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ISO 25197

Second edition
2020-04

Small craft — Electrical/electronic control systems for steering, shift and throttle

Petits navires — Systèmes électriques/électroniques pour le contrôle de la direction, de l'inverseur et des gaz

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Contents

Page

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 (see 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 (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

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 188, *Small craft.*

This second edition cancels and replaces the first edition (ISO 25197:2012), which has been technically revised.

The main changes compared to the previous edition are as follows:

— the terms and definitions have been revised to give coherency with other standard definitions; new terms, such as input device and output device, have been introduced;

— the figures have been revised to clarify the concepts illustrated;

— 7.2, on portable helms, has been revised to make it coherent when an electric propulsion motor is used;

— 9.1 has been revised to include the fail-safe mode and the alarm policy;

— the main change is in 10.1: the request to use three different samples for all tests (except for EMC test) has been deleted because it would have involved a great expense without having significant improvement; only one sample is used for all tests described on the subsequent subclauses;

— the durability test on joystick described in 10.4 has been made an operational test;

— Table 1 in 10.5.1 has been updated introducing the column “immersion” to handle test on immerged components;

— in 10.5.2, all ways to conduct the salt mist test, based on different standards, have been homogenized;

— in 10.7, the shock test has been revised;

— in 10.8, the free fall test has become the drop test with the addiction of the UV test;

— the UV test, described in 10.9, has been clarified;

— in 10.10, there are many changes due to the revision of IEC 60533 and the forthcoming release of IEC 62742; to avoid any direct link to those standards, all tests previously required by IEC 60533 have been embedded and all standards cited have been added to the normative reference list.

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.

Small craft — Electrical/electronic control systems for steering, shift and throttle

1 Scope

This document establishes the requirements for the design, construction and testing of electrical/electronic steering, shift and throttle systems and dynamic positioning control systems, or combinations thereof, on small craft of up to 24 m length of hull.

This document does not apply to electric trolling motors and autopilot systems on sailing craft.

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.

ISO 4892-1:2016, *Plastics — Methods of exposure to laboratory light sources — Part 1: General guidance*

ISO 4892-2:2013, *Plastics — Methods of exposure to laboratory light sources — Part 2: Xenon-arc lamps*

ISO 4892-3:2016, *Plastics — Methods of exposure to laboratory light sources — Part 3: Fluorescent UV lamps*

ISO 4892-4:2013, *Plastics — Methods of exposure to laboratory light sources — Part 4: Open-flame carbon-arc lamps*

ISO 8846:1990, *Small craft — Electrical devices — Protection against ignition of surrounding flammable gases*

ISO 8848:1990, *Small craft — Remote steering systems*

ISO 10133:2012, *Small craft — Electrical systems — Extra-low-voltage d.c. installations*

ISO 10240:2004/Amd1:2015, *Small craft — Owner's manual*

ISO 10592:1994, *Small craft — Hydraulic steering systems*

ISO 11591:2019, *Small craft — Field of vision from the steering position*

ISO 13297:2014, *Small craft — Electrical systems — Alternating current installations*

ISO 16750-2:2012, *Road vehicles — Environmental conditions and testing for electrical and electronic equipment — Part 2: Electrical loads*

ISO 16750-3:2012, *Road vehicles — Environmental conditions and testing for electrical and electronic equipment — Part 3: Mechanical loads*

ISO 16750-4:2010, *Road vehicles — Environmental conditions and testing for electrical and electronic equipment — Part 4: Climatic loads*

ASTM B117:2016, *Practice for operating salt spray (fog) apparatus*

IEC 60068-2-27:2008, *Environmental testing — Part 2-27: Tests — Test Ea and guidance: Shock*

IEC 60068-2-52:2017, *Environmental testing — Part 2-52: Tests — Test Kb: Salt mist, cyclic (sodium chloride solution)*

IEC 60092-507:2014, *Electrical installations in ships — Part 507: Small vessels*

IEC 60945:2002, *Maritime navigation and radiocommunication equipment and systems — General requirements — Methods of testing and required test results*

IEC 61000-4-2:2008, *Electromagnetic compatibility (EMC) — Part 4: Testing and measurement techniques — Section 2: Electrostatic discharge immunity test — Basic EMC publication*

IEC 61000-4-3:2006+Amd1:2007+Amd2:2010, *Electromagnetic compatibility (EMC) — Part 4: Testing and measurement techniques — Section 3: Radiated, radio frequency, electromagnetic field immunity test*

IEC 61000-4-4:2012, *Electromagnetic compatibility (EMC) — Part 4: Testing and measurement techniques — Section 4: Electrical fast transient/burst immunity test — Basic EMC publication*

IEC 61000-4-5:2014+Amd1:2017, *Electromagnetic compatibility (EMC) — Part 4: Testing and measurement techniques — Section 5: Surge immunity test*

IEC 61000-4-6:2013, *Electromagnetic compatibility (EMC) — Part 4: Testing and measurement techniques – Section 6: Immunity to conducted disturbances, induced by radio-frequency fields*

IEC 61000-4-11:2004+Amd1:2017, *Electromagnetic compatibility (EMC) — Part 4: Testing and measurement techniques — Section 11: Voltage dips, short interruptions and voltage variations immunity tests*

IEC 61000-4-16:2015, *Electromagnetic compatibility (EMC) — Part 4: Testing and measurement techniques — Section 16: Test for immunity to conducted, common mode disturbance in the frequency range 0 Hz to 150 KHz*

3 Terms and definitions

For the purposes 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 https://www.iso.org/obp

— IEC Electropedia: available at http://www.electropedia.org/

3.1
electrical steering system
electronic steering system
all components, including CPU (central processing unit) and cable harnesses, from the manual steering *input device* (3.11) up to and including the device [*actuator* (3.22) or electrical motor] regulating the rudder or propulsion unit steering angle

Note 1 to entry: It includes the *joystick* (3.15) and components, i.e. GPS antennas for dynamic positioning, if installed.

3.2
dynamic-positioning system
computer-controlled system to automatically maintain a craft's position and heading by using the craft's own propulsion systems with or without the assistance of bow or stern thrusters

3.3
electrical shift and throttle system
electronic shift and throttle system
all components, including CPU (central processing unit) and cable harnesses, from the shift and throttle *input device* (3.11) up to and including the device controlling the shift and speed of engines

3.4
ignition-protected equipment
electrical equipment designed and tested for use in explosive atmospheres without igniting surrounding flammable gases

3.5
nominal voltage
commonly used voltage, such as 12 V, 24 V, or 36 V DC

3.6
manoeuvring mode
reduced power mode for manoeuvring, determined by the manufacturer of the steering/control systems

3.7
cruising mode
power mode above *manoeuvring mode* (3.6) up to full power, determined by the manufacturer

3.8
X axis
direction of a craft fore or aft, longitudinally

3.9
Y axis
direction of a craft port or starboard, transversely

3.10
Z axis
axis perpendicular to the X-Y plane

3.11
input device
device that transmits commands to a system

3.12
output device
device that operates from commands coming from an *input device(s)* (3.11)

EXAMPLE Electromechanical or electrohydraulic *actuator* (3.22).

3.13
control head
operator *input device* (3.11), other than a steering wheel, for the simultaneous control of steering and *propulsion* (3.20)

EXAMPLE *Joystick* (3.15), track-ball or slide levers.

3.14
control lever
operator *input device* (3.11) for the control of *thrust* (3.23) and/or *propulsion* (3.20)

3.15
joystick
operator *input device* (3.11) for the simultaneous control of *thrust* (3.23), steering and *propulsion* (3.20)

3.16
helm station
location from which steering, *propulsion* (3.20) and *thrust* (3.23) can be controlled

3.17
multiple helm stations
more than one location in the boat from which steering, *propulsion* (3.20) and *thrust* (3.23) can be controlled

3.18
command station
helm station (3.16) location that is in active control

3.19
portable helm
helm providing a combination of shift or throttle or steering, not permanently affixed to the craft's structure, communicating with the system through wired or *wireless* (3.24) means

3.20
propulsion
component or components of *thrust* (3.23) that permit a craft's movement in any direction

Note 1 to entry: Examples of propulsion-generating devices include outboards, stern drives, pod drives, jet drives, inboards and thrusters.

3.21
radio-frequency
RF
frequency within the range of frequencies suitable for utilization in radio communication

3.22
actuator
electromechanical, electropneumatic and/or electrohydraulic device that converts an electrical signal into a mechanical displacement

3.23
thrust
propulsive force from craft's propulsion system, including bow or stern thrusters or a combination thereof in order to move or rotate the craft

3.24
wireless
mode of communication, monitoring and/or control through the use of electromagnetic, acoustic or optical transmission through atmospheric space

3.25
damp area
area where moisture is either permanently or intermittently present

EXAMPLE Bilge, head, galley.

3.26
wet area
area exposed to weather

3.27
interior
protected area inside the craft

3.28
immersion
area totally or partially under water

3.29
EUT
equipment under test
representative system, or part of it, used on tests

3.30
performance criterion
standard by which the functional status of an *EUT* (3.29) during and after testing is judged

3.31
failure modes and effects analysis
FMEA
procedure in product development and operations development for analysis of potential failure modes

3.32
fail-safe mode
device or feature which, in the event of failure, responds in a way that causes no harm, or minimizes the harm, to other devices, and causes no danger, or minimizes the danger, to personnel

3.33
trolling motor
electric propulsion unit that produces less than 500 N *thrust* (3.23), that includes an electric motor, propeller and controls

3.34
autopilot system
system used to control the craft without constant hands on control by a human operator

4 General requirements

4.1 All electrical/electronic components shall be designed to withstand a reversed polarity connection of the power leads. This shall not render the component inoperable when subsequently connected to the power correctly.

NOTE Replacement of an external fuse, after reverse connection of power supply, is acceptable.

4.2 All electrical/electronic components shall be designed with reverse polarity protection from internal surges.

4.3 DC systems shall comply with ISO 10133:2012. AC systems shall comply with ISO 13297:2014. An acceptable alternative to ISO 10133:2012 and ISO 13297:2014 is given in IEC 60092-507:2014.

4.4 The system shall be energized whenever the propulsion engine(s) are running.

4.5 The system, except for dynamic positioning and displays, shall be fully operational within 5 s after being turned on (powered).

4.6 In multi-installed engine control systems, the craft manoeuvrability shall be possible in presence of a control system fault. System performance may be at a reduced speed.

4.7 Each helm station shall give a visual indication when active. A main steering position shall be designated and meet the applicable requirements of ISO 11591:2019, with the location included in the owner's manual.

4.8 Each helm station shall, by visible and/or audible means, alert the operator when the system enters the fail-safe mode.

4.9 The A-weighted sound pressure level of an audible alarm 1 m from the command station shall be at least 75 dB, but not greater than 85 dB. Systems incorporating a mute feature shall maintain the visual alert as long as the failure persists.

If an audible-only alert system is utilized, muting of the alarm is not allowed.

4.10 Instructions for proper installation and use of the steering system shall be made available by the manufacturer.

4.11 Operational characteristics, instructions and warnings for proper use shall be described in the owner's manual and/or by on-product labelling.

4.12 With the exception of an optional temporary override for emergency situations, it shall only be possible to start propulsion equipment in neutral.

NOTE This includes any equipment that drives the propeller or water-jet drive.

4.13 The steering, shift and throttle actuators shall react/adjust input on a physical input command within 0,5 s.

4.14 Steering wheels shall comply with the requirements of ISO 8848:1990.

4.15 Hydraulic systems shall comply with the requirements of ISO 10592:1994.

4.16 Electrical components intended to be installed in petrol engine or petrol tank compartments shall be ignition-protected in accordance with ISO 8846:1990.

4.17 A risk identification/analysis, using an established method, shall be carried out for each system design.

EXAMPLES Failure modes and effects analysis (FMEA), fault-tree analysis (FTA).

Risk identification and functional safety may be carried out as given in the relevant part of IEC 61508:2010.

4.18 Systems that provide both cruising and manoeuvring modes shall provide an indication to the operator at the command station of which mode the system is in, and shall not change modes without input from the operator.

5 Control head

5.1 Control head operation is permitted for both cruising-mode and manoeuvring-mode operation.

5.2 In manoeuvring mode, the control head position shall return to the neutral X, Y and Z axis when the operator's grip is released. See Figure 1. A visual indication when propulsion system is in neutral position shall be provided at the active helm station.

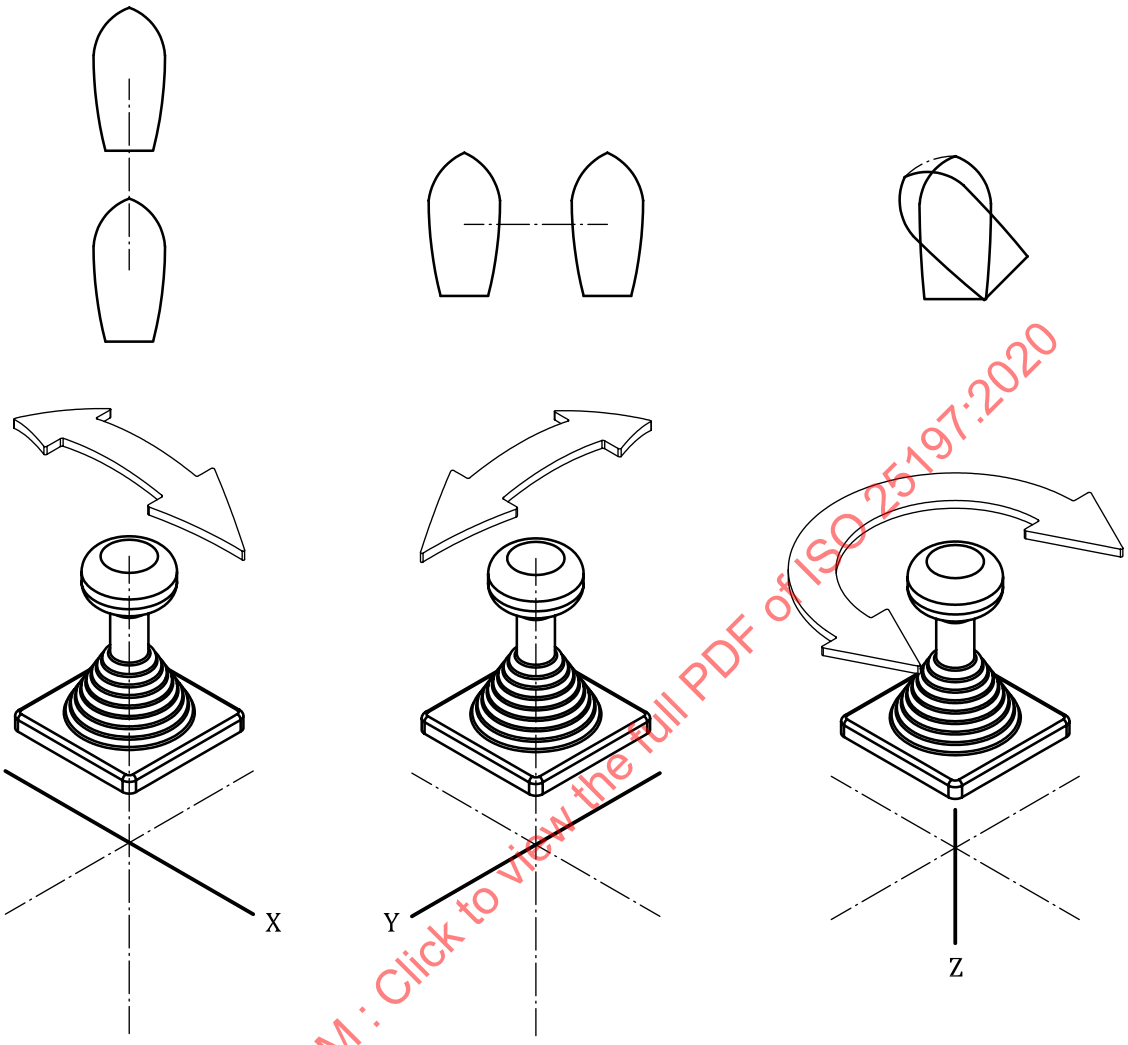


Figure 1 — Craft behaviour on joystick movements

5.3 For operation in the cruising mode, when grip on control head is released, the engine need not return to a low RPM (revolution per minute) or a manufacturer-determined idle state.

5.4 Releasing the control head in the manoeuvring mode to neutral position shall result in:

— a disengaged transmission or water-jet bucket in the neutral position;

and

— a manufacturer-determined idle state or electric motors in the stopped state.

5.5 The craft shall move in the same direction as the control head is oriented relative to the craft.

5.6 Portable helms shall clearly indicate their orientation relative to the craft.

5.7 If the control head includes a rotation function, the control head activation, clockwise or counter-clockwise, shall result in rotating the craft in the same direction.

6 Command station transfer

Transfer of command from one station to another shall be completed at the helm station intended to be active.

7 Portable helm station controls

7.1 Portable helm station controls shall be restricted to permit use only when the manoeuvring mode is selected.

7.2 Loss of communication or malfunction of the portable helm station control shall result in the following:

— combustion propulsion engine(s) shall return to idle, if installed;

— full stop of electric motor(s), if installed;

— disengagement of the transmission when applicable.

The operator shall be notified of the loss of communications and the system shall not prevent transfer to another helm station.

7.3 A warning label on the portable helm or where the device is stored or charged prior to use shall be provided to advise the operator of the following warnings through the use of text or applicable ISO graphical symbols:

— keep proper lookout;

— hold on to prevent falling, boat may move suddenly;

— read owner's manual for safe use of the system (ISO 7000-0790).

7.4 For a wireless device, the signal strength shall be displayed at the portable control or an audible warning signal shall alert the operator that the signal is weak and control is about to be lost.

7.5 A wireless device shall only be able to control the boat of origin.

7.6 A wireless portable helm control shall have an indication of its electrical-charge status. The device shall prevent activation when the charge is insufficient to maintain a connection for 15 min without loss of the wireless communication link.

7.7 A wireless portable helm control shall notify the operator when the device is 15 min from deactivation due to insufficient charge.

8 Dynamic-positioning system (DPS)

8.1 It shall only be possible to activate DPS systems manually.

8.2 DPS systems shall have a display at the craft main helm station for the visual DPS precision value.

8.3 The following warnings shall be conveyed to the operator upon activation of the DPS through the use of applicable ISO graphical symbols or the following text:

— boat is considered underway;

— keep proper lookout;

— stay out of water, propellers are spinning;

— hold on to prevent falling, boat can move suddenly;

— read owner's manual for safe use of the system (ISO 7000-0790).

8.4 Activation shall only be possible if the DPS precision value is within the manufacturer-set limits.

8.5 If the dynamic-positioning (autonomous) mode is activated and the DPS precision value is out of the manufacturer-set limits at any time, the control system shall alert the operator visually and audibly of disengagement of the DPS.

8.6 Maximum allowable envelope/radius and heading deviation shall be manufacturer-set, not adjustable by the operator.

8.7 Maximum engine speed for dynamic positioning shall be manufacturer-set, not adjustable by the operator.

8.8 Helm stations not equipped with a display screen shall be labelled with the same warnings as in 8.3.

9 Failure modes and responses

9.1 Loss of operation

9.1.1 In the event of a command station failure, in a single station system, the system shall:

— switch to a fail-safe mode;

— alert the operator audibly that the command station is not working.

NOTE System performance can be at a reduced level.

9.1.2 In the event of a command station malfunction in a multiple helm station system, the system shall:

— switch to a fail-safe mode;

— not prevent transfer to, or operation from, other helm stations;

— alert the operator audibly that the failed command station is not working.

9.1.3 In the event of loss of steering control affecting only one engine in a multi-engine installation, the system shall still be capable of steering the boat.

9.1.4 In the event of loss of steering control in a single-engine rudder or strut installation, emergency control of the rudder shall be possible.

9.2 Loss of computer command logic

The system shall notify the operator of a command logic loss or a malfunction in its computer command logic.

10 Test requirements

10.1 General test requirements

A representative sample of each electronic and electromechanical component, as sold, shall be environmentally and mechanically tested to verify compliance with this document.

10.2 Steering

10.2.1 The complete system (mechanical and electrical/electronic components) shall be designed to withstand the load tests specified in this subclause. A new system can be used for each test. For clarification purposes, a cycle is defined to begin with the command from an input device sufficient to cause the steering system to move the output device(s) starting from neutral to hard over, to opposite hard over and back to original starting position. A malfunction of any type constitutes a failure.

10.2.2 Durability test: The steering actuator shall travel through no less than 80 % of its range as defined by the manufacturer for 100 000 cycles at a minimum rate of 10° of steering angle per second under an opposing force/torque equivalent to at least the maximum steering force declared by the steering manufacturer.

The system shall be configured as it is intended to be used in a craft application.

10.2.3 High-load test: The steering actuator shall withstand a force equal to two times the force used in 10.2.2 when tested at mid travel in opposing directions.

10.2.4 The tests in 10.2.2 and 10.2.3 shall be conducted at the high ambient operating temperatures in Table 1, ±2 °C, and at 120 ± 2 % of nominal voltage.

10.2.5 The tests in 10.2.2 and 10.2.3 shall be conducted at the low ambient operating temperatures in Table 1, ±2 °C, and at 120 ± 2 % of nominal voltage.

10.2.6 Following these tests, the steering actuator shall continue to operate without failure within the original parameters specified by the manufacturer. Failure includes loose parts, cracks, wear outside of tolerance, or impaired functionality.

10.3 Control lever(s) for separate or combined shift and throttle functions

10.3.1 The system shall be designed to withstand the load tests defined in this subclause. A new system may be used for each test. For clarification purposes, a cycle is defined to begin with the command from an input device sufficient to cause the propulsion control system to move the output device(s) as follows:

— neutral/idle to ahead/idle (full stroke of the shift output device to ahead);

— ahead/idle to ahead/full RPM (full stroke of the throttle output device);

— ahead/full RPM to ahead/idle;

— ahead/idle to neutral/idle;

— neutral/idle to astern/idle (full stroke of the shift output device to astern);

— astern/idle to astern/full RPM (full stroke of the throttle output device);

— astern/full RPM to astern/idle;

— astern/idle to neutral/idle.

10.3.2 The system shall withstand a 75 000 cycle load test when subjected to the loads defined as follows.

The shift output device shall be subjected to a load of a minimum of 67 N, from neutral to near full stroke, with an over-stroke load of a minimum of 178 N applied to the shift device within the last 20 % of the shift stroke, i.e. the shift load will change from a minimum of 67 N at 80 % of the full shift stroke to a minimum of 178 N at full stroke. The load can either ramp up to a minimum of 178 N or be applied as a step function. A load increasing from 22 N at idle to a minimum of 111 N at full stroke shall be applied to the throttle output device.

10.3.2.1 The test shall be conducted at the high ambient operating temperatures in Table 1, ±2 °C, and at 120 ± 2 % of nominal voltage.

10.3.2.2 The test shall be conducted at the low ambient operating temperatures in Table 1, ±2 °C, and at 120 ± 2 % of nominal voltage.

10.3.3 In all tests, the system shall be configured as it is intended to be used in a boat application. The minimum cycle rate shall be 6 cycles per minute.

10.3.4 Following these tests, the system shall continue to operate without failure within the original parameters specified by the manufacturer. Failure includes loose parts, cracks, wear outside of tolerance or impaired functionality.

10.4 Joystick

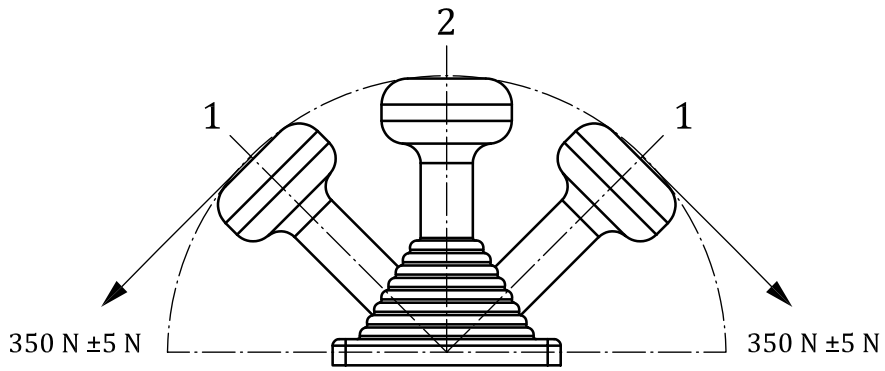
10.4.1 The joystick shall be designed to withstand a test comprising 500 000 cycles (end stop to end stop) at 100 % of its stroke in each direction, (X –X, Y –Y, Z – Z) with the minimum force applied at its end stop. A malfunction of any type, electrical or mechanical, constitutes a failure.

10.4.1.1 When fully moved in the +X and –X direction to its end-stop point, the joystick shall be capable of withstanding a force of 350 ± 5 N applied tangentially to the arc of the throw. See Figure 2.

10.4.1.2 When fully moved in the +Y and –Y direction to its end-stop point, the joystick shall be capable of withstanding a force of 350 ± 5 N applied tangentially to the arc of the throw. See Figure 2.

10.4.1.3 When fully twisted in the +Z and –Z direction, the joystick shall be capable of withstanding a torque of 7,5 ± 0,5 Nm. See Figure 3.

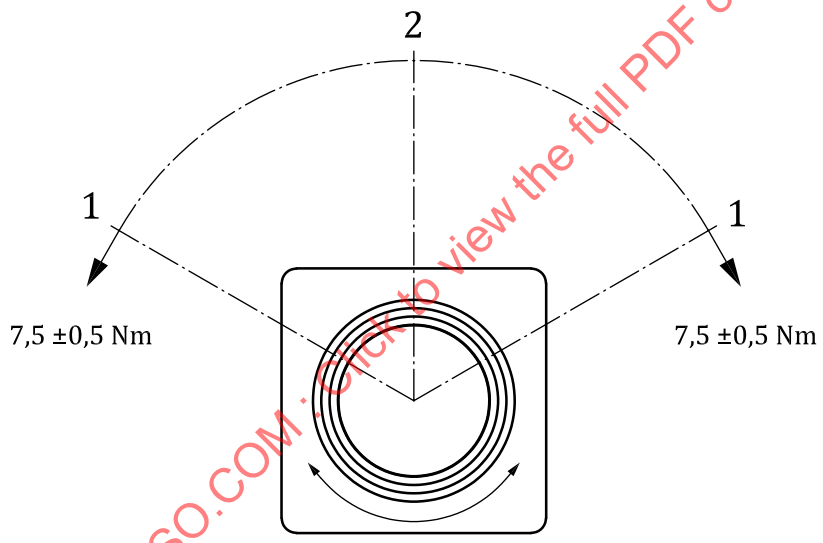
10.4.2 Following this test, the system shall continue to operate without failure within the original parameters specified by the manufacturer. Failure includes loose parts, cracks, wear outside of tolerance, or impaired functionality.



Key

1 end stop
2 neutral

Figure 2 — Extreme-travel test, X and Y movements



Key

1 end stop
2 neutral

Figure 3 — Extreme travel test, Z rotation

10.5 Environmental-test requirements

10.5.1 General

Components shall be tested at a temperature based on their intended installation in accordance with Table 1. An insulation resistance test shall be carried out before and after each damp-heat test, low-temperature test, high temperature test and salt mist test.

If the same EUT is used for the tests, the intermediate insulation resistance test is not required.

Table 1 — Environmental tests for different areas of the craft

Test	Temperature (±2 °C)				
	Interior	Engine compartment	Damp area	Wet area	Immersion
Salt mist	No	Yes	Yes	Yes	Yes
Vibration test	Yes	Yes	Yes	Yes	Yes
Damp heat — Cyclic	30 °C	55 °C	55 °C	55 °C	55 °C
Damp heat — Steady state	30 °C	50 °C	50 °C	50 °C	50 °C
High-temperature test storage	85 °C	85 °C	85 °C	85 °C	85 °C
High-temperature test operation	70 °C	70 °C	70 °C	70 °C	70 °C
Low-temperature test — Operation	–15 °C	–15 °C	–25 °C	–25 °C	–25 °C
Low-temperature test — Storage	–40 °C	–40 °C	–40 °C	–40 °C	–40 °C
Ingress protection (IP) rating	54	55	56	66	67

10.5.2 Salt mist tests

10.5.2.1 General

The test shall be carried out following one of these two standards:

— IEC 60068-2-52:2017;

— ASTM B117:2016.

10.5.2.2 Test chamber parameters

The test chamber parameters shall be as follows:

a) salt solution shall be sprayed into the atmosphere surrounding the EUT in the chamber in the form of a fine mist at approximately one per cent of the volume of the chamber per hour;

b) to avoid contamination, salt solution dripping from the walls and ceiling of the test chamber and from the EUT shall not be recycled for re-spraying.

10.5.2.3 Salt mist — Cyclic

The cyclic test shall be carried out as follows.

a) The spraying shall continue for 2 h, after which the EUT is to be maintained as follows:

   1) temperature: 35 °C ± 2 °C;

   2) relative humidity: 90 % to 95 %;

   3) duration: 7 days;

   4) this procedure shall be repeated four times in succession, following which the test chamber temperature and humidity shall be reduced to ambient conditions.

b) On completion of the cyclic salt mist tests, the complete system shall be subjected to one cycle of performance testing without delay, as described in 10.2, 10.3 or 10.4, as applicable, to ensure the system functions without failure, or that any impaired function is within the original parameters specified by the manufacturer. The EUT shall be examined to ensure that any deterioration or corrosion is superficial in nature.

10.5.2.4 Salt mist — Continuous

The continuous test shall be carried out as follows.

a) The spraying shall continue for 300 h at a temperature between +15 °C and +35 °C.

b) On completion of the continuous salt mist tests, the complete system shall be subjected to one cycle of performance testing without delay, as described in 10.2, 10.3 or 10.4, as applicable, to ensure the system functions without failure, or that any impaired function is within the original parameters specified by the manufacturer. The EUT shall be examined to ensure that any deterioration or corrosion is superficial in nature.

10.5.3 Damp heat — Cyclic

The test shall be carried out in accordance with ISO 16750-4:2010, with the following deviations:

a) the number of cycles shall be four;

b) on completion of the cyclic damp-heat test, the system shall be subjected to one cycle of performance testing without delay, as described in 10.2, 10.3 or 10.4, as applicable, to ensure the system functions without failure, or that any impaired function is within the original parameters specified by the manufacturer.

10.5.4 Damp heat — Steady state

10.5.4.1 The test shall be carried out in accordance with ISO 16750-4:2010.

10.5.4.2 On completion of the steady state damp-heat test, the system shall be subjected to one cycle of performance testing, as described in 10.2, 10.3 or 10.4, as applicable, to ensure the system functions without failure, or that any impaired function is within the original parameters specified by the manufacturer.

10.5.5 High-temperature test — Operation

10.5.5.1 Tests and performance criteria shall be in accordance with ISO 16750-4:2010.

10.5.5.2 The test chamber shall be configured as follows:

— temperature: raised from the initial ambient temperature to the temperature indicated in Table 1;

— duration: 48 h.

10.5.5.3 On completion of the operation high-temperature test, the system shall be subjected to one cycle of performance testing, as described in 10.2, 10.3 or 10.4, as applicable, to ensure the system functions without failure, or that any impaired function is within the original parameters specified by the manufacturer.

10.5.6 High-temperature test — Storage

10.5.6.1 Tests and performance criteria shall be in accordance with ISO 16750-4:2010.

10.5.6.2 On completion of the storage high-temperature test, the system shall be subjected to one cycle of performance testing, as described in 10.2, 10.3 or 10.4, as applicable, to ensure the system functions without failure, or that any impaired function is within the original parameters specified by the manufacturer.

10.5.7 Low-temperature test — Operation

10.5.7.1 The test shall be carried out in accordance to ISO 16750-4:2010 and the test chamber conditions shall be as follows:

— temperature: lowered from the initial ambient temperature to the temperature indicated in Table 1 and maintained within ±2 °C;

— duration: 16 h.

10.5.7.2 On completion of the operation low-temperature test, the system shall be subjected to one cycle of performance testing, as described in 10.2, 10.3 or 10.4, as applicable, to ensure the system functions without failure, or that any impaired function is within the original parameters specified by the manufacturer.

10.5.8 Low-temperature test — Storage

10.5.8.1 The test shall be carried out in accordance to ISO 16750-4:2010 and the test chamber conditions shall be as follows:

— temperature: lowered from the initial ambient temperature to the temperature indicated in Table 1 and maintained within ±2 °C;

— duration: 72 h.

10.5.8.2 On completion of the storage low-temperature test, the system shall endure one cycle of tests described in 10.2, 10.3 or 10.4 subclauses, as applicable, to ensure the system functions without failure, or that any impaired function is within the original parameters specified by the manufacturer.

10.6 Vibration tests and requirements

10.6.1 Equipment mounted on engines, reverse gears or drives shall be tested in accordance with ISO 16750-3:2012, 4.1.2.6.

The same test profile shall be used for components mounted on reverse gears or drives not rigidly attached to the engine since the propeller-induced vibrations are considered to have a relatively high contribution in comparison with engine-induced vibrations.

The EUT shall meet, as a minimum, performance criterion A as described in 10.10.2.

10.6.2 Equipment installed in locations not covered in 10.6.1 shall be tested to a) or b) below. The EUT shall meet, as a minimum, performance criterion A as described in 10.10.2.

The same system shall be used to complete all testing in the present subclause. Prior the tests the system shall be subjected to one cycle as described in 10.2, 10.3 or 10.4, as applicable, to ensure it functions properly.

a) Random vibration — The system shall be subjected to a random vibration, at 0,028 4 g^2/Hz, from 20 Hz to 2 000 Hz, applied along the three mutually perpendicular axes. The test duration shall be eight hours for each axis.

   On completion of the random-vibration test, the system shall be subjected to one cycle, as described in 10.2, 10.3 or 10.4, as applicable, to ensure the system functions without failure, or that any impaired function is within the original parameters specified by the manufacturer.

b) Resonant vibration — In order to identify the major resonant frequencies, major sub-assemblies shall be subjected to a swept sine vibration along the three mutually perpendicular axes from 20 Hz to 2 000 Hz at 1g zero-peak amplitude with a sweep rate of one octave per minute. Once

the resonant frequency for the individual major subassembly is known, it shall be vibrated for 10 million cycles or two hours, whichever is greater, at the maximum displacement frequency (resonant frequency) at a 1g zero-peak amplitude for each axis for off-engine-mounted units, and at four 4g's zero-peak amplitude for each axis for engine-mounted units.

c) On completion of the resonant vibration test, the system shall be subjected to one cycle, as described in 10.2, 10.3 or 10.4, as applicable, to ensure the system functions without failure, or that any impaired function is within the original parameters specified by the manufacturer.

10.7 Shock testing

The system shall be shock-tested in accordance with IEC 60068-2-27:2008 using the following parameters:

— acceleration: 500 m/s^2;

— duration: 11 ms;

— number of shocks: in all six directions (see Figure 4); 18 shocks in total;

— acceptance criterion: any system malfunction shall be considered as a failure.

10.8 Drop test

All components of the system not rigidly mounted (portable helm transmitters, etc.) shall withstand a drop test in all six orientations (see Figure 4) from a height of at least 1 m with impact on a concrete floor. Any system malfunction shall be considered as a failure.

Components to be tested shall pass the UV exposure tests according to 10.9 before conducting the drop test.

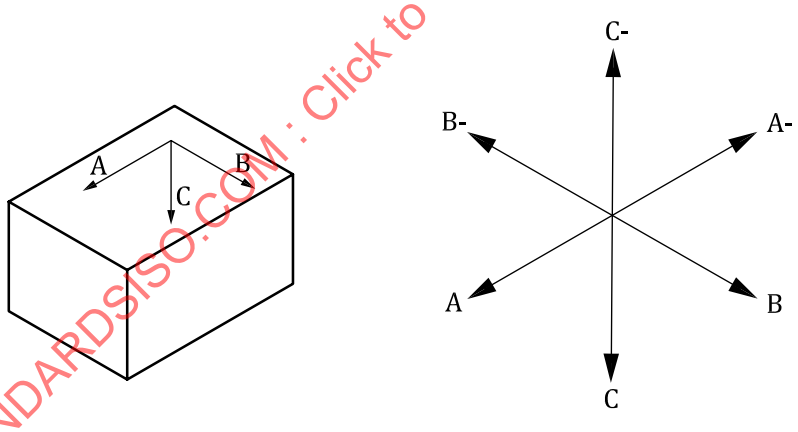


Figure 4 — Principal description of free-fall directions

10.9 Resistance to UV

System components exposed to solar radiation shall be subject to accelerated light exposure according to ISO 4892-1:2016, ISO 4892-2:2013, ISO 4892-3:2016, ISO 4892-4:2013.

After the test, the exposed components shall show no permanent deformation and continue to function as intended.

10.10 Electromagnetic compatibility (EMC)

10.10.1 Electromagnetic interference tests

Electronic equipment shall be subjected to the following electromagnetic interference tests for:

— immunity to conducted low-frequency interference, see 10.10.3;

— immunity to conducted radio-frequency interference, see 10.10.4;

— immunity to radiated radio-frequency fields, see 10.10.5;

— immunity to fast, low-energy transients (bursts) (on power, control and signal lines), see 10.10.6;

— immunity to slow high-energy transients (surges), see 10.10.7;

— immunity to electrostatic discharge (ESD), see 10.10.8;

— immunity to power supply variation, see 10.10.9;

— radiated emissions, see 10.10.10;

— conducted emissions, see 10.10.11.

10.10.2 EMC performance criteria

Test results shall be evaluated in accordance with one of the performance criteria described below, as stated under each specific test.

— **Performance criterion A** (for continuous phenomena): The EUT shall continue to operate as intended during and after the test. No degradation of performance or loss of function, as defined in the technical specification published by the manufacturer, is allowed.

— **Performance criterion B** (for transient phenomena): The EUT shall continue to operate as intended after the tests. No degradation of performance or loss of function, as defined in the technical specification published by the manufacturer, is allowed. During the test, degradation or loss of function or performance which is self-recoverable is, however, allowed but no change of actual operating state or stored data is allowed.

10.10.3 Immunity to conducted low-frequency interference

10.10.3.1 Tests shall be carried out in accordance with IEC 61000-4-16:2015 using the following test parameters:

— AC power lines:

  10 % AC supply voltage 50 Hz to 900 Hz; 10 % to 1 % 900 Hz to 6 KHz; 1 % 6 KHz to 10 KHz;

— DC power lines:

  10 % DC supply voltage 50 Hz to 10 KHz.

10.10.3.2 The EUT shall meet, as a minimum, performance criterion A as described in 10.10.2.

10.10.4 Immunity to conducted radio-frequency interference

10.10.4.1 Tests shall be carried out in accordance with IEC 61000-4-6:2013 using the following test parameters:

AC/DC power lines, signal/control lines and I/O ports

Frequency range: 150 KHz to 80 MHz, sweep rate ≤1,5 × 10^{-3} decade/s

Modulation: AM, 1 000 Hz ± 10 % to a depth of 80 % ± 10 % or 400 Hz ± 10 % to a depth of 80 % ± 10 % where an input signal at a modulation frequency of 1 000 Hz is unavailable.

Field strength: a) 3 V r.m.s. amplitude swept over the frequency range 150 kHz to 80 MHz;
b) 10 V r.m.s. amplitude at spot frequencies: 2 MHz, 3 MHz, 4 MHz, 6,2 MHz, 8,2 MHz, 12,6 MHz, 16,5 MHz, 18,8 MHz, 22 MHz and 25 MHz.

Coupling: Capacitive

10.10.4.2 The EUT shall meet, as a minimum, performance criterion A as described in 10.10.2.

10.10.5 Immunity to radiated radio-frequency fields

10.10.5.1 The test shall be carried out as described in IEC 61000-4-3:2006+Amd1:2007+Amd2:2010 using the following test parameters:

Frequency range: 80 MHz to 2 GHz, sweep rate ≤1,5 × 10^{-3} decade/s

Modulation: 1 000 Hz (or 400 Hz where an input signal at a modulation frequency of 1 000 Hz is unavailable)

Field strength: 30 V/m shall be applied to the whole frequency range

10.10.5.2 The EUT shall be housed in the enclosure shown in the manufacturer's published specification or be tested in an open-rack configuration.

10.10.5.3 The test shall be carried out with the generating antenna facing each of the six sides of the EUT (X Y Z orientation).

10.10.5.4 The EUT shall meet, as a minimum, performance criterion A as described in 10.10.2.

10.10.6 Immunity to fast, low-energy transients (bursts)

10.10.6.1 The test shall be carried out as described in IEC 61000-4-4:2012 using the following test parameters:

Rise time: 5 ns (value between 10 % and 90 %)

Width: 50 ns (50% value)

Test level: a) 2 kV common mode on DC power port and AC power port, capacitive coupling

b) 1 kV common mode on I/O signal and control port, coupling clamp