
**Ships and marine technology —
General requirements for
inclinometers used for the
determination of trim and list of LNG
carriers**

*Navires et technologie maritime — Exigences générales relatives aux
inclinomètres utilisés pour la détermination de l'assiette et liste des
méthaniers*



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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 documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2. www.iso.org/directives

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received. www.iso.org/patents

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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.

This document was prepared by Technical Committee ISO/TC 8, *Ships and marine technology*, Subcommittee SC 8, *Ship design*.

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.

Introduction

Inclinometers are used to determine the trim and list of various types of ships floating on the water. In the case of liquefied natural gas carriers (LNG carriers), on which a large quantity of LNG is traded, based on the results of static measurement, determination of trim and list, along with other elements, is particularly important because the measurement of the liquid level of a cargo tank is inevitably affected by the ship's inclination.

This document provides general requirements for the accuracy, installation, calibration and verification of inclinometers used for the determination of trim and list of LNG carriers, but is not intended to preclude the use or development of any other technologies or methods or the revision of the methods presented. Users of this document are encouraged to review, in detail, the latest editions of the publications, standards and documents referenced in this document in order to gain a better understanding of the methods described.

Users of this document should consider the applicable safety or operating practices recommended by organizations, such as the International Maritime Organization (IMO), the International Chamber of Shipping (ICS), the Oil Companies International Marine Forum (OCIMF), the International Group of LNG Importers (GIIGNL) and the Society of International Gas Tanker and Terminal Operators (SIGTTO), or individual operating companies, as well as any other safety or environmental considerations, local regulations or the specific provisions of any contract.

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Ships and marine technology — General requirements for inclinometers used for the determination of trim and list of LNG carriers

1 Scope

This document provides general requirements for the accuracy, installation, calibration and verification of trim and list inclinometers used for the determination of trim and list of LNG carriers for the purpose of measuring on-board cargo level.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60079-0, *Explosive atmospheres — Part 0: Equipment — General requirements*

3 Terms and definitions

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

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

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

3.1

custody transfer measurement system

CTMS

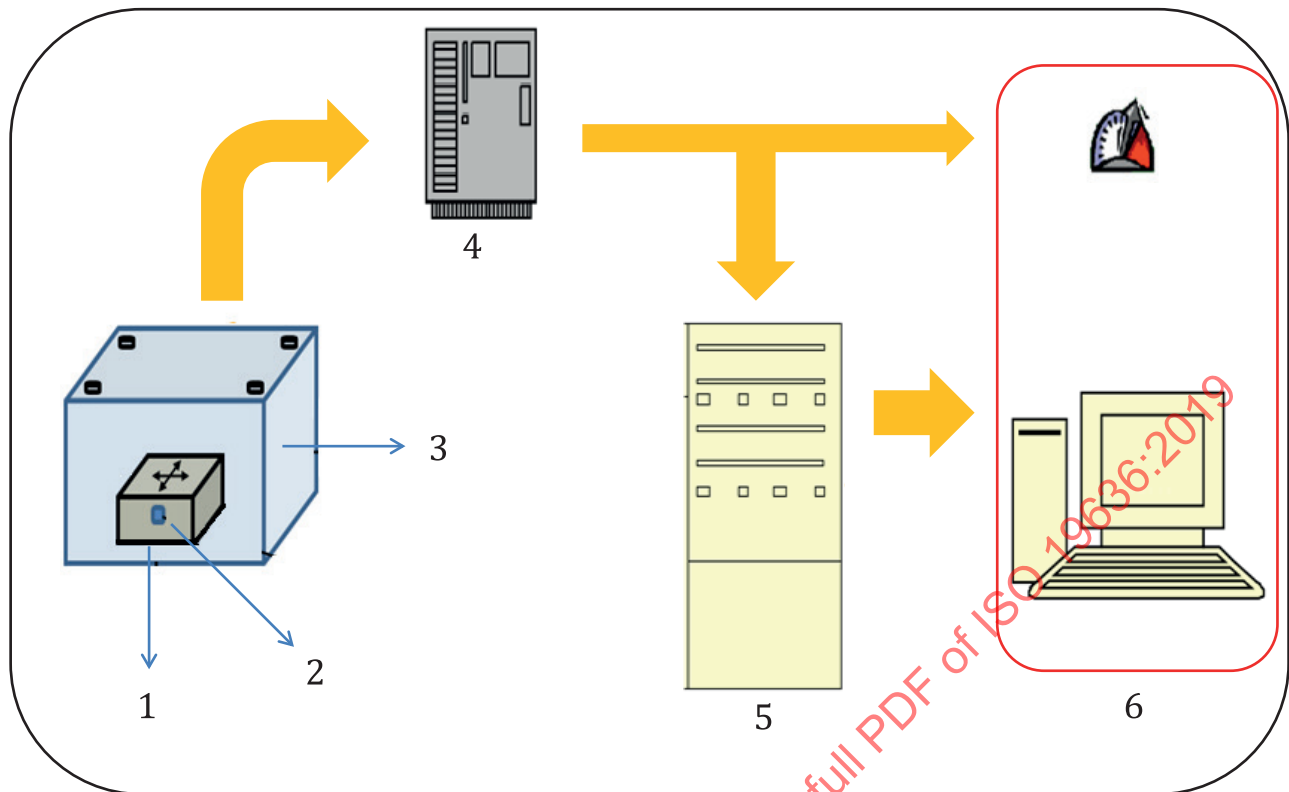
system that processes inputs from an ATG (automatic tank gauge) system, thermometers, pressure gauges, etc., and provides custody transfer measurement information on board, generating documents with regard to custody transfer of LNG

Note 1 to entry: CTMS components include:

- a) automatic level gauge system (radar, microwave, capacitance and float types),
- b) automatic temperature gauge,
- c) automatic pressure gauge,
- d) trim and list indication system

Note 2 to entry: A trim and List inclinometer system can be typically incorporated as part of a CTMS.

Note 3 to entry: See Figure 1.



Key

- | | |
|------------------------------|--------------------------------------|
| 1 trim and list inclinometer | 4 connection/control box |
| 2 sensor | 5 custody transfer system (cts) unit |
| 3 protection box | 6 trim and list indicator |

Figure 1 — Outline of trim and list inclinometer system

3.2

trim and list inclinometer

inclinometer used to determine the trim and list of LNG carriers

3.3

inherent error

error of a trim and list inclinometer when it is tested and verified against a reference standard under controlled conditions as specified by the manufacturer

4 Safety precautions

4.1 Existing safety regulations, standards and classification societies rules

It is the responsibility of the user of this document to consider the applicable safety or operating practices recommended by regulatory agencies and organizations, to establish appropriate health and safety practices and to determine the applicability of regulatory limitations prior to use.

4.2 Equipment precautions

All electric components for the ship's trim and list inclinometer installed in hazardous areas shall meet the requirements of IEC 60079-0 applicable for the specific zone within the hazardous area. They shall conform to the applicable sections of the national and/or international electrical safety standards

and classification societies rules. Trim and list inclinometers shall be maintained in safe operating conditions in accordance with the manufacturers' instructions.

5 Design requirements

5.1 General

A trim and list inclinometer shall meet the design requirement specified in 5.2 to 5.7.

5.2 A Trim and list inclinometer's axes and range

	List axis (X)	Trim axis (Y)
negative (-) angle	list to port	trim by stern (aft)
positive (+) angle	list to starboard	trim by head (forward)
typical range	-5° to +5°	-2° to +2°

An LNG carrier operates typically within a list of $\pm 1^\circ$ and a trim of ± 3 m. A trim and list inclinometer should be chosen to at least cover the normal operation range but preferably to also cover non-typical situations.

5.3 Communication methods

5.3.1 Analogue current interface type

A trim and list inclinometer shall transmit its output signal as from 4 mA to 20 mA current.

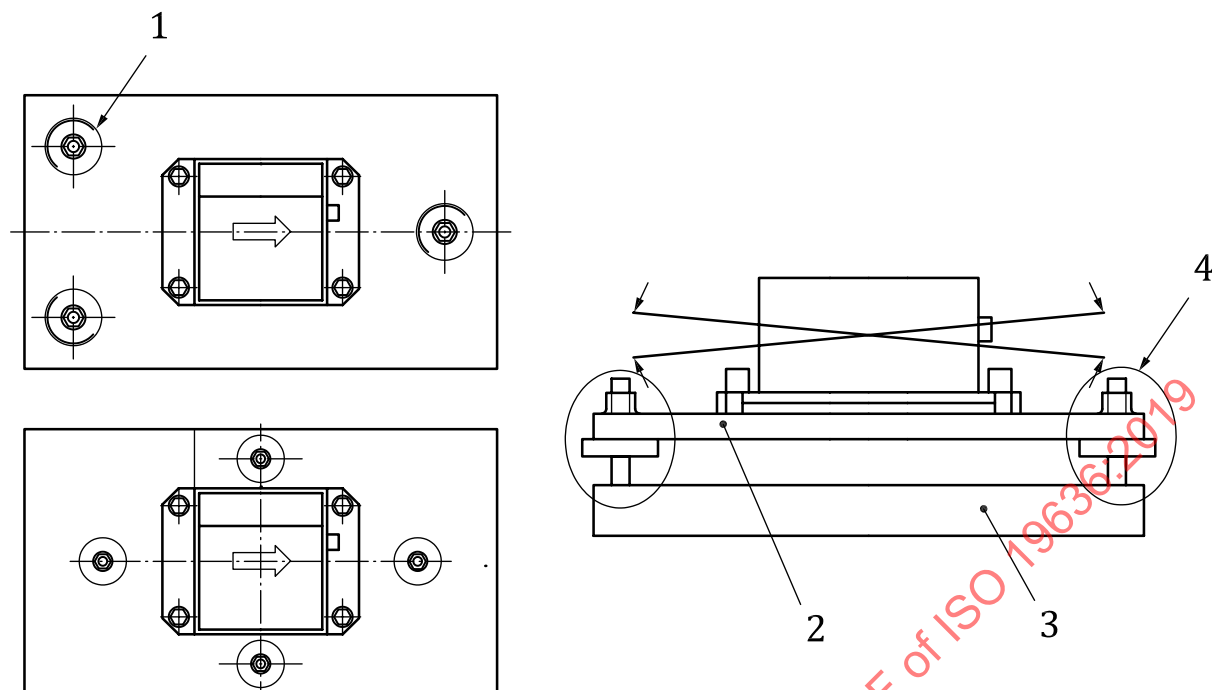
5.3.2 Digital interface type

A trim and list inclinometer is to transmit its output signal as digital protocol as field bus or serial line.

5.4 Levelling of a trim and list inclinometer

It is necessary to be able to make a final adjustment of the levelling for the trim and list inclinometer once it has been installed.

This is typically achieved by placing the sensor on a plate which can be adjusted by screws until it reaches a horizontal position in both axes for the trim and list. See Figure 2.

**Key**

- 1 adjustable screw
- 2 inclinometer's base plate
- 3 hull bottom plate
- 4 adjustable screw or bolt/nut

NOTE The base plate of a trim and list inclinometer is adjustable by adjusting screws or bolts/nuts in two axes.

Figure 2 — Arrangement of 3 or 4 adjustable screws for a Trim and List inclinometer

5.5 A trim and list inclinometer's protection box

The containment box includes a trim and list inclinometer and all the electrical and mechanical parts necessary for the installation and setup. The box shall be powered by electrical supply voltage and signal communication lines are included.

If the trim and list inclinometer is installed out of safety zones, the trim and list inclinometer and its associated devices, such as intrinsic safety (IS) isolators and anti-pressure explosion for signal, power supply and terminal units, shall be contained in a metal box in order to protect them from damage, heat and shock and to provide security.

5.6 Sealing, security and unsealing

A trim and list inclinometer system shall provide means to prevent unauthorized adjustment or tampering. Specifically, a trim and list inclinometer system used in custody transfer applications shall provide security to allow sealing of the calibration adjustment.

The security may include a physical seal. Once the trim and list inclinometer's protection box has been sealed, it shall not be unsealed until the next scheduled calibration/inspection.

5.7 Marking serial number

The serial number of a trim and list inclinometer shall be clearly marked on the cover of the trim and list inclinometer and on the protection box by the manufacturer.

6 Installation

6.1 General

A trim and list inclinometer shall be installed in accordance with the manufacturer's instructions with a third party surveyor, or marine classification societies requirements.

The accuracy of trim/list measurement by a trim and list inclinometer is affected by the inherent error of the trim and list inclinometer. The error can happen due to installation (for example, stability and location), interface error, the effect of changes in operating conditions, the ship's motion and, most of all, the ship's bending (hogging and sagging).

The trim and list inclinometer shall be installed with the correct alignment for the x and y axes at flat plate to the longitudinal and transverse.

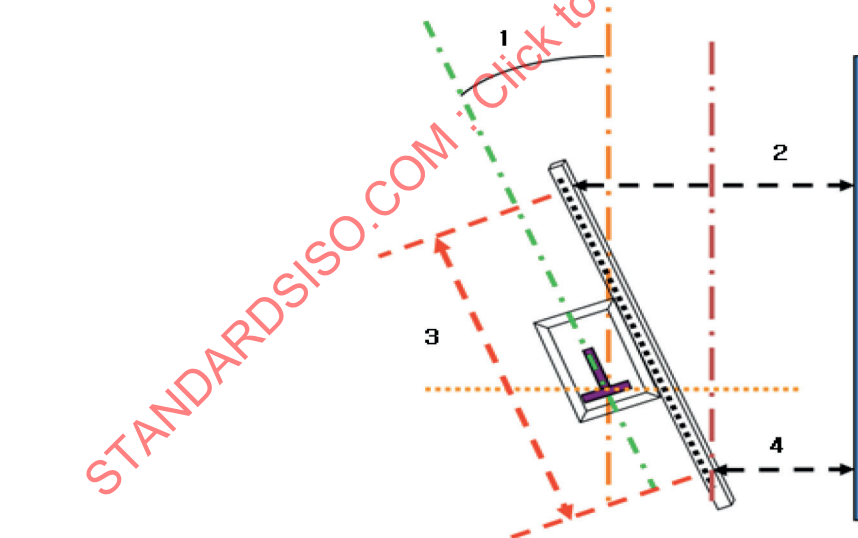
6.2 Installation of a trim and list inclinometer

A trim and list inclinometer is typically placed in an accommodation area, machinery room on deck, passage way and cofferdam area which are adjacent to ship's mid and centre line.

6.3 Alignment of a trim and list inclinometer

The trim direction of the inclinometer shall be parallel to the ship's longitudinal line. If the trim direction is correct, the list direction will also be correct.

The direction of longitudinal bulkheads which run parallel to the flat side of the ship shall be considered the same as the ship's longitudinal direction. The trim direction of the inclinometer shall be matched to longitudinal direction. See Figure 3.



Key

- 1 θ
- 2 D_f
- 3 D_r
- 4 D_a

Figure 3 — Alignment measurement for the trim and list inclinometer

$$\Delta D = D_a - D_f$$

$$\Delta D = D_r \times \sin(\theta)$$

where

D_r is the length of rule

D_a is the measured length at aft point of rule

D_f is the measured length at forward point of rule

θ is the alignment deviation

when

$$D_r = 500 \text{ mm and } \Delta D = 35 \text{ mm } (D_a - D_f)$$

$$\text{alignment deviation } \theta = 4^\circ$$

$$\sin(\theta) = 35/500$$

$$\sin(\theta) = 0,07$$

That means it is apparently possible to align the inclinometer within 4° deviation.

NOTE See [Annex A](#) (calculation and effected error of alignment for trim and list inclinometers) for more information.

6.4 Alignment of a trim and list inclinometer — Ship at dry dock

It is desirable to install a trim and list inclinometer when a ship's trim and list are at a minimum, for instance, when a ship is stationed at dry dock.

Dry dock inclination shall be ensured prior to installation of a trim and list inclinometer.

If the dry dock inclination is angle " 0° ", the ship shall be on even keel (trim angle zero " 0° ") and upright (list angle zero " 0° ").

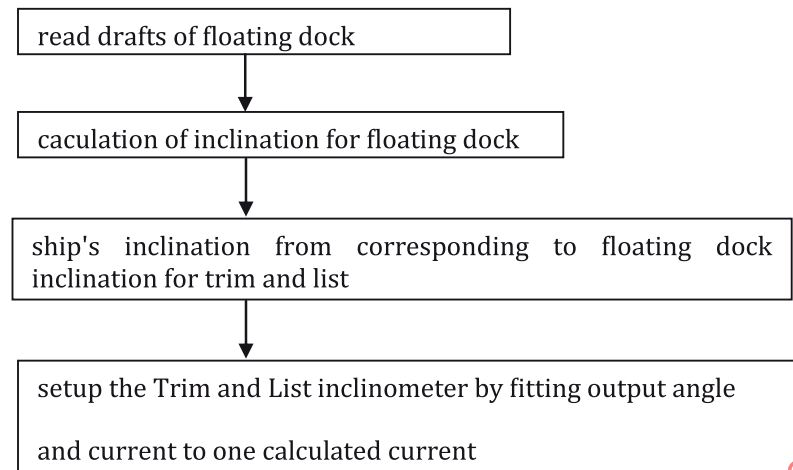
Trim axis: angle zero " 0° " or current 12 mA for output signal from the trim and list inclinometer.

List axis: angle zero " 0° " or current 12 mA for output signal from the trim and list inclinometer.

If the dry dock inclination is not at angle " 0° ", the dry dock slope shall correspond to the ship's lying angle.

6.5 Installation of a trim and list inclinometer — Ship at floating dock

A trim and list of a ship shall be calculated from a floating dock's inclination and corresponding currents for the trim and list respectively shall be calculated. See Figure 4.



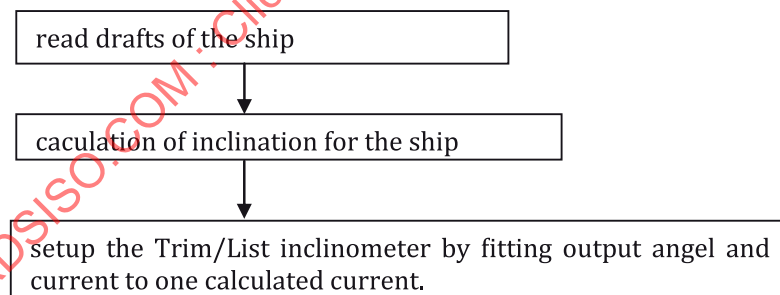
trim angle of floating dock = $\tan^{-1}(\text{forward draft} - \text{aft draft})/\text{LBDM}$ for forward & aft
 list angle of floating dock = $\tan^{-1}(\text{port draft} - \text{starboard draft})/\text{LBDM}$ for port & starboard
 where LBDM is the length between draft mark

Figure 4 — Process of a trim and list inclinometer setup in floating dock

6.6 Installation of a trim and list inclinometer — Ship anchored or moored

A trim and list inclinometer shall be installed when the sea is calm, and the ship's motion, especially bending (hogging and sagging) shall be minimized.

The inclination of the ship and the corresponding angle and current for the trim and list respectively shall be calculated. See Figure 5.



trim angle of the ship = $\tan^{-1}(\text{forward draft} - \text{aft draft})/\text{LBDM}$ for forward & aft
 list angle of the ship = $\tan^{-1}(\text{port draft} - \text{starboard draft})/\text{LBDM}$ for port & starboard
 (= ship's breadth)

where LBDM is the length between draft mark

Figure 5 — Process of a trim and list inclinometer setup when a ship is anchored or moored

The actual trim and list shall be read/calculated with 6 points of draft (forward, middle, after for each port and starboard sides).

Stem and stern corrections for distance between draft mark readings and perpendiculars shall be calculated.

7 Accuracy

7.1 General

The calibration reference shall be traceable to a national metrology institute. The uncertainty of the certified reference shall not exceed the tolerance described below, with calibration correction applied.

7.2 Uncertainty of a Trim and List inclinometer's inherent error - Factory acceptance test (FAT)

The determination of the inherent error is typically done during a Factory Acceptance Test (FAT).

During testing of the trim and list inclinometer prior to installation on board the ship, the uncertainty of the inherent error shall be as follows:

- trim axis: less than $\pm 0,02^\circ$;
- list axis: less than $\pm 0,05^\circ$.

FAT is to verify the accuracy of a trim and list inclinometer at the manufacturer's shop or laboratory before delivery to the ship.

The reference instrument used for the FAT shall have individual calibration certificates directly traceable to National Standards.

The FAT procedure data shall be accurately recorded on each serialized data sheet. The trim and list inclinometer has its own serial number. All identification and testing data requirements shall be answered completely.

7.3 Uncertainty of reference standard -Site acceptance test (SAT)

The site acceptance test (SAT) is to verify the accuracy of the setup of a trim and list inclinometer at the ship's actual inclined condition when the ship is anchored or moored, and the signal matching and interface of trim and list inclinometer system on board after installation of the trim and list inclinometer.

The trim and list inclinometer setup shall be tested when the sea is calm. The ship's motions, bending (hogging and sagging) and ship's inclination shall be minimized.

Determination of the interface error is typically done during SAT.

For testing the trim and list inclinometer on board the ship, the uncertainty of the inherent error shall be kept as follows:

- trim axis: less than $\pm 0,02^\circ$;
- list axis: less than $\pm 0,05^\circ$.

The output signals (angle and current) of the trim and list inclinometer shall be simulated to CTMS by a calibrating instrument.

For analogue current interface type, current signals typically (4 mA, 8 mA, 12 mA, 16 mA, 20 mA) are simulated to CTMS for trim and list interface.

Error of digital interface type is designed with the range of angle.

For the test of the trim for the interface to CTMS, the trim degree shall be calculated to meter based on the ship's length between perpendiculars (LBP).

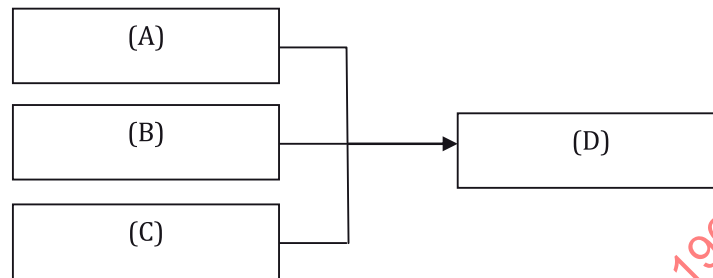
NOTE Trim meter of the ship = $\tan(\text{trim angle of the ship}) \times \text{ship's LBP}$.

EXAMPLE When the ship's trim angle is $0,5^\circ$ and its LBP is 250 m, $\tan(0,5) \times 250 = 2,18$, the ship's trim meter is 2,18 m.

The SAT procedure data shall be accurately recorded with the serial number on the data sheets. Each serialized unit has its own data sheet. All identification and testing data requirements shall be answered completely.

7.4 Integrated overall accuracy

Integrated accuracy is covered from a trim and list inclinometer's inherent error to the indication of trim and list value's error on CTMS for trim and list inclinometer system overall. See Figure 6.



Key

- A trim and list inclinometer's maximum inherent error
- B signal matching/interface maximum error
- C alignment/installation maximum error

D integrated overall accuracy of trim and list inclinometer system, $\sqrt{A^2 + B^2 + C^2}$

NOTE The value of alignment error, C in the above equation, is omitted if the trim and list inclinometer is properly setup at the time of installation.

Figure 6 — Integrated overall accuracy of a trim and list inclinometer system

For integrated accuracy of a trim and list inclinometer system on board the ship, the uncertainty of the overall error shall be as follows:

- trim axis: $\pm 0,02^\circ$;
- list axis: $\pm 0,05^\circ$.

8 Verification test and certification

8.1 General

Accuracy of the trim and list inclinometer system shall be verified and certified by a third party (sworn) surveyor at the manufacturer's shop or laboratory before their shipment. The trim and list inclinometer is shipped as FAT, and after it is installed on the ship as SAT.

This process normally involves verifying the accuracy of the trim and list inclinometer system and, if necessary, the trim and list inclinometer shall be reset/adjusted against a calibration reference.

Adjustment shall normally be made by an authorized service engineer with results certified by a third party qualified surveyor.

8.2 Visual examination

The trim and list inclinometer under test shall be carefully examined for physical defects, verifying that the unit conforms to the mechanical and visual quality agreed between the manufacturer and purchaser.

The appearance of the trim and list inclinometer shall be examined for any apparent damage.

8.3 Verification test

The accuracy of a trim and list inclinometer shall be verified by the manufacturer using an optical (or electronic) measurement equipment calibrated by a competent calibration and test facility.

The integrated overall accuracy of a trim and list inclinometer shall be verified by a third party (sworn) surveyor in the following sequence:

- inherent error verified at the manufacturer's shop or laboratory;
- installation and setup verified on board;
- signal matching and interface error of trim and list inclinometer to CTMS verified on board.

The serial number of a trim and list inclinometer on board shall be checked to confirm that the correct gauge was tested at the FAT for the ship. The serial number shall be traceable.

8.4 Sealing

After setup verification of a trim and list inclinometer, its protection box shall be sealed by a third party (sworn) surveyor.

8.5 Certificate

After verification of a trim and list inclinometer, the accuracy certificate shall be issued by a third party (sworn) surveyor.

The certificate shall include the manufacturer model, type, serial number, measuring range, seal number and integrated overall accuracy.