



**International  
Standard**

**ISO 6996**

**Bunkering — Meter verification using  
master Coriolis mass flow meter**

*Soutage — Vérification des compteurs au moyen d'un compteur  
massique étalon à effet Coriolis*

**First edition  
2024-03**

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Published in Switzerland

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## Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO document should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see [www.iso.org/directives](http://www.iso.org/directives)).

ISO draws attention to the possibility that the implementation of this document may involve the use of (a) patent(s). ISO takes no position concerning the evidence, validity or applicability of any claimed patent rights in respect thereof. As of the date of publication of this document, ISO had not received notice of (a) patent(s) which may be required to implement this document. However, implementers are cautioned that this may not represent the latest information, which may be obtained from the patent database available at [www.iso.org/patents](http://www.iso.org/patents). ISO shall not be held responsible for identifying any or all such patent rights.

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For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see [www.iso.org/iso/foreword.html](http://www.iso.org/iso/foreword.html).

This document was prepared by Technical Committee ISO/TC 28, *Petroleum and related products, fuels and lubricants from natural or synthetic sources*, Subcommittee SC 2, *Measurement of petroleum and related products*.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at [www.iso.org/members.html](http://www.iso.org/members.html).

## Introduction

The objective of this document is to set qualifying requirements for the master Corolis mass flow meter in the bunkering context as well as to establish meter verification requirements and a verification procedure for using the master meter. The meter verification is performed to:

- a) verify the mass flow meter (MFM) that is used for custody transfer;
- b) track the meter stability of the duty meter used in the MFM system at regular intervals during its commercial service.

Regular meter verification provides another option to MFM users other than regular re-calibration. It is more efficient, less costly and less time-consuming to monitor the measurement performance of the MFM over time in compliance with the metrological requirements for custody transfer.

This document is intended to complement the meter verification requirements in ISO 22192 and ISO 6963.

In this document, the following verbal forms are used:

- “shall” indicates a requirement;
- “should” indicates a recommendation;
- “may” indicates a permission;
- “can” indicates a possibility or a capability.

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# Bunkering — Meter verification using master Coriolis mass flow meter

## 1 Scope

This document specifies the criteria and metrological requirements to qualify a master meter and subsequently maintain its qualification. It establishes requirements and procedures for meter verification, using a master mass flow meter to verify the accuracy and functionality of a duty meter installed on a bunker tanker or at a terminal.

## 2 Normative references

There are no normative references in this document.

## 3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

- ISO Online browsing platform: available at <https://www.iso.org/obp>
- IEC Electropedia: available at <https://www.electropedia.org/>

### 3.1

#### accuracy

closeness of agreement between a measured quantity value and a true quantity value of a measurand

[SOURCE: ISO/IEC Guide 99:2007, 2.13, modified — Notes 1, 2 and 3 to entry deleted.]

### 3.2

#### error

$E$

measured quantity value minus a reference quantity value

[SOURCE: ISO/IEC Guide 99:2007, 2.16, modified — Notes 1 and 2 to entry deleted.]

### 3.3

#### error percentage

$E\%$

error (3.2) divided by the same reference quantity value

### 3.4

#### master meter

Coriolis mass flow meter which is qualified to verify the *meter under test* (3.9)

### 3.5

#### maximum mass flow rate

$Q_{\max}$

maximum flow rate to which the *meter under test* (3.9) and the *master meter* (3.4) have been qualified to operate in compliance with the required accuracy

### 3.6

#### **measurement uncertainty**

non-negative parameter characterizing the dispersion of the quantity values being attributed to a measurand, based on the information used

[SOURCE: ISO/IEC Guide 99:2007, 2.26, modified — Notes to entry deleted.]

### 3.7

#### **meter factor**

totalized mass quantity from the master meter divided by totalized mass quantity from the meter under test

### 3.8

#### **meter stability**

property of a measuring instrument whereby its metrological properties remain constant over time

Note 1 to entry: Stability may be quantified in several ways:

- in terms of a time duration over which a metrological property changes by a stated amount,
- in terms of the change of a property over a stated time.

[SOURCE: ISO 22192:2021, 3.32]

### 3.9

#### **meter under test**

##### **MUT**

Coriolis mass flow meter or any mass flow meter approved for custody transfer that is undergoing *meter verification* (3.11)

### 3.10

#### **meter verification report**

report generated after the completion of the *meter verification* (3.11) containing the results and relevant critical data pertaining to meter verification

### 3.11

#### **meter verification**

verification of the *accuracy* (3.1) of a *meter under test* (3.9) from the start of the first run to the end of the final run

### 3.12

#### **meter verification process**

requirements and procedures for verifying the accuracy of the *meter under test* (3.9) by the *master meter* (3.4)

### 3.13

#### **minimum mass flow rate**

$Q_{\min}$

minimum flow rate to which the *meter under test* (3.9) and the *master meter* (3.4) have been qualified to operate in compliance with the required *accuracy* (3.1)

### 3.14

#### **nominal K factor**

##### **NKF**

coefficient entered in the accessory equipment by the *verification officer* (3.23), which relates a frequency (mass) input from the Coriolis transmitter to a mass flow rate

Note 1 to entry: The nominal K factor is expressed in pulses per unit quantity (mass).

### 3.15

#### **repeatability**

proximity of a match among a series of results obtained with the same method on identical test material, under the same conditions (same operator, same apparatus, same laboratory and short intervals of time)

[SOURCE: ISO 22192:2021, 3.39]

**3.16**

**run**

activity during which a quantity of flow is measured and assessed during *meter verification* (3.11)

**3.17**

**run density**

average density recorded during a *run* (3.16)

**3.18**

**run pressure**

average pressure recorded during a *run* (3.16)

**3.19**

**run temperature**

average temperature recorded during a *run* (3.16)

**3.20**

**test service provider**

company that is competent in all provisions of this document and qualified as a *third party* (3.21) to carry out the *meter verification process* (3.12) for custody transfer purposes

**3.21**

**third-party**

person or organization that is unrelated to the manufacturer or supplier of the object of conformity or their customers

**3.22**

**verification flow rate**

flow rate during *meter verification* (3.11) that is between the *minimum mass flow rate* ( $Q_{\min}$ ) (3.13) and the *maximum mass flow rate* ( $Q_{\max}$ ) (3.5) of the *meter under test* (3.9) and the master meter's  $Q_{\min}$  and  $Q_{\max}$  calibrated on oil

Note 1 to entry: The verification flow rate is determined from the data on historical operational flow rates of a bunker tanker/terminal in consultation with a *test service provider* (3.20) during a pre-test meeting.

Note 2 to entry: Historical operational flow rates data show the data on flow rate typically used during bunkering. This data lies between the duty meter's minimum mass flow rate and maximum mass flow rate, accumulated over time during bunkering, from which the verification flow rate is determined.

**3.23**

**verification officer**

person who is competent and qualified as a *third party* (3.21)

## 4 Safety, health and environment during meter verification

4.1 The requirements expected to be observed by all personnel during meter verification are set out in [Annex A](#).

NOTE Relevant local requirements and international safety standards can apply to the personnel of both a bunker tanker/terminal and a test service provider.

4.2 The masters of the bunker tanker and the test service provider shall remain responsible for the safety of their vessel, crew, cargo and equipment at all times and should not permit safety to be prejudiced by the actions of others.

4.3 All parties involved in the meter verification process shall equip themselves with the following minimum personal protective equipment (PPE) safety items:

- safety helmet;

- safety shoes;
- gloves;
- life jacket.

All parties involved in the meter verification shall wear PPE at all times while on board the bunker tanker and at the terminal. They shall equip themselves with multi-gas detectors [hydrogen sulphide (H<sub>2</sub>S) and oxygen (O<sub>2</sub>), carbon monoxide (CO), low explosion limit (LEL)] and use them on site at all times.

**WARNING — The meter verification process shall only be performed by qualified persons. All parties involved in the meter verification process should be able to execute their work safely and efficiently, without any impairment to their personal health.**

## 5 Metrological requirements for master meter

### 5.1 General

This clause specifies a master meter's metrological traceability, calibration and re-calibration requirements in this application and the maintenance of its master meter metrological status.

### 5.2 Master meter requirements

**5.2.1** The master meter shall be calibrated in water in a laboratory.

NOTE Laboratories meeting ISO/IEC 17025 are deemed to be competent with the approved calibration and measurement capability (CMC) to cover the flow measurement.

**5.2.2** For water calibration with direct traceability to an SI unit of mass, the master meter calibrated errors between its evaluated and certified flow rates between the minimum mass flow rate,  $Q_{\min}$ , and the maximum mass flow rate,  $Q_{\max}$ , shall be not more than  $\pm 0,033$  %, which is one-third of the water calibration requirement (level 1) for the duty meter. The water calibration rig shall have a measurement uncertainty of not more than 0,017 %.

The uncertainty components of the master meter shall include the calibration of the meter, meter error, repeatability, reproducibility and zero stability. The components for uncertainty estimation for meter verification under site conditions are listed in the uncertainty budget table as shown in [Table B.1](#).

**5.2.3** The water and oil calibration of the master meter shall meet the combined measurement uncertainty of 0,1 %, which is one-third the combined measurement uncertainty of the duty meter. As evidence to meet this requirement, it is expected that there is a report (or reports) with supporting documents issued by:

- a) a national metrology institute; or
- b) an appointed International Organization of Legal Metrology (OIML) issuing authority.

**5.2.4** The oil calibration shall use bunker fuels or equivalent and shall cover from  $Q_{\min}$  to  $Q_{\max}$ , with a total of five or more flow calibration points evenly distributed from  $Q_{\min}$  to  $Q_{\max}$ . Each flow calibration point shall have three runs.

**5.2.5** In deciding the  $Q_{\max}$  of the master meter for oil calibration, it is important to consider that the verification flow rate shall be within the  $Q_{\min}$  and  $Q_{\max}$  during meter verification.

**5.2.6** The master meter can only be used for meter verification for the flow direction for which it was calibrated.

### 5.3 Maintenance of master meter status

**5.3.1** The master meter shall maintain its performance status and shall undergo annual re-calibration in water. Refer to [Annex B](#) for the uncertainty budget table.

**5.3.2** The master meter shall solely be used for meter verification as specified in this document and shall not be used for custody transfer operations at any time.

## 6 Meter verification process

### 6.1 General

This clause explains the meter verification process, which includes the requirements and procedures for verifying the accuracy of the duty meter by the master meter. The procedure carried out by a third party is applicable for checking the duty meter used for a custody transfer operation.

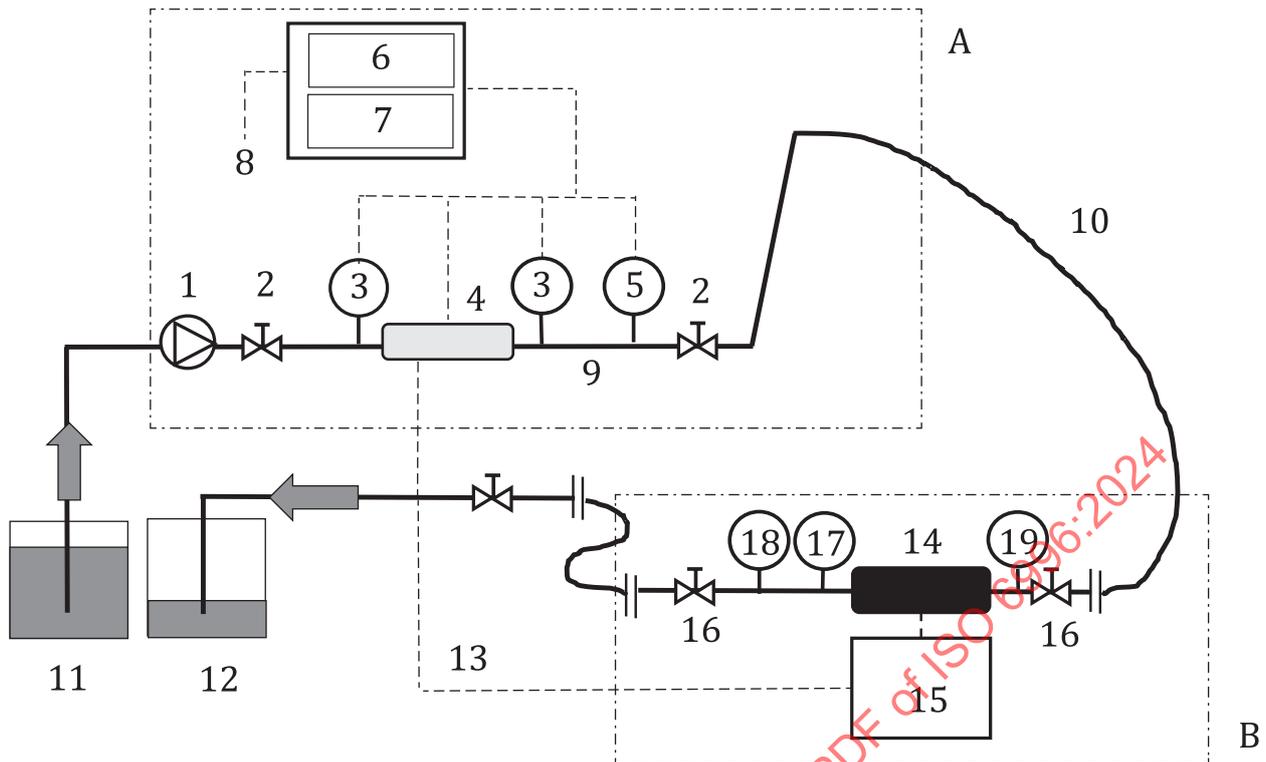
### 6.2 Requirements

The requirements for meter verification are as follows:

- a) Stable flow conditions (e.g. pressure, temperature, density, aeration within an acceptable limit as specified by the meter vendor) shall be established before meter verification can commence.
- b) Meter verification shall be done with a minimum of one verification flow rate.  
NOTE 1 It is good practice to carry out meter verification with more than one verification flow rate, taking into consideration the range of the operational flowrates of the meter under test (MUT).
- c) A minimum of three consecutive runs shall be performed at each verification flow rate.
- d) The measured quantity of each run shall not be less than the master meter and meter under test (MUT)'s certified minimum measured quantity.  
NOTE 2 Legal requirements can apply.  
NOTE 3 Users can refer to the meter's type evaluation certificate or report provided by the meter vendor for details on the certified minimum measured quantity.
- e) Repeatability of all runs shall be no more than 0,12 %.
- f) MUT accuracy (error percentage) shall be no more than  $\pm 0,3$  %.
- g) For meter verification to proceed, the actual verification flow rate for the MUT shall be between its  $Q_{\min}$  and  $Q_{\max}$ , and shall be between the master meter's  $Q_{\min}$  and  $Q_{\max}$  as per oil calibration.
- h) The actual verification flow rate of each run may deviate  $\pm 10$  % of the pre-determined verification flow rate, granted the requirements in [6.2 g\)](#) are met.

### 6.3 Meter verification setup

In a typical meter verification setup, the MUT is connected in series with the master meter skid by means of flexible composite hoses. The master meter will be positioned downstream of the MUT and as close to the MUT as possible to minimize uncertainty in measurement (see [Figure 1](#) and [Figure 2](#)).



**Key**

MFM system components:

- 1 pump
- 2 gate/ isolation valves
- 3 pressure transmitters
- 4 coriolis flow meter (MUT)
- 5 temperature transmitter
- 6 human machine interface
- 7 uninterrupter power supply
- 8 custody printer

Other components:

- 10 flow boom
- 11 delivery cargo tank on test tanker
- 12 receiving cargo tank on test tanker
- 13 MUT data link

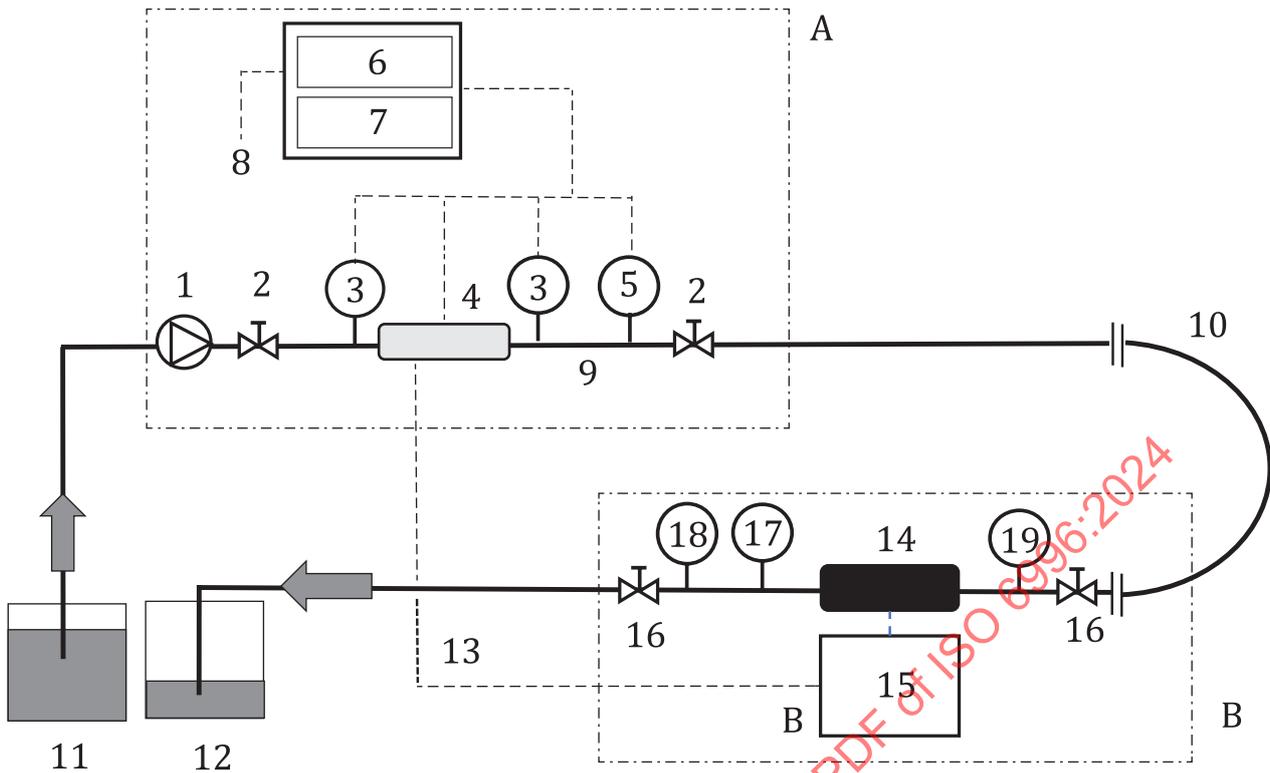
Master meter skid components:

- 14 master meter
- 15 flow computer
- 16 isolation valves
- 17 temperature transmitter
- 18 pressure transmitter
- 19 pressure transmitter (optional for upstream)

Boundaries:

- A mass flow meter system
- B master meter skid

**Figure 1 — Typical schematic diagram of meter verification setup for bunker tanker**



**Key**

MFM system components:

- 1 shore pump
- 2 gate/ isolation valves
- 3 pressure transmitters
- 4 coriolis flow meter (MUT)
- 5 temperature transmitter
- 6 human machine interface
- 7 uninterrupter power supply
- 8 custody printer
- 9 pipeline

Other components:

- 10 pressurized flexible hose
- 11 delivery storage tank
- 12 receiving storage tank
- 13 MUT data link

Master meter skid components:

- 14 master meter
- 15 flow computer
- 16 isolation valves
- 17 temperature transmitter
- 18 pressure transmitter
- 19 pressure transmitter (optional for upstream)

Boundaries:

- A mass flow meter system
- B master meter skid

**Figure 2 — Typical schematic diagram of meter verification setup for land based MFM**

## 6.4 Procedures

### 6.4.1 Pre-test meeting

Prior to the meter verification, a pre-test meeting shall be held in advance with all relevant parties present, including the test service provider and the owner of MUT, in order to facilitate and achieve the successful conduct of the meter verification process.

Some of the tasks required to be performed by the test service provider are listed below but they are not limited to the following:

- a) Work with the bunker tanker or terminal to determine the verification flow rate for meter verification in line with [6.2 g](#)).
- b) Confirm the bunker tanker or terminal's readiness to conduct the meter verification process. The readiness refers to the likelihood of achieving stable flow conditions at the verification flow rate.
- c) Coordinate a suitable test schedule which includes both the test timing and site location.
- d) Determine and identify the product storage tanks to be used for meter verification. It is recommended to ensure sufficient product for meter verification at the verification flow rate and to have sufficient ullage in the receiving tank for the returning loop.
- e) Determine the appropriate and required logistics needed for meter verification (e.g. flexible hoses, reducers, electrical connecting points, wiring diagram of MUT).

### 6.4.2 Steps and actions

Actions for meter verification are as follows:

- a) Record the non-resettable totalizer readings of the MUT at the start and end of the meter verification process.
- b) Check and record the critical performance parameters of the MUT as shown in the checklist in [Annex C](#) before and after meter verification.
- c) Start the pump and circulate the product to both the MUT and the master meter to pack the lines and flow conditioning once the meter verification setup is completed and checked.
- d) Ensure all mechanical connections are secured and free from all possible leaks.
- e) Increase the pumping rate until it reaches the verification flow rate.
- f) Check and ensure all test data or readings (e.g. meter make, model, identification tag, serial number, mass flow rate, temperature, density) necessary for meter verification can be monitored or captured by the master meter system.
- g) Continue flow conditioning for both the MUT and the mass master meter until a stable flow rate can be achieved or seen from variables such as pressure, temperature, density and aeration.
- h) Perform the zero verification on the master meter to the required specified allowable limits set by the test service provider. The master meter pre-set zero shall be verified to be within the prescribed error of 0,2 % of its certified minimum flow rate.
- i) Commence the meter verification of the meter under test once the master meter zero verification is completed.
- j) Perform a minimum of three consecutive runs at each verification flow rate to achieve a repeatability of not more than 0,12 %.
- k) Record the error percentage of the meter under test by averaging the error values of the three runs to achieve not more than  $\pm 0,3$  %, if the repeatability is within the limits specified in step j).

- l) Repeat steps h) and i) for different verification flow rates (if required) and record the error percentage of the MUT respectively.
- m) Abort the meter verification and investigate the causes. Undertake another meter verification after the issues have been resolved if the repeatability is not achieved within the limits in step j).
- n) Proceed to generate a meter verification report as shown in [Annex D](#) upon successful completion of the meter verification.
- o) Clear the verification loop and ensure the product is returned to the respective storage tank.
- p) Power down the master meter verification setup and disconnect the master meter skid from the verification setup. Care shall be taken to prevent possible leakages or spillages from the disconnection process.
- q) Secure the MUT and its MFM system with the respective security seals (i.e. Weights and Measures seal and third-party seals). Issue the meter verification report and the new seal verification report.

## 6.5 Documentation

**6.5.1** The outcome of meter verification is the meter verification report. A copy of the report shall be kept on board the bunker tanker/terminal.

**6.5.2** The meter verification report shall contain all details in [Annex D](#).

**6.5.3** For the purpose of harmonization of the meter verification, the following requirements apply:

- a) The average density and average temperature of three or more consecutive runs shall be captured and recorded in the meter verification report.
- b) The verification flow rate, run density, run temperature and run pressure during meter verification shall be closely monitored for process stability. These parameters shall be within the limits as specified by the manufacturer of the master meter. These meter verification data shall be kept and made available for analysis when required.

## **Annex A** (informative)

### **Safety, health and environment**

#### **A.1 Safety, health and environment and security requirements during meter verification process for duty meter installed at oil terminal**

##### **A.1.1 Safety, health and environment and security policy at the oil terminal**

NOTE Safety, health, environment and security requirements can apply to personnel involved in the master meter verification activity.

Personnel are expected to comply with the in-house rules in each terminal and adhere to applicable international standards and codes of practice (CP), which may be advised by the terminal from time to time while performing work in the terminal or visiting the terminal(s).

##### **A.1.2 Oil terminal in-house rules**

**A.1.2.1** Personnel who are required to work in the terminal shall attend and successfully complete the terminal's safety induction course before they are allowed to perform any work in the terminal premise(s).

**A.1.2.2** Personal protective equipment (PPE) shall be worn appropriately when working in the operation area, complying with terminal SHE requirements.

**A.1.2.3** A method of statement and risk assessment shall be conducted and submitted to the terminal for approval prior to any work activity to be carried out.

**A.1.2.4** Personnel who are required to work in the terminal shall fully comply with the terminal security rules and provisions.

**A.1.2.5** Personnel who are required to drive any form of vehicles are expected to conform fully to the terminal traffic rules and speed limit.

**A.1.2.6** A permit to work (PTW) shall be applied by the personnel carrying out the meter verification activity prior to commencement of activity. The PTW shall be approved by the terminal representative.

**A.1.2.7** Any incident that involves injury to personnel or damage to property or pollution to the environment shall be reported to terminal representative immediately.

##### **A.1.3 Pre-delivery conference**

As meter verification at the terminal is conducted as part of the loading from shore tank to bunker tanker, a pre-delivery conference prior to the commencement of this operation shall be conducted between the representatives of the terminal bunker tanker and bunker surveyor (when engaged) as set out in [Clause 4](#).

**A.2 Safety and field inspection checklist for the meter verification process involving duty meter installed on bunker tanker**

**A.2.1** The master of the bunker tanker is responsible for all safety and oil pollution prevention matters of the bunker tanker and its personnel while the duty meter is undergoing the meter verification process.

**A.2.2** The test service provider is responsible for all safety and oil pollution matters involving meter verification skid during the meter verification process.

Below is a field inspection checklist.

**Field inspection checklist**

Inspector: \_\_\_\_\_ Date: \_\_\_\_\_

This inspection checklist monitors the compliance activities at the MFM verification skid. It also serves as a hazard assessment to current activities. The inspection shall be completed in all the working areas of the facility. Any abnormal findings/issues shall be summarized on the last page. Corrections shall be made and the completion date shall be documented on the summary page. All corrections are expected to be completed in a timely manner.

<b>Emergency preparedness</b>	<b>Yes</b>	<b>No</b>	<b>N/A</b>	<b>Comments</b>
Are all employees aware of the evacuation procedure in the event of an emergency?				

<b>Housekeeping</b>	<b>Yes</b>	<b>No</b>	<b>N/A</b>	<b>Comments</b>
Is the movement restricted within the testing area (i.e. non-essential personnel are clear of the area)?				
Are tools safely secured and stored when not in use?				
Are there any other housekeeping issues that need to be addressed?				

<b>Electrical</b>	<b>Yes</b>	<b>No</b>	<b>N/A</b>	<b>Comments</b>
Are the circuit breakers regularly tripping?				
Are the wirings in the skid in good condition?				
Are all extension cords plugged into a grounded outlet when in use?				
Are there any other electrical issues that need attention at this time?				

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<b>Mechanical</b>	<b>Yes</b>	<b>No</b>	<b>N/A</b>	<b>Comments</b>
Are flanges/hoses properly connected?				
Has the securing/harnessing of hoses been completed?				
Has the leak test been conducted prior to the actual proving?				

<b>Personal protective equipment (PPE)</b>	<b>Yes</b>	<b>No</b>	<b>N/A</b>	<b>Comments</b>
Are PPE available to all test personnel?				
Are lifejackets available for test personnel while crossing the gangway?				
Are there any other PPE issues that need to be addressed at this time?				

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## Annex B (informative)

### Uncertainty budget for meter verification

[Table B.1](#) shows the sources and components which contribute to uncertainty measurement.

**Table B.1 — Uncertainty budget table**

No.	Sources contributing to uncertainty measurement	Components
1	Reference standard and master mass flow meter (MFM) used	a) Linearity, reproducibility, error b) Long term instability c) Laboratory calibration
2	Method and reference materials used (bunker fuel)	a) Process – flow rate instability, synchronised error b) Hydraulic circuit – between master meter and duty meter
3	Environmental conditions (actual flow measurement and site conditions)	a) Repeatability b) Resolution
4	Properties and site conditions of master meter	a) Low flow cut off b) Zero instability c) Error of zero and meter factor
5	Operator	Repeatability