The master meter method is not applicable for a full-stroke type of pipe prover with a small volume.

4 General requirements for the testing of measuring systems using a pipe prover

4.1 Test liquids

A measuring system shall be tested using one of the liquids marked on the data plate of the measuring system, or with a liquid whose flow characteristics are within the ranges of those of the stated liquids. Any regulations concerning the security of handling of the measuring system shall be observed.

4.2 Preliminary runs

A sufficient number of preliminary runs shall be carried out before the test run in order to eliminate gas which may be contained in the measuring system or the testing equipment, and to make sure that the temperatures of the liquid used for testing the measuring system and the pipe prover are stable.

The measuring system shall be tested for leakage before the tests begin.

4.3 Temperature and pressure measurement

4.3.1 In order to determine the necessary temperature corrections for the test liquid, the measuring system and the pipe prover being used, temperature measuring devices shall be used. These temperature measuring devices shall be mounted at suitable places on the measuring system and the testing equipment. It is recommended to use temperature measuring devices with an accuracy of ± 0.2 °C or better. For accurate measurement of large volumes of petroleum products, it may be necessary to measure the temperature to within ± 0.05 °C to take into account the expansion and contraction changes in these products and in the measuring systems. Temperature measuring devices should be provided with calibration certificates.

4.3.2 When a correction for the pressure of the liquid and/or prover is required, a pressure gauge shall be mounted at a suitable place on the measuring system or on the testing equipment in order to measure the pressure with the necessary accuracy. Normally, pressure gauges with an accuracy of ± 0.05 MPa (0.5 bar) or better will be suitable, although for high accuracy applications, such as bulk petroleum measurements, an accuracy of 0.025 MPa or better is required. Pressure gauges should be provided with calibration certificates.

4.4 Inspection of electronic devices

The electronic devices including detectors, pulse generator and pulse counter shall be inspected to confirm that they function correctly.

4.5 Test flowrates

The number of flowrates at which the measuring system shall be checked is specified in OIML R 117, or in other OIML Recommendations for the control of particular measuring systems.

The following flowrates are recommended as a minimum.

4.5.1 For the verification of a meter or for the first stage in a two-stage verification, where the first stage concerns the meter itself or any ancillary devices which must be associated with it and possibly included in a sub-system if these are fitted to the meter, the test shall be carried out at the following flowrates:

- the minimum flowrate Q_{min}, stated on the meter,
- the maximum flowrate Q_{max}, stated on the meter,
- a flowrate between Q_{min} and Q_{max}.

4.5.2 For the second stage in a two-stage verification or for the complete test in a single-stage verification, and for the subsequent verification of a measuring system, the tests shall be carried out at the following flowrates:

- the minimum flowrate Q_{min}, stated on the measuring system,
- the maximum attainable flowrate, but not exceeding Q_{max},
- a flowrate at which the measuring system is normally operated.

4.6 Test volume

It should be ensured that the proving volume of the pipe prover shall be matched to the resolution of the measuring system and shall be adequate to meet the requirements of 2.2.

Where the system is equipped with a pulse generator which does not generate enough pulses for the test volume, the pulse interpolation methods may be used in compliance with ISO 7278-3.

4.7 Number of test runs

The number of test runs to be carried out at a particular test flowrate is specified in OIML R 117, or in other Recommendations for the control of particular measuring systems.

In general the number of test runs carried out at a particular flowrate shall be more than two so that an estimate may be made with regard to the repeatability of the measurement and also to verify whether each individual result meets the maximum permissible errors.

4.8 Calculation of meter error

The value of the error may be calculated either from the meter factor determined according to ISO 4267-2, clause 7, or directly using the following equations (in which the second order terms are neglected).

$E = E' + E_\alpha + E_\beta + E_\gamma + E_\delta$

$E' = [(V_{lm} - V_B) / V_B] \times 100$

$E_\alpha = \alpha \times (t_{lp} - t_{lm}) \times 100$

$E_\beta = \beta \times (t_s - t_{lp}) \times 100$

$E_\gamma = \gamma \times (p_{lm} - p_{lp}) \times 100$

$E_\delta = \delta \times (p_s - p_{lp}) \times 100$

where

E is the meter error, in %

E' is the uncorrected error, in %

E_α is the temperature correction for the test liquid, in %

E_β is the temperature correction for the pipe prover, in %

E_γ is the pressure correction for the test liquid, in %
E_δ is the pressure correction for the pipe prover, in %
V_{lm} is the volume indicated by the meter, in L
V_B is the base volume of the pipe prover, in L
t_{lp} is the liquid temperature in the pipe prover, in °C
t_{lm} is the liquid temperature in the meter, in °C
t_s is the reference temperature of the pipe prover, in °C
p_{lp} is the liquid pressure in the pipe prover, in kPa
p_{lm} is the liquid pressure in the meter, in kPa
p_s is the liquid pressure when the base volume of the pipe prover was determined, in kPa
α is the cubic expansion coefficient of the test liquid due to temperature, in $°C^{-1}$
β is the cubic expansion coefficient of the pipe prover due to temperature, in $°C^{-1}$
γ is the compression coefficient of the test liquid, in kPa^{-1}
δ is the pressure expansion coefficient of pipe prover, in kPa^{-1}

Notes: α: Refer to OIML R 63 or ISO 91-1 for petroleum products; refer to ISO 8222 for water
β: 33×10^{-6} $°C^{-1}$ for mild steel, 51×10^{-6} $°C^{-1}$ for stainless steel
γ: Refer to ISO 4267-2, C_{ps}
δ: Refer to ISO 4267-2, C_{p1}

An example of a test report is given in Annex A.

5 Test procedures for the verification of measuring systems

In clauses 6, 7 and 8, descriptions are given of test procedures which can be used for the verification and checking of the following measuring systems:

clause 6:
- measuring system on road tanker
- measuring system for the unloading of road and rail tankers, ships' tanks and tank containers
- measuring system for the loading of road and rail tankers, ships' tanks and tank containers
- measuring system fitted on pipeline

clause 7:
- measuring system for LPG under pressure

clause 8:
- LPG dispenser
- fuel dispenser

It should be noted that there exist many other acceptable methods which may be described in OIML Recommendations or in ISO Standards; examples below are given to illustrate the range. The sole criterion for the acceptability of a method is whether it complies with the metrological requirements of this Recommendation and thus ensures the integrity of testing.

6 Test procedures for the verification of measuring systems for liquid fuel, excluding fuel dispensers

Typical installations in which a pipe prover and a measuring system for liquid fuel are connected are shown in Figures 8 to 11, depending upon the applications of the measuring systems.

The test procedures shall be as follows:

(1) Carry out a sufficient number of preliminary runs.
(2) Locate the displacer at the starting position, and reset the pulse counter and the interval timer to zero.
(3) Start the displacer movement. Check whether the pulse counter and the interval timer starts when the detector switch is activated.
(4) While the pulse counter is counting, read and record the temperatures and pressures of the pipe prover and measuring system.
(5) Check that the pulse counter and the interval timer stop when the next detector switch is activated.
(6) Read and record the indicated results of the pulse counter and the interval timer.

If an electronic pulse counter is attached to the measuring system for proving, it will be necessary to separately verify the register used in normal operation of the measuring system.

Note: The type of prover shown Figure 8 to 14 is given as an example.

7 Test procedures for the verification of measuring systems for LPG under pressure

A typical installation in which a measuring system for LPG under pressure is tested using a pipe prover is shown in Figure 12. It should be ensured that the LPG remains in liquid phase inside the pipe prover, if necessary, by means of an appropriate device.

The test procedures shall be the same as described in clause 6.

8 Test procedures for the verification of LPG and liquid dispensers

Typical installations in which a full-stroke type of pipe prover is used for testing dispensers are shown in Figures 13 and 14, depending upon the applications of the dispensers.

The test procedures shall be as follows:

(1) Locate the pipe prover horizontally close to the dispenser, and make the pipework as short as possible.
(2) Connect the outlet nozzle of the dispenser to the pipe prover inlet.

(3) Position the flow diverter valve to cause circulation of flow. Purge gas adequately and conduct preliminary runs. Check that no air bubbles are present, by means of the sight glass.

(4) Locate the displacer at the starting position, and reset the indication of the dispenser to zero.

(5) Start the displacer movement.

(6) Read and record the temperature, pressure and flowrate of the liquid during flow.

(7) Read and record the total count on the dispenser when the displacer reaches the end point of its stroke and stops.

Note: Ordinary nozzles for liquid fuel dispensers (other than LPG) operate the automatic over-flow stop by taking air into the liquid stream. The use of a full-stroke prover is therefore only possible when this type of nozzle is replaced or bypassed during tests.

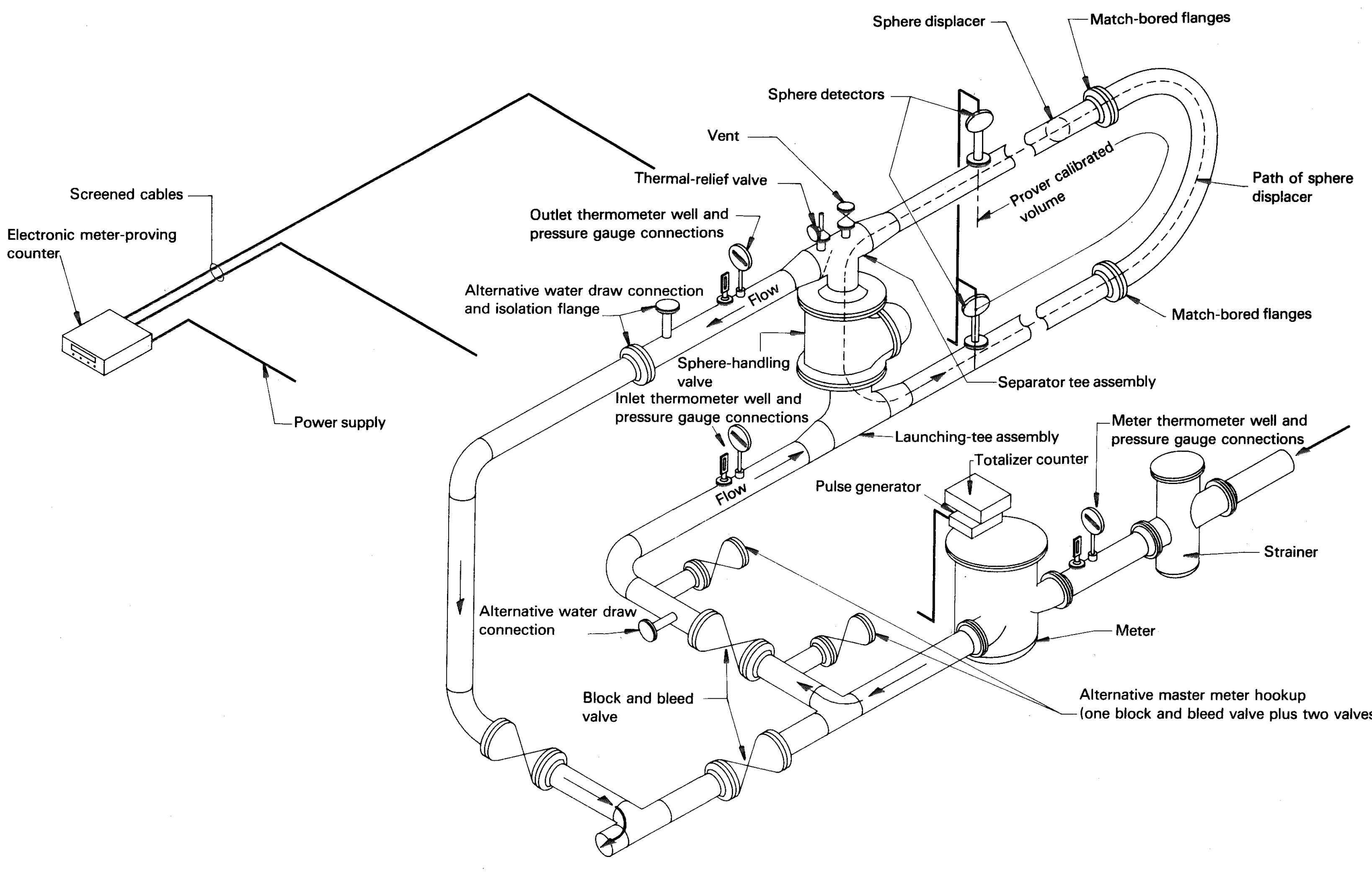

Figure 1 Typical unidirectional pipe prover
(Extracted from ISO 7278; see foot-note in page 7)

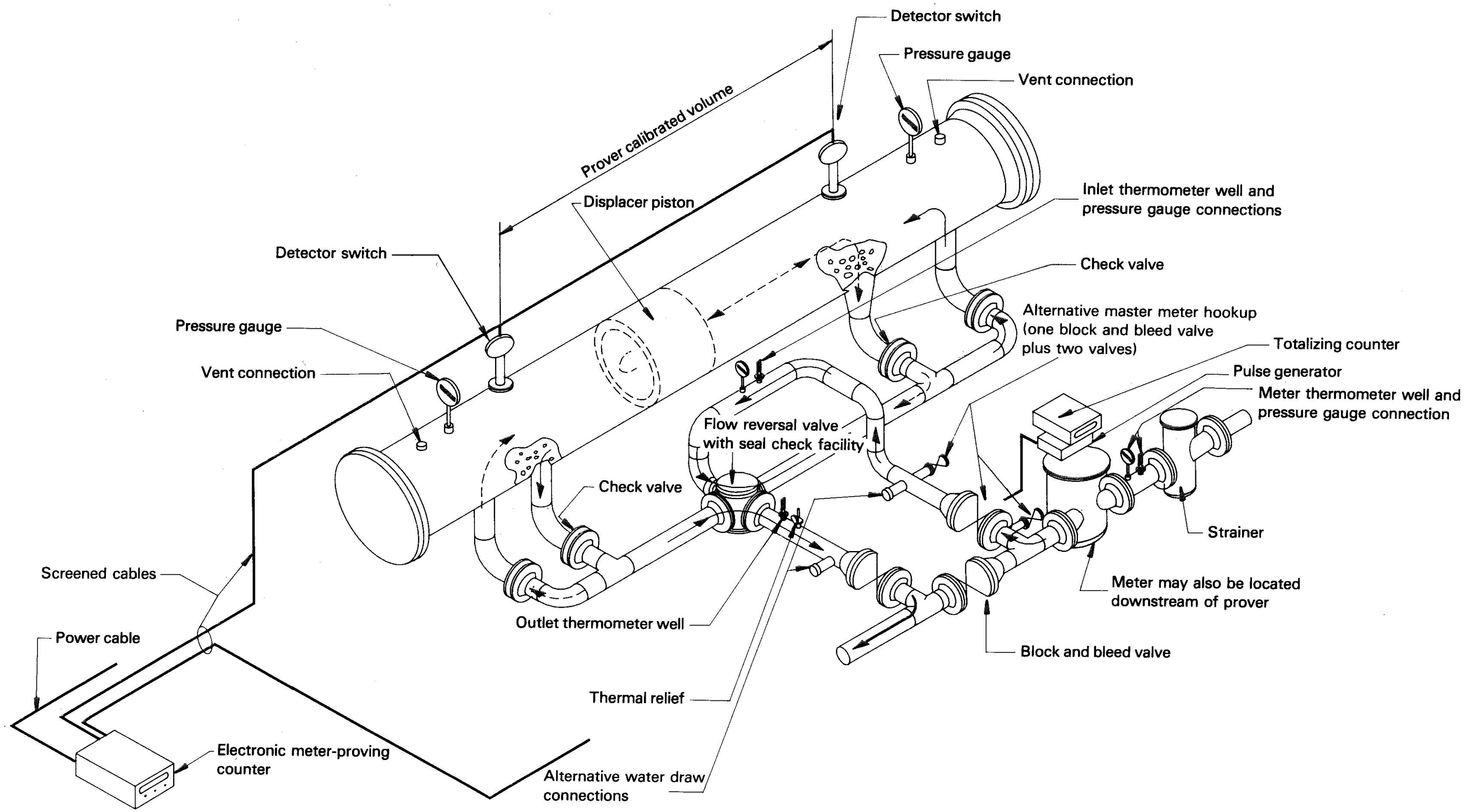

Figure 2a Typical bidirectional straight-type piston pipe prover
(Extracted from ISO 7278; see foot-note in page 7)

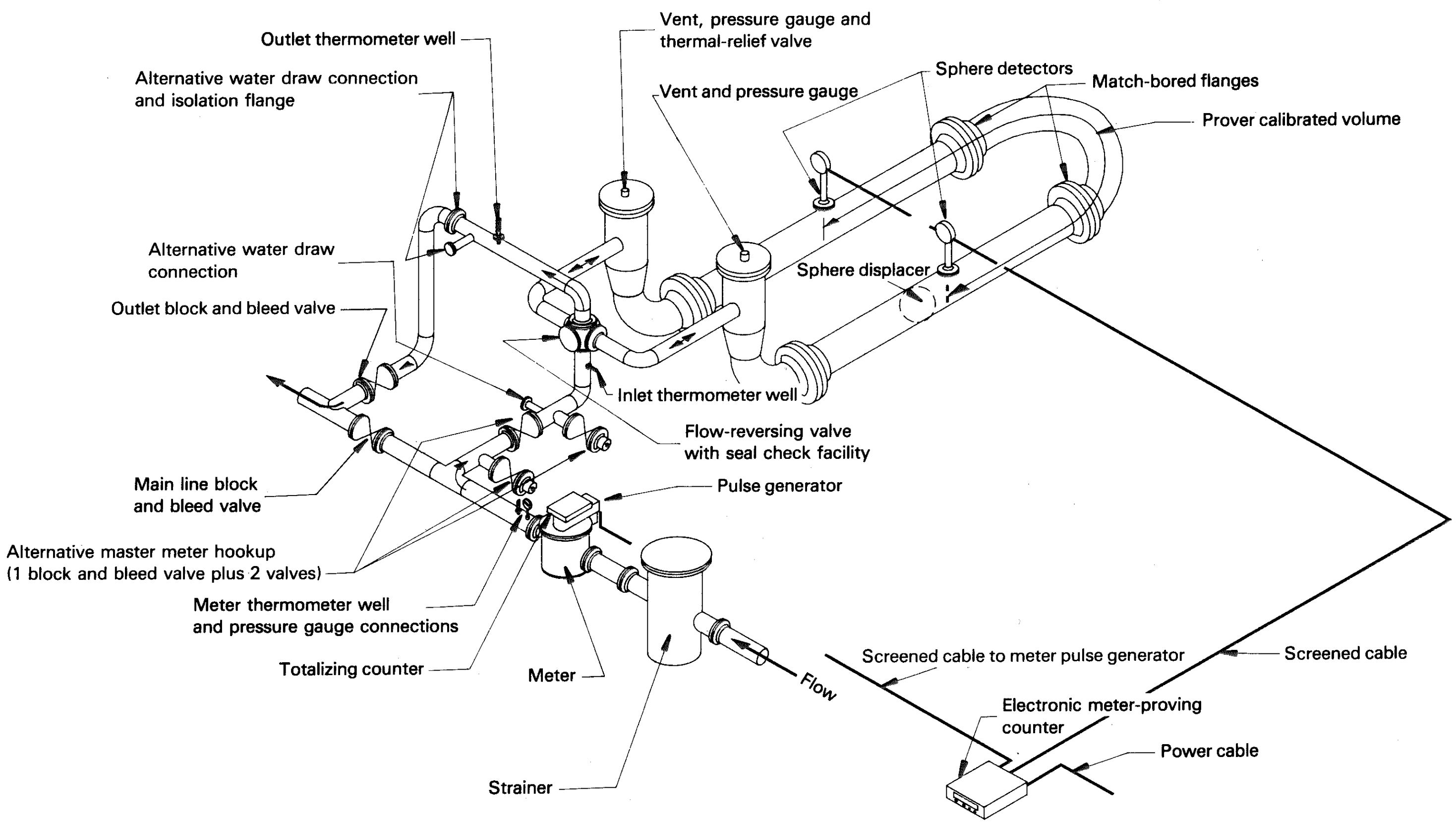

Figure 2b Typical bidirectional U-type pipe prover
(Extracted from ISO 7278; see foot-note in page 7)

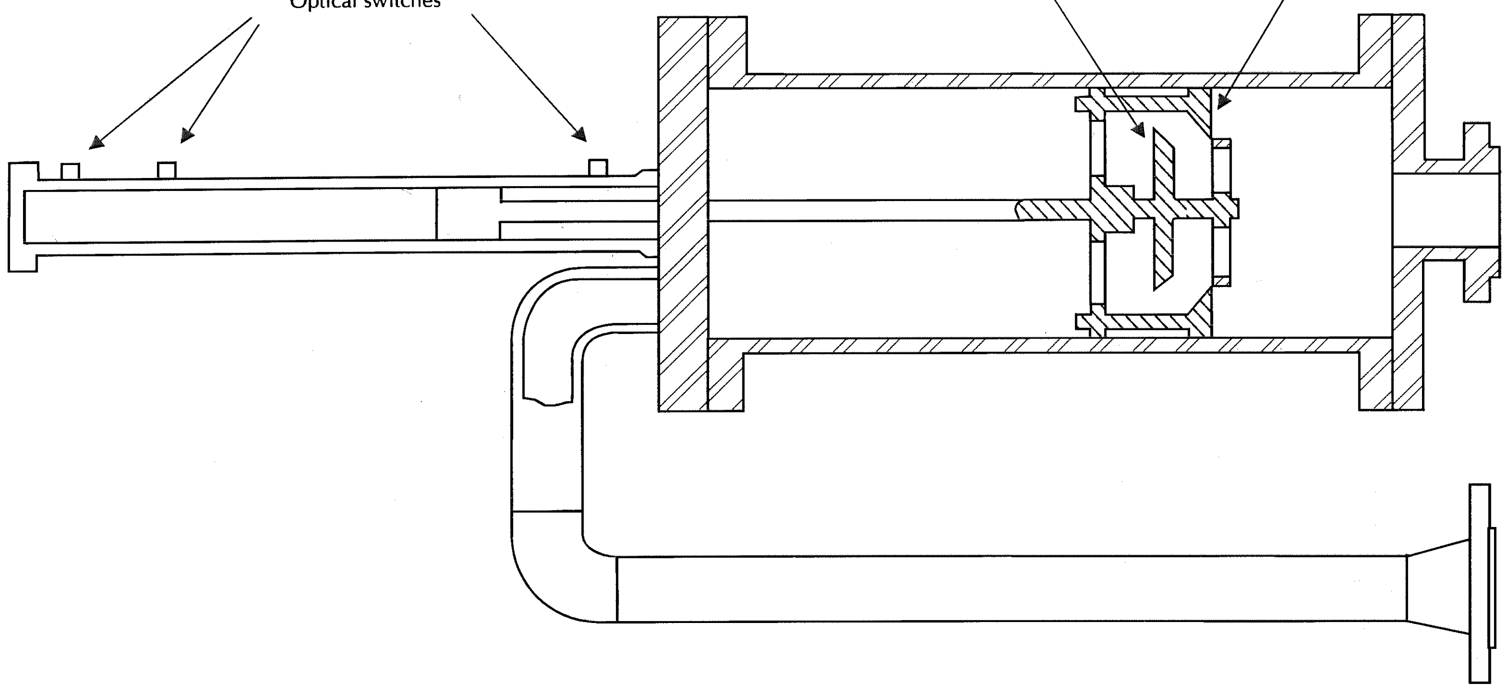

Figure 3a Typical small volume pipe prover with internal valve
(Extracted from ISO 7278; see foot-note in page 7)

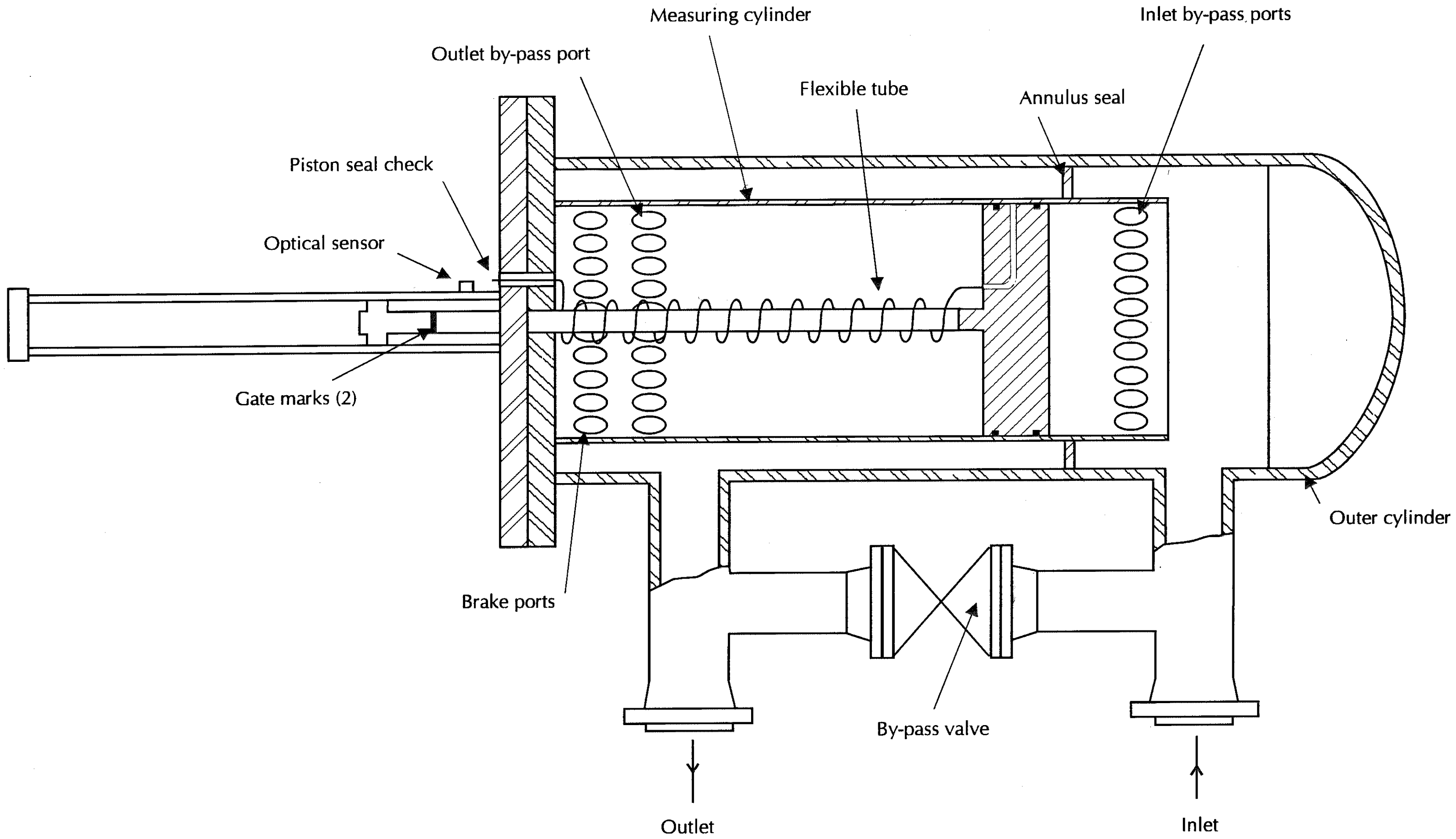

Figure 3b Typical small volume pipe prover with external valve
(Extracted from ISO 7278; see foot-note in page 7)

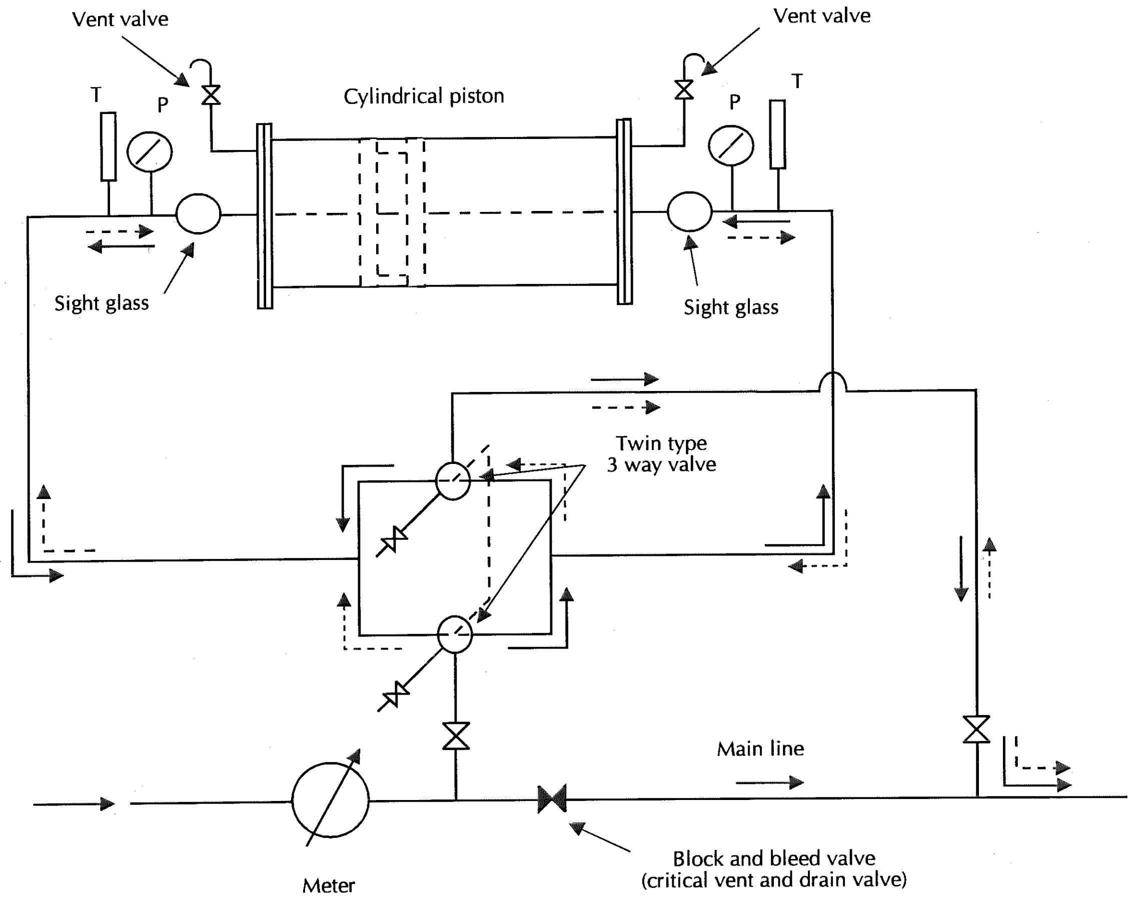

Figure 4 Typical full-stroke type pipe prover

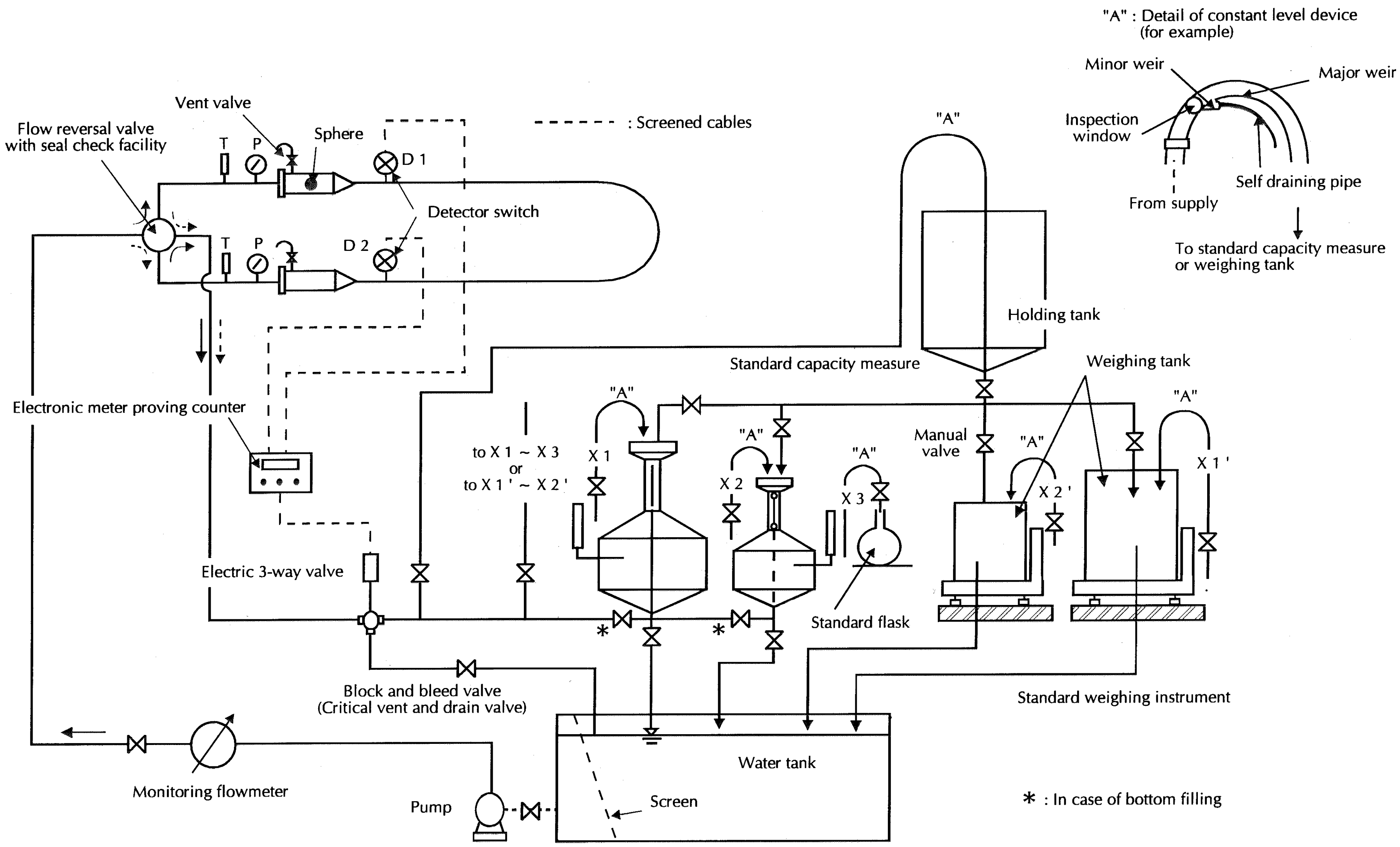

Figure 5 Calibration of pipe prover (water draw method)

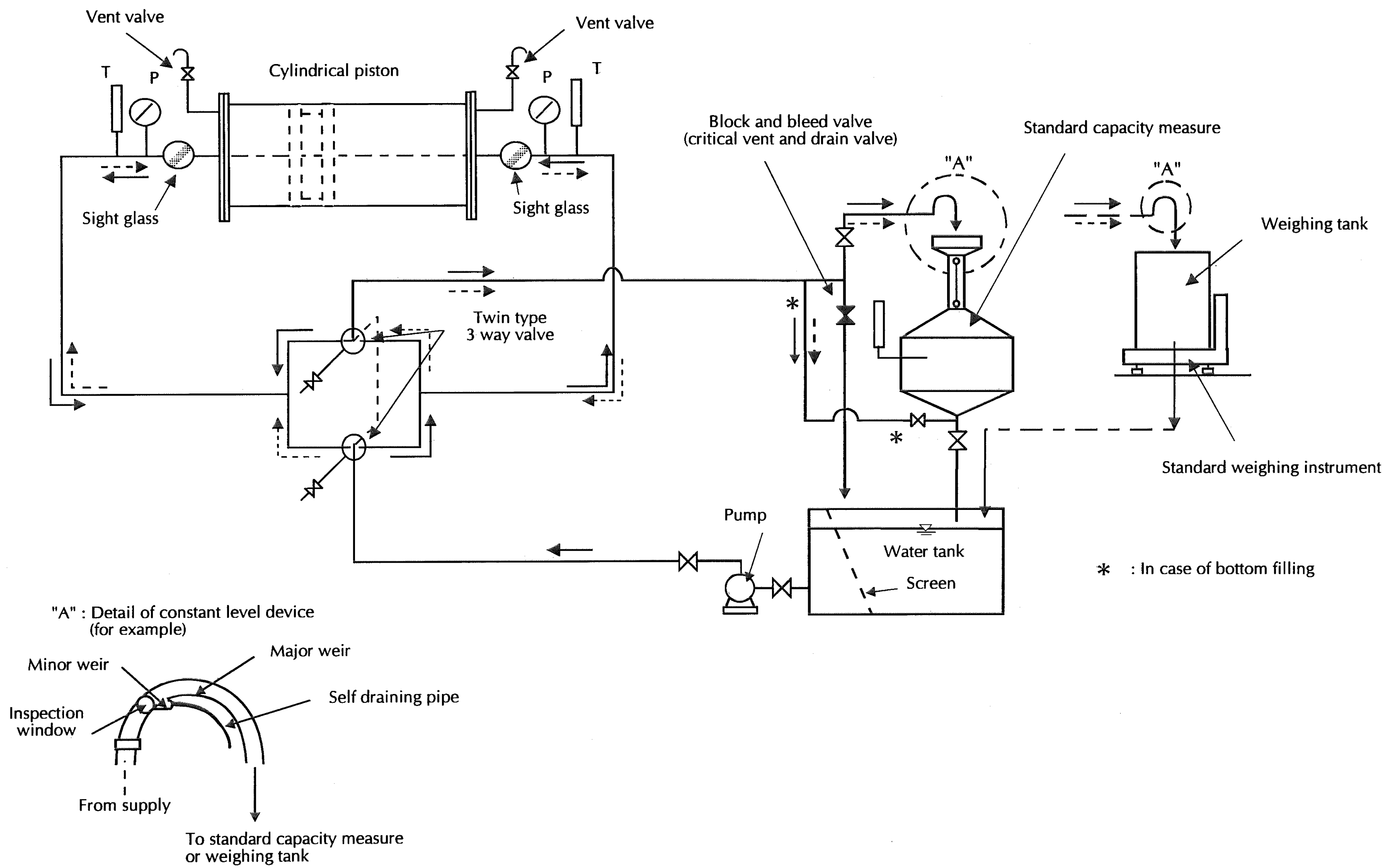

Figure 6 Calibration of full-stroke type pipe prover (water draw method)

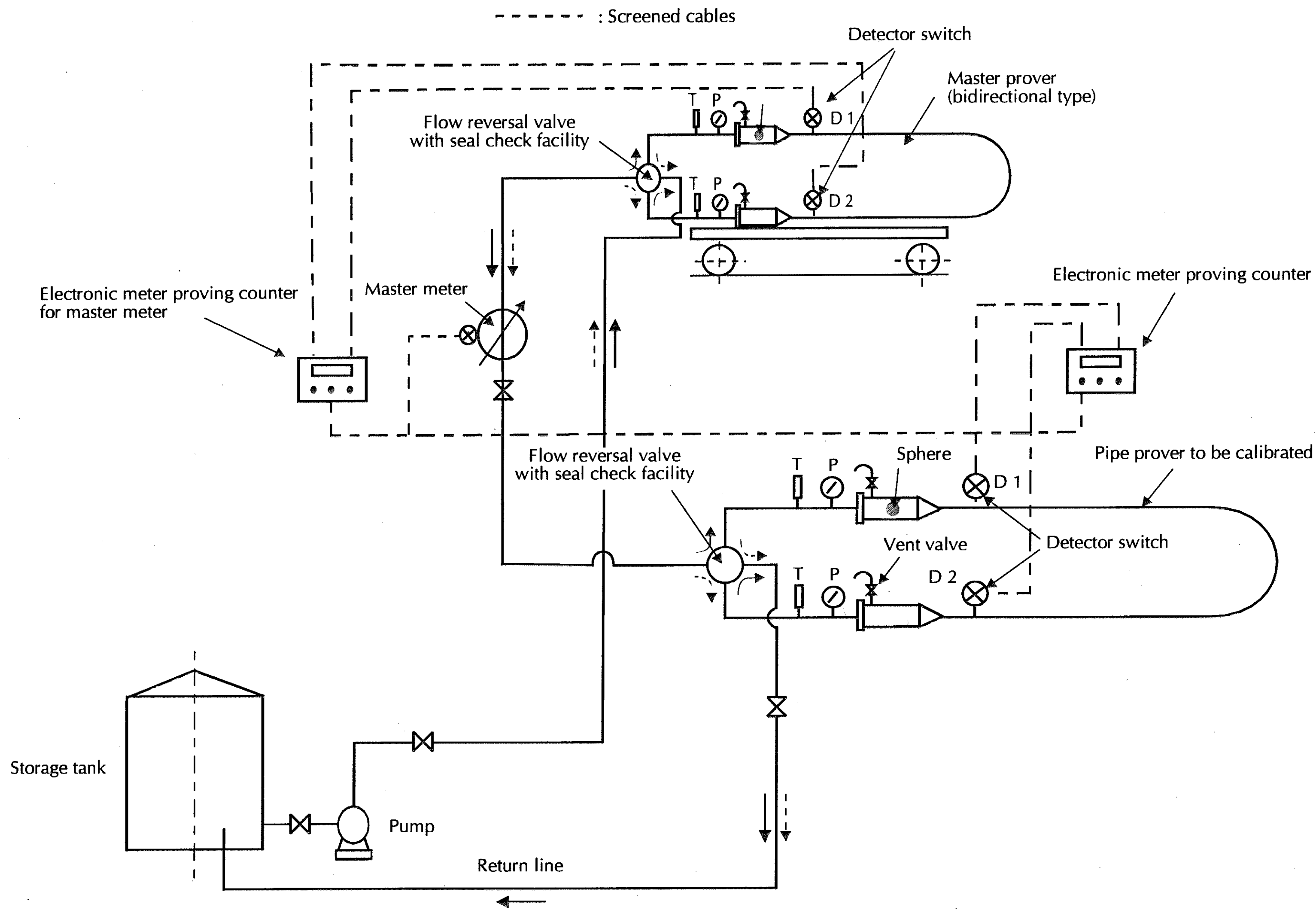

Figure 7 Calibration of pipe prover (master meter method)

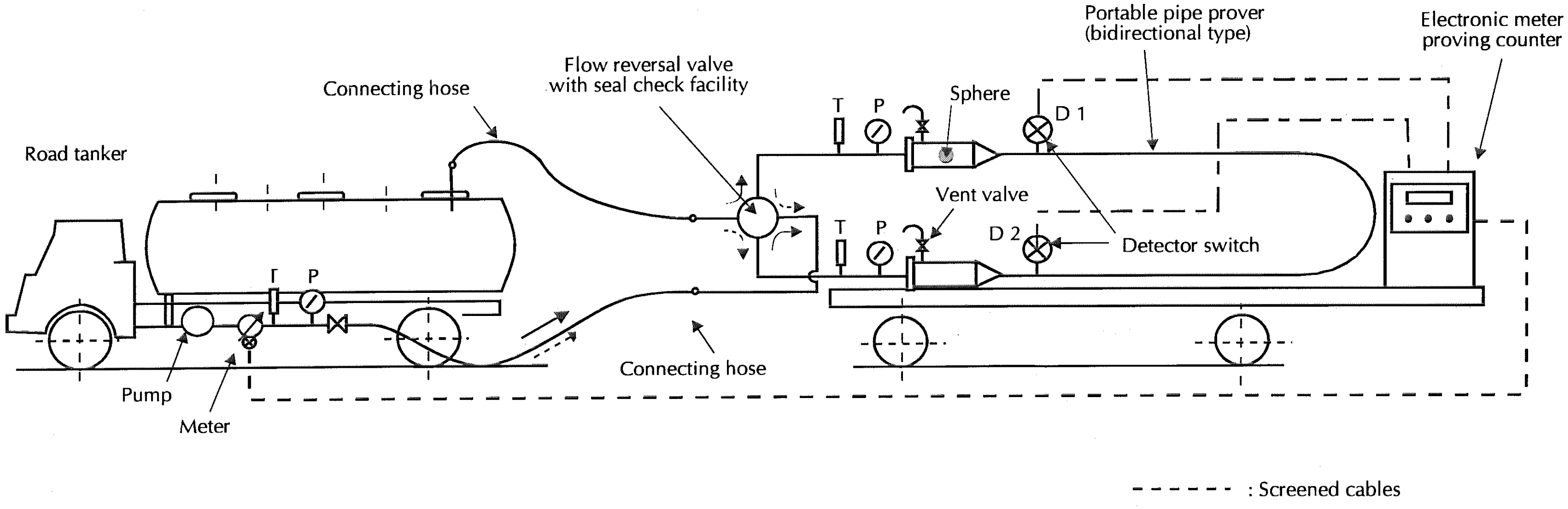

Figure 8 Verification of measuring systems on road tankers

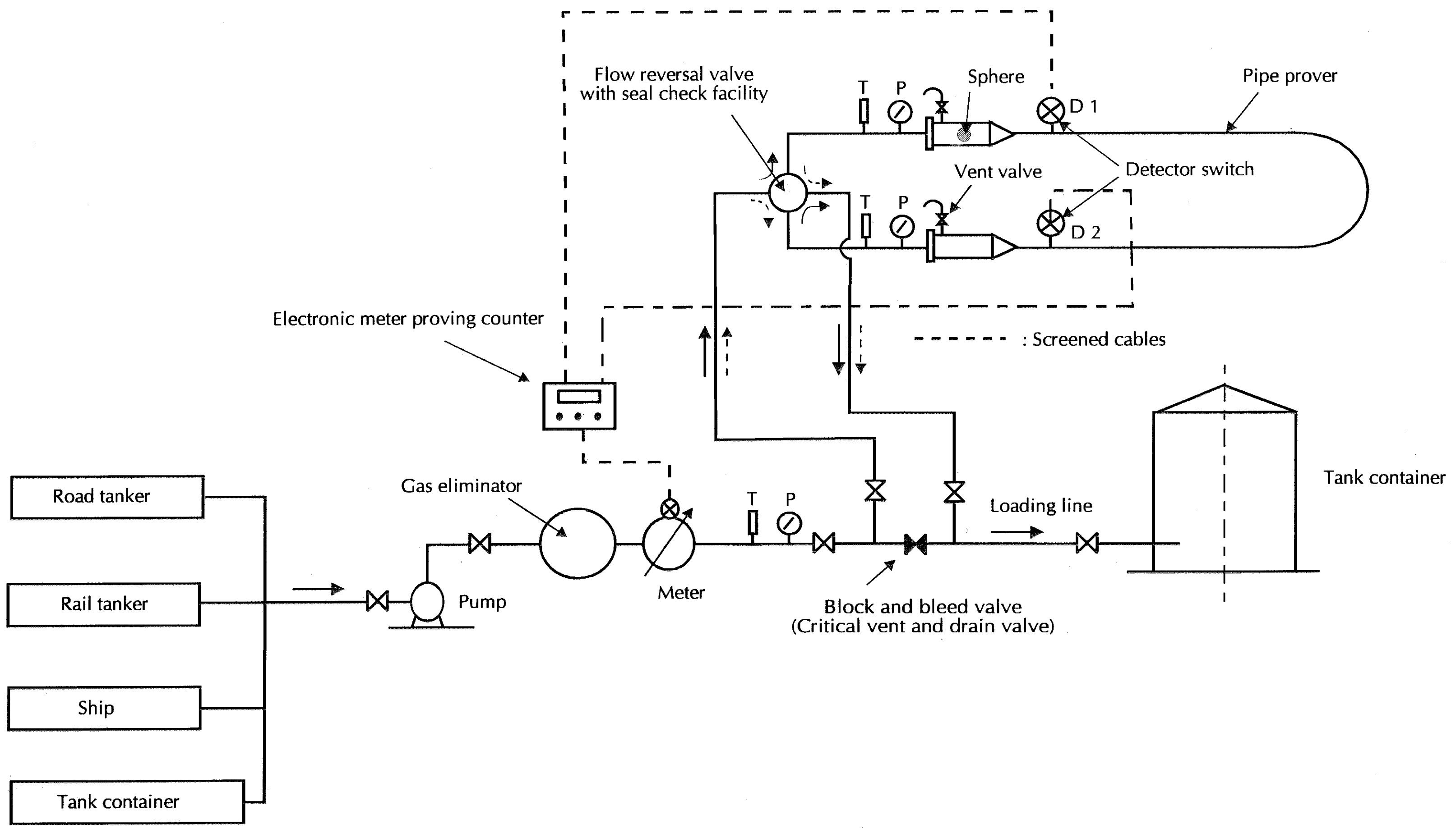

Figure 9 Verification of measuring systems for the unloading of road and rail tankers, ships' tanks and tank containers

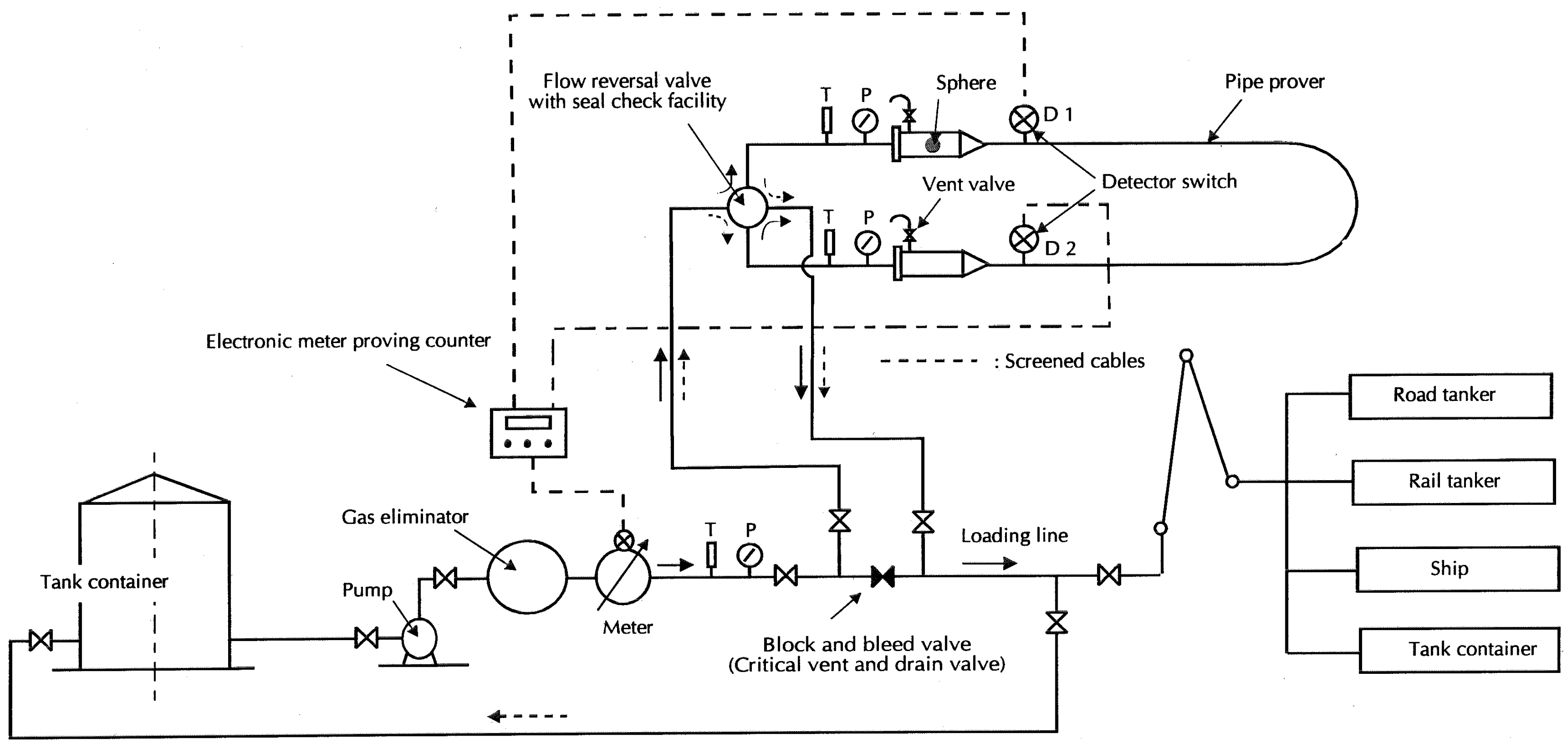

Figure 10 Verification of measuring systems for the loading of road and rail tankers, ships' tanks and tank containers

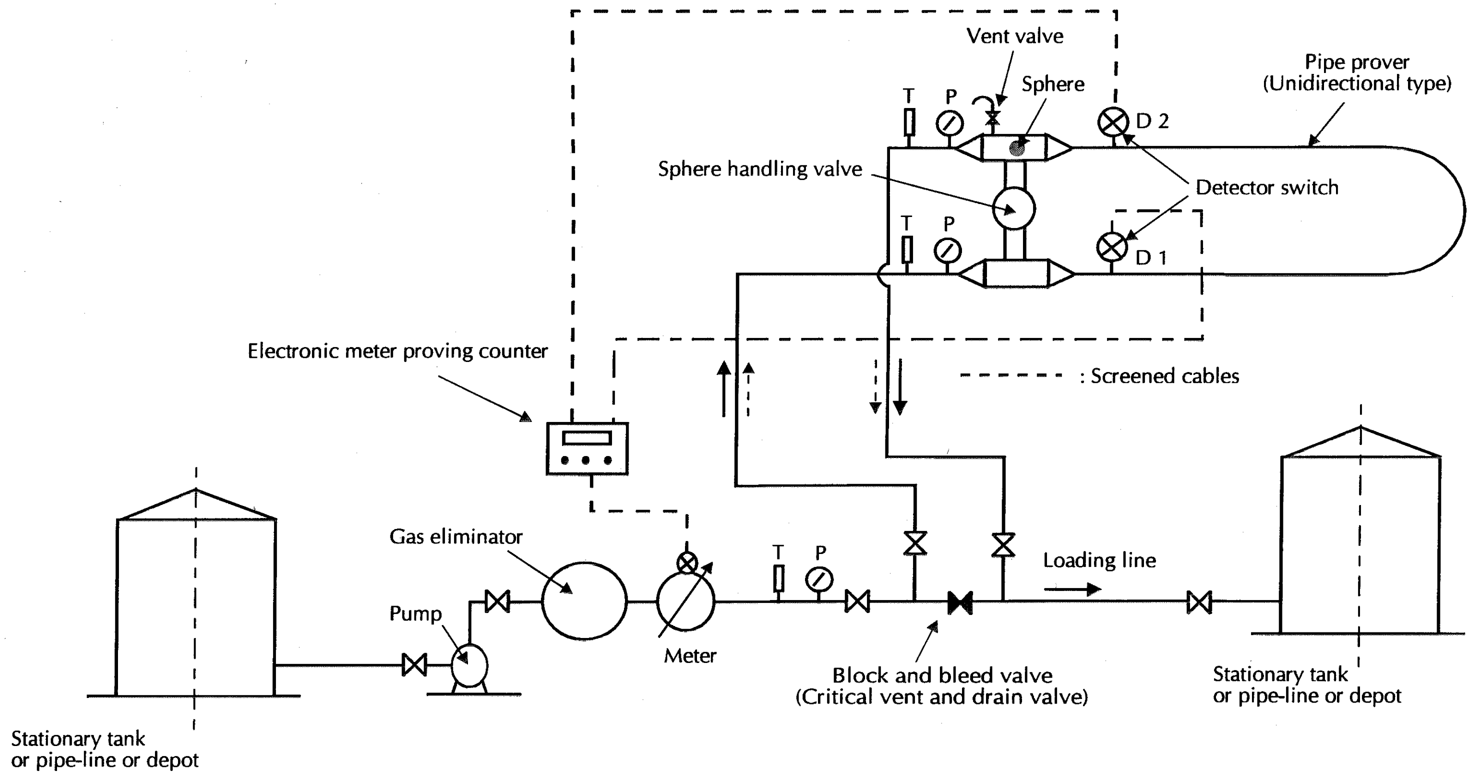

Figure 11 Verification of measuring systems on pipe-line

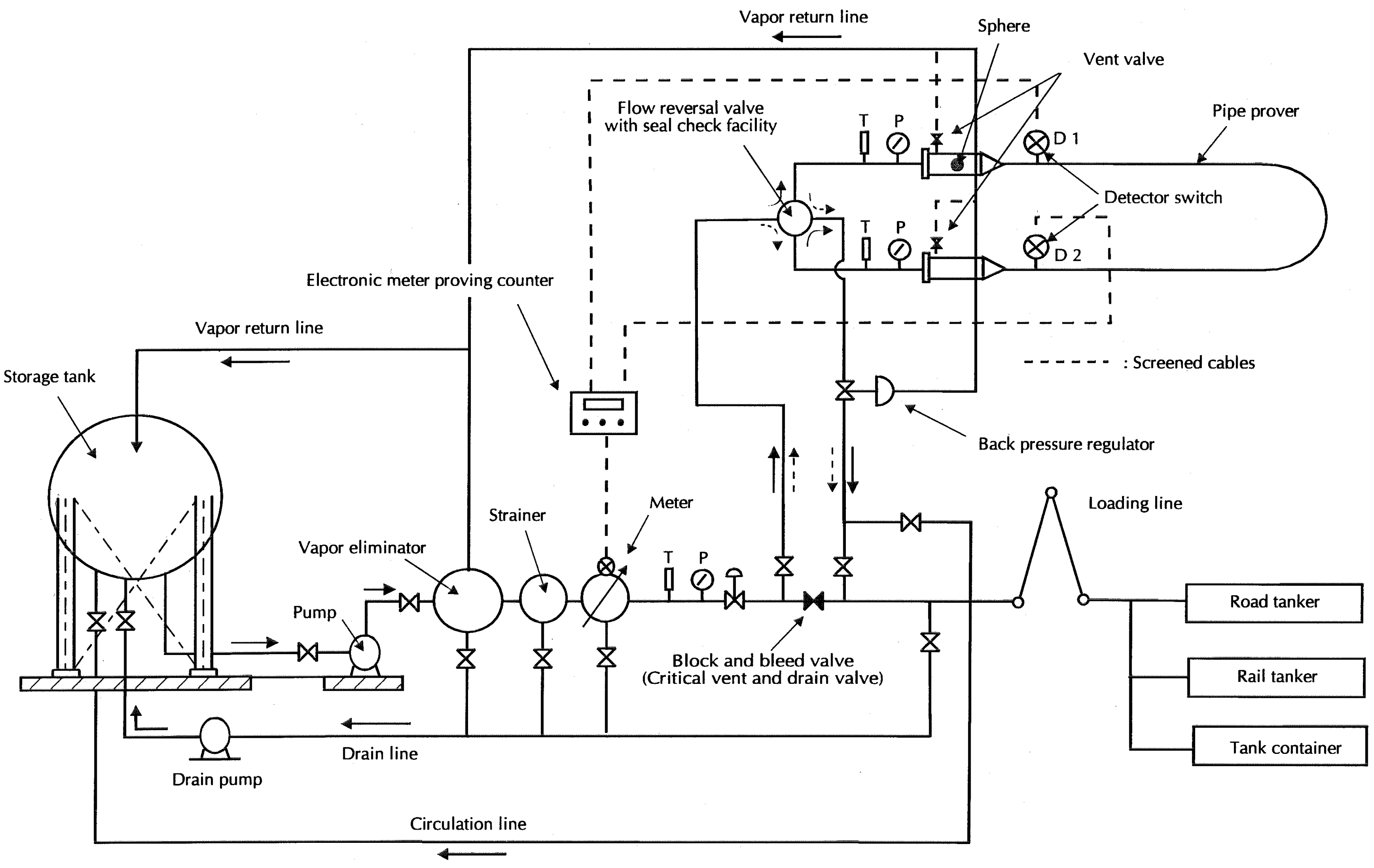

Figure 12 Verification of measuring systems for LPG under pressure

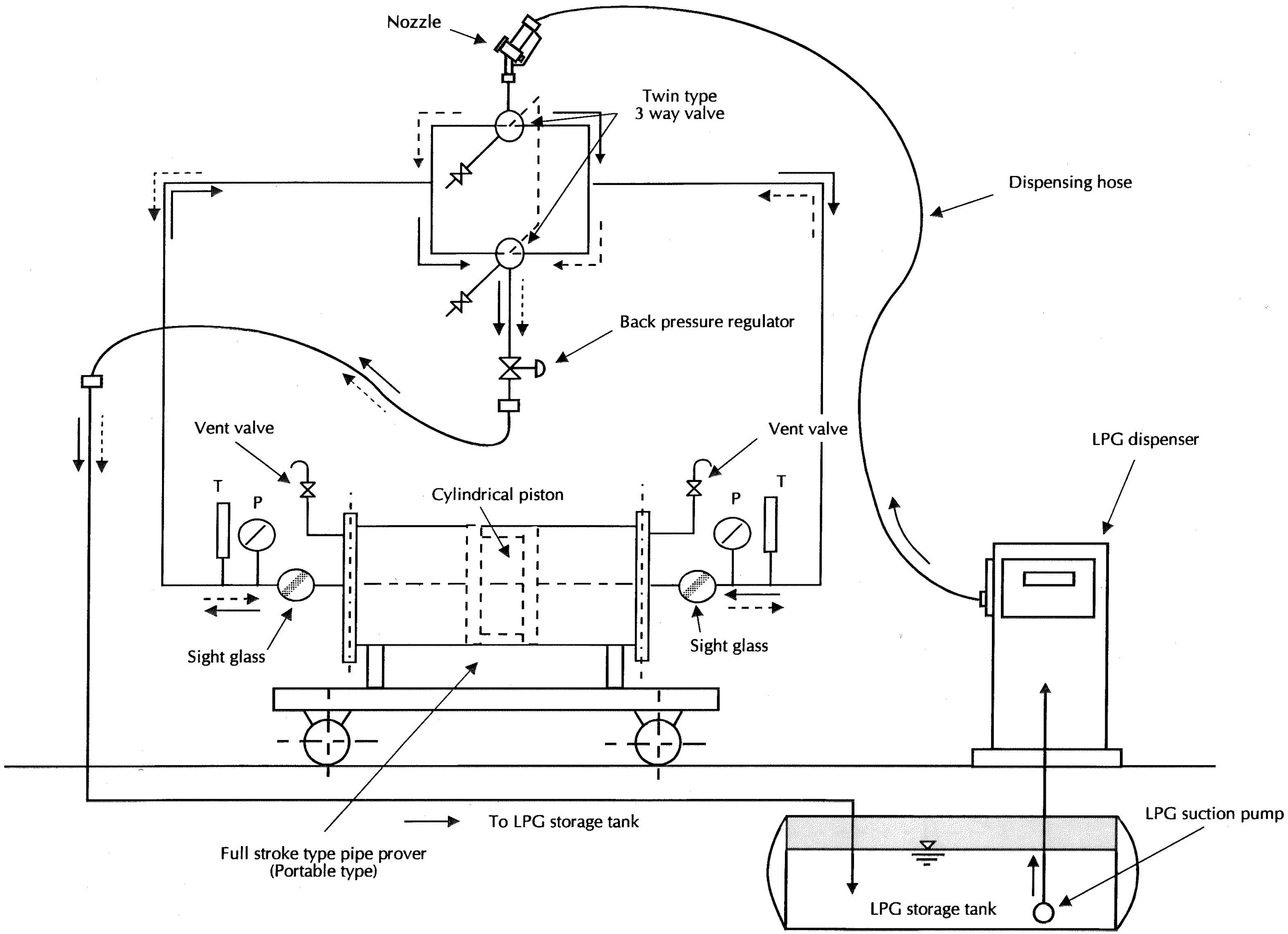

Figure 13 Verification of LPG dispensers

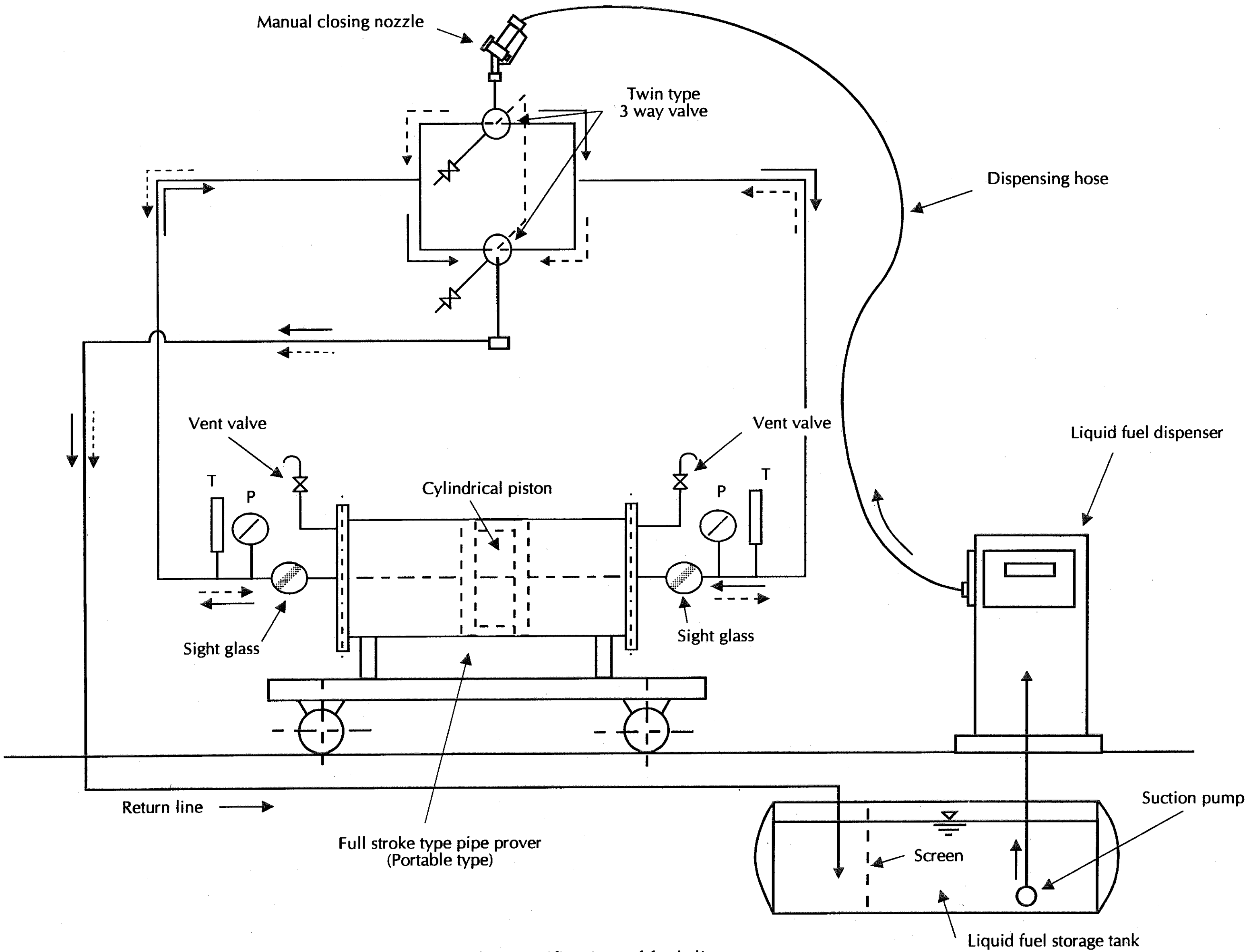

Figure 14 Verification of fuel dispensers

ANNEX A
EXAMPLE OF TEST REPORT
(Informative)

Company:		Date:
Location:	Test liquid:	
Viscosity of test liquid: ________ mPa·s at ______ °C	Density of test liquid: ________ kg/m^3 at ______ °C	
Designation of meter:	Meter model:	Identif. number of meter:
Totalizer of meter:	Size of meter:	
Meter factor previous:	new:	
Type of pipe prover:	Identif. number of prover:	
Size of prover	Proving volume:	
Prover rated minimum:	maximum:	Ambient temperature:

No	Item	Unit			
	Test flowrate	m^3/h			
1	Liquid temperature in pipe prover t_{lp1} – – t_{lp3}	°C			
	Average liquid temperature t_{lp}	°C			
2	Liquid pressure in prover p_{lp}	kPa			
3	Base volume of prover V_B	L			
4	Actual flowrate	m^3/h			
5	Liquid temperature in meter t_{lm1} – – t_{lm3}	°C			
	Average liquid temperature t_{lm}	°C			
6	Liquid pressure in meter p_{lm}	kPa			
7	Indicated volume of meter V_{lm}	L			
8	Uncorrected error E'	%			
9	Temperature correction for test liquid E_α	%			
10	Temperature correction for pipe prover E_β	%			
11	Pressure correction for test liquid E_γ	%			
12	Pressure correction for pipe prover E_δ	%			
13	Meter error E	%			

For: ____________________ Signed by: ____________________

Notes:

$E = E' + E_\alpha + E_\beta + E_\gamma + E_\delta$

$E' = (V_{lm} - V_B) / V_B \times 100$

$E_\alpha = \alpha (t_{lp} - t_{lm}) \times 100$ α = ________ (°C^{-1})

$E_\beta = \beta (t_s - t_{lp}) \times 100$ β = ________ (°C^{-1})

$E_\gamma = \gamma (p_{lm} - p_{lp}) \times 100$ γ = ________ (kPa^{-1})

$E_\delta = \delta (p_s - p_{lp}) \times 100$ δ = ________ (kPa^{-1})

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