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Ships and marine technology — Night vision equipment for high-speed craft — Operational and performance requirements, methods of testing and required test results

Navires et technologie maritime — Équipement de vision nocturne pour navires à grande vitesse — Exigences opérationnelles et de performance, méthodes d'essai et résultats d'essai exigés

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ISO copyright office
CP 401 • Ch. de Blandonnet 8
CH-1214 Vernier, Geneva
Phone: +41 22 749 01 11
Email: copyright@iso.org
Website: www.iso.org

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Foreword

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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).

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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 6, *Navigation and ship operations*.

This second edition cancels and replaces the first edition (ISO 16273:2003), which has been technically revised.

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

— definitions 3.5 "performance check", 3.6 "performance check (EMC)", 3.7 "performance test" 3.8 "single operator action", 3.9 “field of view" and 3.10 “instantaneous field of view" have been added;

— 4.8 "Stabilisation of the field of view against the motions of the vessel" has been added;

— 4.10 "Clear view", former 4.11, has been clarified;

— 4.13 "Line of sight" has been added;

— 4.15 "Presentation of information", former 4.16, has been modified;

— 4.22 "Interfacing" has been modified;

— 5.1.2 "Performance test" has been added;

— 5.1.3 "Performance check", former 6.3, has been modified;

— 5.1.4 "Performance check (EMC)" has been added;

— 5.2.3 "Roll and pitch test", former 6.2.2, has been modified;

— 5.4.2.8 "Wind endurance test" has been added;

— 5.4.3 "Test of thermal imaging systems", former 7.2, has been modified;

— 5.4.3.2, Table 2 "Atmospheric extinction coefficients for different wavelength ranges" values have been adjusted;

— 5.4.4 "Test of active image-intensifier systems", former 7.3, has been modified and testing of non-visible illumination has been added;

— 5.5 "Sea trials", former Clause 8, has been modified, the surface of test specimen has been specified;

— Annex D (normative) "Measurement of MTDP (minimum temperature difference perceived) of thermal imagers" has been added;

— Annex E (normative) "Stabilisation test for thermal imaging systems" has been added.

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

This document has been developed to support the implementation of the International Code of Safety for High-Speed Craft (HSC code), Chapter 13, of the International Maritime Organisation (IMO), and the IMO performance standards for night vision equipment for high-speed craft in the IMO Resolution MSC.94 (72)

Ships and marine technology — Night vision equipment for high-speed craft — Operational and performance requirements, methods of testing and required test results

1 Scope

This document specifies operational and performance requirements and methods of testing for night vision equipment fitted to high-speed craft.

NOTE In this document, the text identical to IMO Resolution MSC.94 (72) is printed in italics; references to the paragraphs concerned in the IMO Resolution are given in brackets.

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 9335, *Optics and photonics — Optical transfer function — Principles and procedures of measurement*

ISO 15529, *Optics and photonics — Optical transfer function — Principles of measurement of modulation transfer function (MTF) of sampled imaging systems*

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

IEC 61162, *Maritime navigation and radiocommunication equipment and systems — Digital Interfaces*

IEC 62288:2014, *Maritime navigation and radiocommunication equipment and systems — Presentation of navigation-related information on shipborne navigational displays — General requirements, methods of testing and required test results*

IEC 62388:2013, *Maritime navigation and radiocommunication equipment and systems — Shipborne radar — Performance requirements, methods of testing and required test results*

IEC 62923, *Maritime navigation and radiocommunication equipment and systems — Bridge alert management (all parts)*

IMO Resolution A.694(17), *General requirements for shipborne radio equipment forming part of the global maritime distress and safety system (GMDSS) and for electronic navigational aids*

IMO Resolution MSC.94(72), *Performance standards for night vision equipment for high speed craft*

IMO Resolution MSC.191(79), *Performance standards for the presentation of navigation-related information on shipborne navigational displays*

IMO Resolution MSC.302(87), *Adoption of performance standards for Bridge Alert Management*

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
night vision equipment
technical fixed means enabling the position and aspect of objects above the water surface relative to one's own craft to be detected at night

[SOURCE: IMO MSC.94(72) 4]

3.2
high-speed craft
HSC
craft capable of a maximum speed in metres per second (m/s) equal to or exceeding $3{,}7V^{0{,}1667}$, where V is the displacement corresponding to the design waterline

[SOURCE: IMO HSC Code 2000]

3.3
test target for sea trials
target that simulates the real hazard of a surface object that can be found at sea such as, small unlit boats, floating logs, oil drums, containers, buoys, ice, hazardous waves and whales

[SOURCE: IMO MSC.94(72) 4]

3.4
lit vessel
vessel that, in addition to the standard navigation lights, has a row of five unshielded lamps with a luminous flux of 460 lm at 1 m horizontal spacing and 4 m above sea level

Note 1 to entry: This is equivalent to e.g. 21 W, 12 V.

3.5
performance check
short functional test carried out during or after a technical test to confirm that the equipment operates

[SOURCE: IEC 60945:2002, 3.1.4]

3.6
performance check (EMC)
short functional test carried out during or after an EMC test to confirm that the equipment complies with the required immunity performance criteria

[SOURCE: IEC 60945:2002, 3.1.5]

3.7
performance test
measurement or a group of measurements carried out during or after a technical test to confirm that the equipment complies with selected parameters as defined in the equipment standard

[SOURCE: IEC 60945:2002, 3.1.6]

3.8
single operator action
procedure achieved by no more than one hard-key or soft-key action, excluding any necessary cursor movements, or voice actuation using programmed codes

[SOURCE: MSC.252(83), Appendix 1]

3.9
field of view
FoV
solid angle through which a detector with mounted optic is sensitive to electromagnetic radiation

3.10
instantaneous field of view
iFoV
angle subtended by a single detector element on the axis of the optical system

Note 1 to entry: iFoV is used as measure of the spatial resolution of a remote sensing imaging system.

4 Performance requirements

4.1 Functions and their availability

[IMO MSC.94(72), 5.1] *At night, night vision equipment* shall *be capable of detecting objects* at least each second *above the water's surface within a certain distance from one's own craft, and of displaying the information pictorially in real time,* at least each second*, to assist in collision avoidance and safe navigation.*

This requirement is fulfilled if the sea trials in 5.5 and the requirement in 4.4 are met.

4.2 Continuous operation

[IMO MSC.94(72), 5.2.1] *Night vision equipment on board HSC, while navigating at sea,* shall *be capable of continuous operation from after sunset until before sunrise. After the equipment has been switched on it* shall *be operational in less than 15 minutes.*

See 5.4.2.4.

4.3 Standard test target

[IMO MSC.94(72), 5.2.2] *The standard test target* shall *be a black metal target of such a size that when at least 50 % is immersed, 1,5 m long and 0,5 m high remains above the water at right angles to the desired direction of detection. Administration may use other smaller targets to reflect local conditions.*

See 5.5.2 for more detailed specification of the standard test target.

4.4 Detection range

[IMO MSC.94(72), 5.2.3] *With the required field of view, the equipment* shall *detect the standard test target at a distance of not less than 600 m with a minimum probability of 90 %, when the target has been immersed in the sea for at least 24 hours under mean starlight conditions without clouds and without moon.*

See 5.4.3.2, 5.4.4.5 and 5.5.4.2.

4.5 Field of view

[IMO MSC.94(72), 5.2.4] *The required horizontal field of view* shall *be at least 20°, 10° on either side of the bow. The vertical field of view* shall *be at least 12° and* shall *be sufficient to enable the equipment to fulfill the performance requirements of MSC.94(72) as well as being able to see the horizon.*

Optionally other fields of view may be provided. Their selection shall *be made with a non-locking switch, which returns to the required field of view when released.*

See 5.4.2.5.

4.6 Pan and tilt ranges of the field of view

[IMO MSC.94(72), 5.2.5] *The axis of the field of view of the equipment* shall *be capable of being moved at least 20° horizontally to either side.*

The elevation axis of the field of view shall *be capable of being adjusted of at least 10° to compensate for the trim of the craft.*

See 5.4.2.6.

4.7 Speeds of panning of the field of view

[IMO MSC.94(72), 5.2.6] *By activation of a single control element, the axis of the field of view* shall *be capable of being returned automatically to the ahead position at a minimum angular speed of 30°/s. The system* shall *be capable of panning at a minimum angular speed of 30°/s.*

The minimum angular speed shall be at least 30°/s. The operational angular speed may be lower.

See 5.4.2.6.

4.8 Stabilisation of the field of view against the motions of the vessel

The imaging system shall not show a shift of more than the instantaneous field of view (iFoV) (e.g. 0,83 mrad) when looking onto a fixed onshore target under ship's movement at sea. Ship movement at sea as defined in 4.11.

See 5.2.3.

4.9 Heading marker indication

[IMO MSC.94(72), 5.2.7] *When inside the field of view, the graphical ahead mark of the craft* shall *be indicated on the display with an error not greater than ±1°.*

When the sensor/camera is orientated right ahead, the graphical heading marker shall be displayed in the centre with an error not greater than +/-1°.

When outside the field of view, a visual indication of relative bearing with an error not greater than ±1° shall *be provided.*

See 5.4.2.6.

4.10 Clear view

[IMO MSC.94(72), 5.2.9] *Arrangement* shall *be provided to ensure efficient cleaning of the sensor head/lens from the operating position. Administration may require some additional facilities such as de-icing.*

Essential cleaning of the sensor head and/or lens shall be performed before the use of the night vision equipment. During operation, mainly dried salt mist and spray can occur that shall be removed by a cleaning device to get back a clear view. The technical way how to achieve that result is left to the discretion of the manufacturer of the device.

See 5.4.2.7.

4.11 Roll and pitch

[IMO MSC.94(72), 5.2.8] *The performance of the night vision equipment* shall *be such that when the craft is rolling and/or pitching up to ±10°, the performance requirements in this* document shall *be complied with.*

See 5.2.3.

4.12 Optical interference

[IMO MSC.94(72), 5.2.10] *Measures* shall *be taken, to ensure that objects commonly encountered at sea and in ports* shall *not be displayed less clearly on the monitor of the night vision equipment because of dazzle effects, reflection, blooming, or any other effects due to the surroundings.*

See 5.2.4.

4.13 Line of sight

Vibrations shall not disturb the created image for the operator.

See 5.2.5.

4.14 Controls and ergonomics

[IMO MSC.94(72), 6] *The night vision equipment* shall *be designed in accordance with sound ergonomic principles.*

The number of operational controls shall *be limited to the minimum required for operation.*

Whilst in operational mode, double functions of controls shall *be avoided on such controls as for pan, vertical trim, field of view and other essential functions.*

The functions of the individual operational controls shall *be clearly labelled.*

The operational functions of night vision equipment shall *be activated directly through the operational controls; menu-driven controls* shall *be avoided.*

The operational controls shall *be clearly identifiable in the dark. If illumination is used, the brightness* shall *be adjustable.*

The operational controls of night vision equipment shall *meet the requirements of IMO Resolution A.694(17) as well as applicable requirements of* IEC 60945 and IEC 60447.

4.15 Presentation of information

[IMO MSC.94(72), 6.3] *the status of operation of the equipment* shall *be continuously displayed.*

The display shall *be non-dazzling and non-flickering. The display* shall *be capable of displaying a visible image of at least 180 mm in diagonal.*

The selected field of view, if more than one is provided, (see 4.5) shall *be continuously indicated at the operating position.*

The image shall be presented on the display, with the same aspect ratio as the sensors, as default (natural picture).

Any processing of the image on user demand is allowed as a temporary aid to enhance the detection of objects. The fact that any processing is in operation shall be permanently indicated by means next to the image. The navigation personnel shall be able to return to the unaltered image, only processed by an automatic gain control algorithm, in a one-handed single operator action. The latency period of the processing shall not exceed 250 ms. Unaltered means that only point operations which not consider the pixels neighbourhood, are applied to the image raw data, such as contrast and brightness enhancement or tone mapping.

Additional information may be displayed, but shall not mask, obscure or degrade essential information required for the display by its primary task as specified in this document.

The refresh rate for an optical system shall be at least 60 Hz.

The presentation of navigation-related information on navigational displays shall be in accordance with MSC.191(79) and IEC 62288.

See 5.4.2.2.

4.16 Software

[IMO MSC.94(72), 5.4] *the operational characteristics of the software* shall *meet the following requirements in particular:*

[IMO MSC.94(72.), 5.4.1.1] *self-description of the functions implemented by means of software;*

[IMO MSC.94(72), 5.4.1.2] *display of user interface status; and*

[IMO MSC.94(72), 5.4.1.3] *software protection against unauthorized changes.*

If certain functions of night vision equipment are implemented using software, such software shall *meet the applicable requirements of IEC 60945.*

If any software is used, the manufacturer shall provide a description of the functions implemented by means of software and state how the requirements have been complied with.

"Self-description of the functions implemented by means of software" means that the functions available through menus (or similar) rather than separate controls shall be clear from the menu description.

"User interface status" may be an indicator of which functions are operational.

"Software protection" may be a password or lockable cover.

4.17 Durability and resistance to environmental conditions

[IMO MSC.94(72), 7.1] *Night vision equipment* shall *withstand the environmental conditions specified in IMO Resolution A.694(17) and in IEC 60945.* Provisions shall be made, if necessary, to protect the night vision equipment against high light conditions.

[IMO MSC.94(72), 7.4.5] *Night vision equipment should be installed in such a way that its operation and detection functions are not impaired by head wind and/or true wind up to 100 knots*

In addition to the requirements in IEC 60945 Durability and resistance to environmental conditions, the sensor of the night vision equipment and its mounting requires an additional shock/vibration test as well as wind endurance test (IEC 62388). The shock test provides a simulation in which the resonant responses, comparable with those likely to be experienced in practice in the operational environment, can be reproduced in the test laboratory.

See 5.4.2.1. and 5.4.2.8

4.18 Electrical and electromagnetic interference

[IMO MSC.94(72), 7.2] *With respect to electrical and electromagnetic interference, night vision equipment* shall *meet the requirements of IMO Resolution A.694(17) and IEC 60945.*

See 5.4.2.1.

4.19 Power supply

[IMO MSC.94(72), 7.3] *The power supply of night vision equipment* shall *meet the requirements of IMO Resolution A.694(17) and IEC 60945.*

See 5.4.2.1.

4.20 Back up and fall back arrangements

[IMO MSC.94(72), 9] *In the event of failure of the pan-tilt device, the sensor* shall *be capable of being fixed in the ahead position while underway.*

4.21 Malfunctions, alerts and indications

[IMO MSC.94(72), 5.3] *The night vision equipment* shall *include a visual indication of any failure.*

A warning of category B according to IMO Resolution MSC.302(87) shall be provided on the following conditions:

— malfunction of the night vision equipment or failure of power supply, see 4.19;

— malfunction of pan-tilt device, see 4.6;

— malfunction of zoom and focus.

An alert output shall be provided for any alert conditions.

The alert shall conform to the presentation and handling requirements of IMO Res. MSC.302(87) and IEC 62923.

4.22 Interfacing

[IMO MSC.94(72), 8] *Interfaces with other radio and navigation equipment* shall *meet IEC 61162. A recognized international standard video output for image recording* shall *be provided.*

The talker identifier to be used is "NV".

The following sentences shall be provided for the alert communication interface.

Sentences transmitted by the night vision equipment:

— ALC, ALF, ARC, HBT: see IEC 61162-1.

Sentences received by the night vision equipment:

— ACN, HBT: see IEC 61162-1.

NOTE ALR and ACK can be implemented if needed for legacy VDR equipment.

See 5.3.

4.23 Safety precautions

[IMO MSC.94(72), 10] *The safety features of night vision equipment* shall *meet the requirements of IMO Resolution A.694(17) and IEC 60945.*

See 5.4.2.1.

4.24 Acoustic noise and signals

Acoustic noise and signals shall meet the requirements of IEC 60945.

See 5.4.2.1.

4.25 Compass safe distance

Compass safe distance shall be determined according to IEC 60945 and the device shall be marked accordingly.

See 5.4.2.1.

4.26 Active illumination for active image intensifier system

Any system using active image-intensifier systems shall ensure good conditions of operation for all common traffic and weather conditions. An active IR illumination or any alternative technology is acceptable.

5 Methods of testing and required test results

5.1 General test conditions

5.1.1 General

Environmental and safety tests shall be carried out first, followed by laboratory tests and sea trials to verify whether the same equipment under test (EUT) meets all technical requirements. Where electrical tests are required, they shall be carried out using the normal test voltage as specified in IEC 60945.

Requirements detailed in Clause 4 for which a specific test is not detailed shall be confirmed by a visual check of the equipment and/or documentation.

5.1.2 Performance test

The performance test shall confirm that the EUT complies with the following selected parameters:

a) detection range: 600 m, test according to ISO 15529 and ISO 9335 (see requirement in 4.4);

b) stabilisation test to meet 4.8, test according to 5.4.2.5;

c) motion test conditions shall be at least 20° horizontal to either side and at least 10° vertical interval, the EUT shall be capable of being returned automatically to the ahead position at a minimum angular speed of 30°/s. The system shall be capable of panning at a minimum angular speed of 30°/s (see requirements in 4.6 and 4.7).

5.1.3 Performance check

The performance check shall verify that the EUT is still operational during or after being subjected to the environmental tests and any other test where it is specified.

The performance check shall ensure that the EUT shows:

a) pan and tilt motion;

b) display operation.

5.1.4 Performance check (EMC)

The EUT shall show no deterioration of the image when exposed to radiation.

5.2 Environmental tests

5.2.1 General

Environmental tests are intended to assess the suitability of the construction of the EUT for its intended physical conditions of use. After each environmental test and, if specified, also during the test, the EUT shall comply with the requirements of a performance check and/or performance test. No preconditioning of the equipment shall be necessary. The performance test in 5.1.2 a), b), and c) shall apply.

Night vision equipment shall, as far as applicable, meet the requirements and pass the tests according to IEC 60945, Durability and resistance to environmental conditions.

Outside mounted camera equipment is categorized as "exposed" equipment according to IEC 60945. The remaining equipment installed on the navigation bridge is categorized as "protected".

The exposed part of the equipment is required to function only during the night. Therefore, the solar gain of 23 °C does not need to be applied for the functional dry heat test; i.e. the chamber temperature can be decreased during the performance test. The performance test shall be started after the EUT has reached a steady temperature.

The test “Corrosion (salt mist)” according to IEC 60945 is mandatory, and shall not be waived.

5.2.2 Sensor shock test

5.2.2.1 General

The sensor and its mounting shall be designed to withstand the test without external indications of damage or subsequent degradation in performance. A performance check (see 5.1.3) shall be carried out before and after the test.

5.2.2.2 Procedure

The sensor and mount provided with the EUT shall be mounted so that a shock can be applied to the sensor mounting base to simulate an upward vertical impulsive force. The sensor shall be mechanically connected to the shock machine by its normal means of attachment. The procedure shall be carried out in normal laboratory environmental conditions. The severity of the test is specified by the peak acceleration, pulse shape and duration given in Table 1. The shock pulse shall be measured by an accelerometer placed at the sensor fixing point nearest to the centre of the table surface.

Table 1 — Sensor shock test

Pulse shape	Peak acceleration	Duration
Half sine	100 m/s^2	25 ms

NOTE The test is harmonized with those specified in IEC 62388:2013.

5.2.2.3 Methods of testing and required results

Confirm by observation that after three successive upward shocks of the required test severity and pulse shape have been applied and the power supply is switched off, there is no external indication of physical damage.

5.2.3 Roll and pitch test

This test is intended to prove the ruggedness of the system under the ship motions of 4.11.

The sensor and mount shall be mounted on top of a motion simulation platform being excited with a defined mechanical excitation, resembling a HSC in motion (e.g. a Scorsby table). It shall be aligned to within ± 1° of the table roll axis. The following nominal simple harmonic motions shall be applied simultaneously to the roll and pitch axes of the table for 25 min:

— roll axis: peak amplitude $10^{\circ}{}^{+2^{\circ}}_{-0^{\circ}}$, period 15 s ± 1 s;

— pitch axis: peak amplitude $10^{\circ}{}^{+2^{\circ}}_{-0^{\circ}}$, period 6 s ± 1 s.

During the roll and pitch test, the EUT shall be subjected to the performance test specified in 5.1.2 b) to demonstrate the stabilisation of the iFoV.

At the end of 25 min, the table motion shall be stopped, the table returned to its original position and the EUT shall continue to operate without interference.

NOTE The lengths of period are harmonized with those specified in ISO 16328.

5.2.4 Optical interference test

The EUT shall meet the requirements of 4.12 when tested in accordance with 5.4 and 5.5.4.3.

5.2.5 Line of sight test

The camera shall be exposed to the following vibration:

— 2 Hz up to 15 Hz with an excursion of ± 2,5 mm ± 10 %;

— above 15 Hz up to 50 Hz with a constant maximum acceleration of 23 m/s^2.

If the test is performed as a sweep test, the sweep rate should be selected according to IEC 60945.

During the line of sight test, the EUT shall be subject to the performance test specified in 5.1.2 b).

5.3 Interface test

Interfaces shall be tested according to IEC 61162.

5.4 Further laboratory tests

5.4.1 General

Laboratory tests shall be performed with the EUT which has passed the environmental tests specified in 5.2.

Tests shall be performed to verify the requirements given in Clause 4, except 4.3 and 4.4. The requirement given in 4.2 may alternatively be verified at the sea trials. The test results shall be documented.

The purpose of the following technical tests is to provide a means of performing laboratory controlled tests on all types of night vision equipment. The results of these tests shall be used to compare the measured performance to pre-established standards that have been validated via at-sea tests to meet the navigational needs for night navigation of HSCs.

The laboratory tests have been developed to measure the various capabilities of the EUT, including man-machine interfaces, displays, mechanical operation, and sensor.

The methods and procedures of the laboratory tests have been derived so that, when the results are compared to previous test results, they reliably predict the at-sea performance of the system.

5.4.2 Test for all types of night vision equipment

5.4.2.1 General

Night vision equipment shall, as far as applicable, meet the requirements and pass the tests according to IEC 60945, Ergonomics and HMI, Software, Power supply, Electromagnetic emission, Immunity to electromagnetic environment, Acoustic noise and signals, Compass safe distance and Safety precautions.

5.4.2.2 Presentation of information

The requirements regarding presentation of information shall be tested according to IEC 62288 presentation of operational information.

5.4.2.3 Back up and fall back arrangements

The requirements regarding back up and fall back arrangements shall be tested by visual inspection.

5.4.2.4 Continuous operation test

The EUT shall be switched on and it shall be observed whether it is operational within 15 min.

See 4.2.

5.4.2.5 Field of view test

Generate the real field of view (FoV) using the test pattern defined in Annex E for thermal imaging systems.

For active image-intensifier systems, Annex F defines a setup.

Confirm whether the FoV of the EUT meets the requirements as specified in 4.5.

Note The field of view test is used to demonstrate stabilisation of the reproduction of the image for the vessel condition roll and pitch (5.2.3) as well for the vibration (5.2.5).

5.4.2.6 Pan and tilt ranges as well as speeds of panning of the field of view test, and heading marker indication test

a) Confirm that a heading marker is indicated on the display, see 4.9.

b) Move the camera/sensor in the right ahead position. Verify that the graphical heading marker is displayed in the centre of the displayed picture with an error not greater than +/-1°, see 4.9.

c) Move the camera/sensor to the right edge of the FoV of the EUT.

   Verify that the heading marker line stays within the FoV with an error not greater than +/-1°, see 4.9.

d) Repeat c) to the left side of the FoV, see 4.9.

e) Move the camera/sensor to the right of the pan range of the EUT.

   Check that pan range reaches at least 20° (see 4.6).

   Verify that the relative bearing is indicated with an error not greater than +/- 1°, see 4.9.

f) Repeat e) to the left side of the pan range, see 4.9.

g) Measure the maximum panning speed and confirm that it is at least 30°/s (see 4.7).

h) Check whether the axis of the FOV is capable of being returned automatically to the ahead position by activation of one single operator action. Confirm that this speed of panning is at least 30°/s (see 4.7).

i) Move the camera/sensor back to the centre position and then to the top end of the tilt range.

   Record the tilt range and check whether 10° of range is met.

   Check the accuracy of the heading marker for ±1°, see 4.9.

   Check the minimum FoV of at least 12°, see 4.5

j) Repeat i) to the bottom end of the tilt range.

5.4.2.7 Clear view test

After the salt mist test, the EUT shall comply with the requirements of the performance check, and the cleaning of the sensor head and/or lens shall be tested. The sensor head and/or lens shall appear clean with a stainless and shiny surface after only one cleaning cycle.

5.4.2.8 Wind endurance test

The requirement according to 4.17 shall be tested in accordance with IEC 62388 (subsection "Antenna design").

5.4.3 Test of thermal imaging systems

5.4.3.1 Thermal imaging system

Minimum temperature difference perceived (MTDP) shall be measured according to Annex D. A general description including the number of observers, room and target temperature and other relevant data shall be presented.

Figures from both the horizontal and the vertical measurements shall be recorded in a diagram with the spatial frequency (cycles/mrad), linear scale, on the horizontal axis, and the temperature difference ΔT (degrees Celsius), logarithmic scale, on the vertical axis.

At least four targets shall be measured. In the diagram, the desired target shall be plotted at a Δt of 1 °C. The targets used at the measurement shall have a spatial frequency both larger and equal to/smaller than:

Horizontal: target equivalent instantaneous field of view ($IFoV_t$) = 1,5/600 = 0,0025 rad = 2,5 mrad or target equivalent frequency (F_t) = $1/IFoV_t$ = 1/2,5 = 0,4 cycles/mrad.

Vertical: target equivalent instantaneous field of view ($IFoV_t$) = 0,5/600 = 0,00083 rad = 0,83 mrad or target equivalent frequency (F_t) = $1/IFoV_t$ = 1/0,83 = 1,2 cycles/mrad.

5.4.3.2 Range prediction test

A range-prediction calculation shall be performed using a generally accepted software model such as NV-IPM or the TRM4 or an equivalent thermal range performance model or the attached algorithm in Annex A and Figures A.1 and A.2.

The following input data shall be used: the detection range shall be calculated at 1,3 line pairs using the target dimensions of 1,5 m × 1,5 m × 0,5 m (length × width × height).

The resulting detection range shall be greater than 600 m.

Different atmospheric extinction constants shall be used for different types of images in accordance with Table 2.

Table 2 — Atmospheric extinction coefficients for different wavelength ranges

Cut-on and cut-off wavelength	Atmospheric extinction coefficient[a]
Visual: 0,4 to 0,8 µm	**0,50** km^{-1}
Short wave IR: 0,8 to 2,5 µm	**0,50** km^{-1}
Mid wave IR: 3 µm to 5 µm	0,67 km^{-1}
Long wave IR: 8 µm to 12 µm	0,33 km^{-1}
[a] See Annex A.	

Temperature equivalent ΔT: 1,0 K.

5.4.4 Test of active image-intensifier systems

5.4.4.1 General

The procedures under 5.5.4.2 to 5.5.4.5 are recommended.

NOTE These procedures are taken from the previous edition of this document, where they were given with a view to gaining experience. Since no data from these procedures could be further evaluated, they are taken over in this edition, unchanged.

5.4.4.2 Illuminator spectrum

In order to protect night vision of the bridge personnel, the illuminator shall include optical filters so that light emission in the visible spectrum (380 nm to 780 nm) does not exceed a luminance of 0,2 % (when calculated using the scotopic response of the human eye).

For the non-visible illumination, the detection system shall include measures for reducing/minimizing the interference effects.

5.4.4.3 Image-intensifier sensor

The image-intensifier sensor under test shall be placed on an optical measurement bench in a laboratory capable of controlling the illumination level (in the same spectrum as used by the illuminators) down to 1×10^{-4} lx.

The following procedure is used to establish the performance and to provide an acuity curve for evaluating the performance.

a) Arrange one of the system illuminators with a variety of aperture stops employed to vary the illumination level so that it provides the only illumination in the dark laboratory.

b) Mount the sensor at a fixed range of at least 25 m, so that the acuity chart is in-focus.

c) Select an acuity chart of 25 %, 40 % and 60 % target contrast. Adjust the aperture stops on the illuminator and determine the limiting spatial frequency of the system, in the dark laboratory, for each of the patterns on the acuity chart.

d) The incident illumination level at the chart position shall be measured.

e) The acuity curve (spatial frequency vs. illumination level) can then be plotted. The spatial frequency axis can be replotted as a range by assuming a number of cycles across the target for a detection task at 90 % probability.

5.4.4.4 Infrared illuminators

The infrared illuminators used by the EUT shall be placed on an optical measurement bench and the following measurements shall be taken.

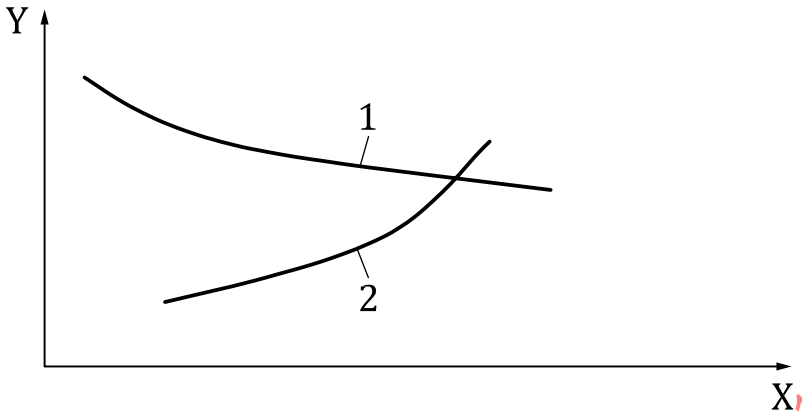
a) The optical spectrum of the light emission.

b) The intensity of the light emission (this may be taken at any convenient distance). The measured intensity of light emission is used to produce the illumination fall-off curve in Figure 1.

c) Plots of the horizontal and vertical emission intensity of the illuminator. The light emission (corrected for distance) shall be maintained over at least 20° if the illuminator tracks the sensor head movement. If the illuminator(s) is (are) fixed relative to the craft's heading, the light emission shall be maintained over at least 60°. Combination plots may be used to provide this data if more than one illuminator is declared by the supplier.

5.4.4.5 Range prediction

The imager acuity curve and the illuminator fall-off curve shall be plotted. The crossing point of these two curves determines the range performance of the active system, see Figure 1.



Key

X range (m)/spatial frequency (cycles/mrad)[a]

Y illumination level (lx)[a]

1 illumination fall-off curve

2 image acuity curve

[a] There are two scales on the axis. The range can be calculated from the spatial frequency using the formula given in Annex A.

Figure 1 — Range prediction for active image-intensifier systems

The extinction coefficient for calculating the illumination fall-off due to atmospheric effects is σ_{atm} = 0,22 km^{-1}. The fall-off due to the "photometric distance law" shall be considered additionally (illuminance ≅ $1/R^2$, where R is the range).

Required result: the point on the curve at which the two curves cross shall show a range equivalence of at least 600 m.

Typical plots are shown in Annex B, Figure B.1.

5.5 Sea trials

5.5.1 Introduction

Sea trials shall be performed with the same EUT which has passed the environmental tests according to 5.2 and which has been subjected to laboratory tests according to 5.4.

Night vision equipment shall pass a sea trial before approval. Test conditions and test results shall be recorded. A suitable report form can be found in Annex C. The sea trial shall be conducted at night under normal test conditions (see 5.5.3), which shall be measured and recorded.

Approval agencies shall maintain a matrix of sea trial results and laboratory test results. Initial input shall be generated using the EUTs' sensors to conduct sea trials on various vessels under the defined environmental conditions. During sea trials, illuminators shall be used when defined as part of the EUT. The sea trial shall measure the actual performance of the EUT.

NOTE The accurate recording of sea trial data may allow future development of a robust laboratory validation process in future editions of this document.

5.5.2 Standard test target

The test target for sea trials shall be an enclosed black sea-proofed aluminium box of 6 mm thickness which has been immersed in the sea for at least 24 h. The box shall either be anodized or painted black. If painted, the colour shall not be brighter and the reflection shall not be higher than that of anodized aluminium in the spectral band used by the EUT. For the properties of the described surface, the following applies:

— reflection < 10 % for the entire spectral range used by the EUT;

— emissivity for thermal systems > 90 %;

— roughness: sandblasted surface.

Provisions shall be made to measure the actual temperature at the centre of the test side of the target.

The size of the box shall be so that, when at least 50 % is immersed:

— 1,5 m long;

— 1,5 m wide;

— 0,5 m high;

remains above the water.

Administrations may use smaller targets to reflect local conditions.

5.5.3 Test conditions

Sea trials shall be conducted at night under the following test conditions:

— apparent sea state: 2 to 5, according to the Beaufort-scale;

— wind speed: 4 kn to 22 kn;

— sea temperature: 1 °C to 25 °C;

— air temperature: 0 °C to 35 °C;

— humidity: 40 % to 96 %;

— at least 2 h after sunset;

— good visibility: not less than 5 NM (nautical miles);

— speed of vessel: ⩾ 8 kn;

— height of sensor above waterline: 8 m to 10 m;

— natural illumination level shall be mean starlight conditions without clouds and without moon (5×10^{-4} lx to $1{,}3 \times 10^{-3}$ lx). For thermal imaging systems, this environmental condition may be omitted because of the used technology, see 5.5.4.2.

5.5.4 Test procedures

5.5.4.1 General

The test target (as defined in 5.5.2) shall be immersed in the water at the test site for at least 24 h so that the approach to the test target can be performed against an open-water background.

The sensor of the EUT shall be mounted on the craft used for the sea trials in a height of 8 m to 10 m above the waterline and according to the installation requirements defined in Clause 7. Before starting

and during the sea trials, the following data shall be measured by using calibrated measurement equipment, and recorded:

— sea temperature [°C];

— air temperature [°C];

— humidity [% RH];

— height of sensor above waterline [m];

— test target temperature [°C];

— target-background contrast, depending on the technology used either [K] or [ratio];

— barometric pressure [hPa];

— speed over ground of the vessel [kn];

— natural illumination level [lx];

— visibility [NM];

— wind speed [kn].

The following shall be observed and recorded:

— sea state according to the Beaufort-scale;

— sky condition;

— target condition and identification;

— location of trials.

If the actual conditions are outside the range of the test conditions, no sea trial shall be conducted.

The measurements and observations, including times, shall be recorded in accordance with the form shown in Annex C.

5.5.4.2 Detection-range evaluation test

The target shall be placed in the test area 24 h before the test. The craft, on which the EUT is installed, shall proceed away from the test target up to a minimum distance of 1 200 m and then proceed with a minimum speed of 8 kn towards the target, in such a way that the target remains within a sector of ±5° from the craft's bow.

The target shall be placed in open water with no background sources of interference so that the test can be performed against an open-water background. The craft shall approach the target at 90° ± 10° to one of the target faces.

The target shall be observed by the radar operator to measure continuously its actual distance. The observer (or observers) for night vision equipment shall observe the monitor of the EUT and may operate the EUT as usual.

When the target is detected on the monitor, the actual distance of the target shall be measured by the radar operator. The measured data shall be recorded. This procedure shall be repeated ten times. One failure (e.g. detection range less than 600 m with the required field of view) is allowed in 10 times. If two failures occur in the 10 runs, it is permissible to go to a total of 20 runs and, if no further failures occur, the EUT has passed.

5.5.4.3 Optical interference test

The craft on which the EUT is installed shall maintain a position 500 m from the test target that shall be within 5° of the craft lubber line. The target shall present a side at 90° =± 10°.

A lit vessel (as defined in 3.4) shall proceed at about 5 kn approximately on a bow-crossing course with a closest point of approach of 1 500 m.

The observer shall monitor the target during the crossing to confirm that the displayed target remains clearly visible during the crossing.

6 Marking and identification

[IMO MSC.94(72), 11] *night vision equipment* shall *be marked in accordance with the requirements of resolution A.694(17) and the applicable IEC 60945.*

The night vision equipment and any ancillary equipment shall be marked clearly and durably with the following data:

— identification of the manufacturer;

— equipment type number or model identification under which it was type-tested;

— serial number of the unit; and

— magnetic compass safe distance.

7 Installation

[IMO MSC.94(72), 7.4.1] *Full installation instructions to meet the following requirements* shall *be included in the documentation*.

— *general installation instructions;*

— *power supply (voltage, power consumption, frequency) and earthing information;*

— *special tools required, maintenance material and spare parts (e.g. fuses, spare bulbs);*

[IMO MSC.94(72), 7.4.2] *The controls of night vision equipment* shall *be installed in the workstation for navigating and manoeuvring, within easy reach of the navigator.*

[IMO MSC.94(72), 7.4.3] *The observation distance from a dedicated display* shall *not exceed 2,3 times the image diagonal* (i.e. a dedicated night vision workstation).

For a general bridge display, the observation distance from the display shall not exceed 8 times the image diagonal, but shall be situated so that observation from a distance of 2,3 times the image diagonal is also possible.

[IMO MSC.94(72), 7.4.4] *The sensor of the night vision equipment* shall *be installed in such a way that:*

a) *the horizontal panning area required in 4.6 is free of blind sectors up to 30° on either side; and*

b) *in the required field of view, in the direction right ahead, visibility of the water surface for the vertically tilted sensor is not reduced by more than two craft's lengths by the blind angle of own craft;*

c) it is placed on the fore-and-aft centre line of the HSC.

[IMO MSC.94(72), 7.4.5] *Night vision equipment* shall *be installed in such a way that its operation and detection functions are not impaired by head wind and/or true wind up to 100 knots and roll and/or pitch angles up to ± 10°.*

[IMO MSC.94(72), 7.4.6] *Its performance* shall *not be impaired by vibration occurring during normal craft's operation.*

8 Maintenance

[IMO MSC.94(72), 7.5] *With respect to maintenance, night vision equipment* shall *meet the requirements of IMO Resolution A.694(17) and IEC 60945. Where the manufacturer requires maintenance at specific periods, an operating hours meter* shall *be provided.*

9 Documentation

[IMO MSC.94(72), 12] *Night vision equipment* shall *be delivered complete with its technical documentation. Such documentation* shall *include the following information, if applicable:*

General information:

— *manufacturer;*

— *type designation;*

— *general description of equipment; and*

— *ancillary equipment and description.*

Instructions for installation:

— *general installation instructions;*

— *power supply (voltage, power consumption, frequency) and earthing information;*

— installation instructions listed in 7;

— identification of exposed or protected equipment.

Operation of equipment:

— *description of functions, controls, display;*

— *description of start-up procedures;*

— *calibration of equipment and error messages;*

— *testing capabilities of equipment;*

— *description of software used and interfaces*.

Troubleshooting; maintenance and service:

— *special tools required, maintenance material and spare parts (e.g. fuses, spare bulbs);*

— *equipment care and maintenance on board HSC;*

— *available services.*

Documentation for night vision equipment shall *also meet the requirements of IMO Resolution A.694(17) and IEC 60945.*

Annex A
(informative)

Range prediction calculation

Convert "spatial frequency" of MRTD (minimum resolvable temperature difference) curve into "range (R)" by using the following formula.

$$R = \frac{\sqrt{A_t}}{N_{90\,\%}} f$$

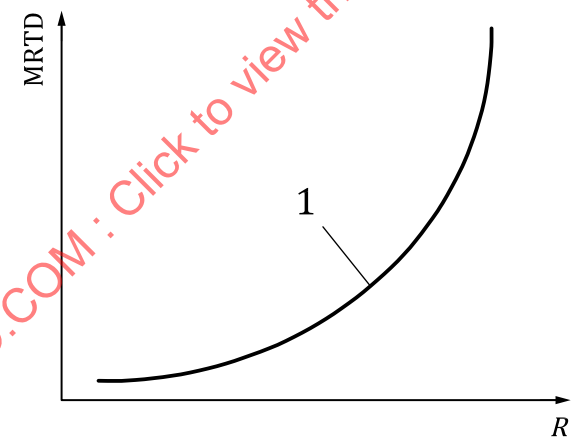
where

R is the predicted range, in which a target can be detected;

A_t is the target area (=1,5 m × 0,5 m);

$N_{90\,\%}$ is the number of line pairs for 90 % detection probability (= 1,3 line pairs);

f is the spatial frequency in cycles/mrad.



Key

1 $MRTD_{2D}$

Figure A.1 — Typical MRTD versus range curve

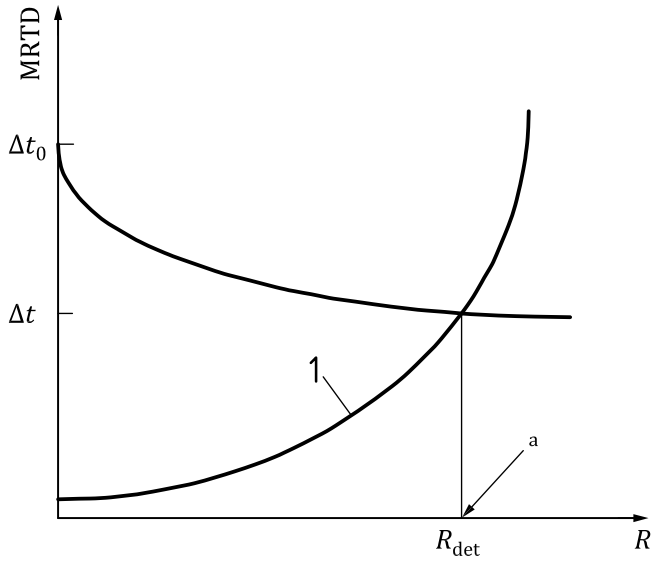
Calculate the target apparent temperature difference (ΔT) by using the following formula, and draw a line of ΔT curve on the MRTD versus R graph (see Figure A.1).

$$\Delta t = \Delta t_0 \exp(-\sigma R)$$

where

Δt_0 is the initial temperature difference, 1 °C

σ is the atmospheric extinction coefficient as given in Table 2



Key

1 $MRTD_{2D}$

a Detection range

Figure A.2 — Prediction of range performance from MRTD curve

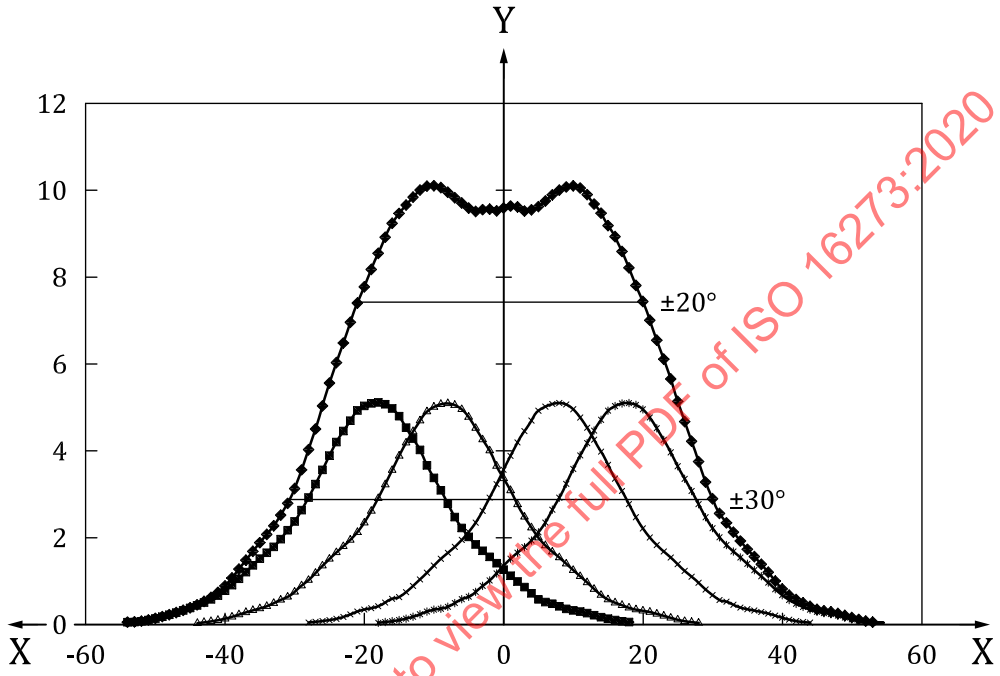
Determine the detection range (R_{det}) by using the graph in Figure A.2.

The detection range shall be not less than 0,6 km.

NOTE The number of line pairs for 90 % detection probability ($N_{90\ \%}$ = 1,3 line pairs) is calculated by $N_{50\ \%}$ = 0,75 line pairs according to Reference [7].

Annex B
(informative)

Infrared illuminator, typical plots



Key

X degrees

Y illumination level (lx)

Figure B.1 — Horizontal angular power distribution of 4 IR illuminators and composite response

The four illuminators shown in Figure B.1 are at:

+18°, +8°, −8°, −18°

relative to own craft heading.

Annex C
(informative)

Sea trial record

C.1 General data

Company/Applicant _____

Equipment name _____

Equipment type/class _____

Testing organization _____

Trials vessel _____

File reference _____

C.2 Equipment identity

The equipment listed below has been supplied for testing.

C.2.1 Sensor Head	
Type	
Sensor technology	
Lens/Optical system	
C.2.2 Display Unit	
Type	
Size	
Monochrome/Colour	
C.2.3 Illuminators (Only applicable for active image intensifier systems)	
Type	
Number used	
Position on test vessel	

Remarks/Comments

Accepted for test

Signature _____ Date _____

C.3 Trial installation details

Date of test _____

Location of trails site _____

Latitude _____ Longitude _____

C.3.1 Trial vessel	Detail
Name of vessel	
Length of vessel	
Mounting height of sensor	
Mounting height of illuminators (if fitted)	
Number of illuminators (if fitted)	

C.3.2 Test target		Detail
Designation/Serial number		
Size of face above water		
Test target temperature	°C	
Colour of face		
Nature of surface finish (delete)		Paint/Anodizing/Other (state)

C.3.3 Trial conditions		Detail		
		Start of trial runs		End of trial runs
Air temperature	°C			
Sea temperature	°C			
Visibility	NM			
Target-background contrast	ratio or K			
Humidity	%RH			
Barometric pressure	hPa			
Wind speed	kn			
Sea state	Bft			
Sky condition		Clear		
		Mostly clear		
		Partly cloudy		
		Mostly cloudy		
		Cloudy		
Natural illumination	lx			

Remarks/Comments

Remarks/Comments

Trials engineer name _____

Signature _____ Date _____

Annex D
(normative)

Measurement of MTDP (minimum temperature difference perceived) of thermal imagers

D.1 Validity

The MTDP applies for well and under sampled thermal imagers. The applicable spectral range is 3 µm to 14 µm or parts of this range.

NOTE The MTDP is a further development of the minimum resolvable temperature difference (MRTD) concept. For details compare to Reference [8]. A definition of MRTD measurement is given in NATO STANAG 4349.

D.2 Definition of MTDP

The MTDP is the minimum temperature difference that allows at least three observers to resolve a 4-bar-test pattern (Figure D.1) in accordance with a given criterion. It depends on the spatial frequency of the test pattern, the environmental temperature, and on the position and orientation of the test pattern relative to the detector.

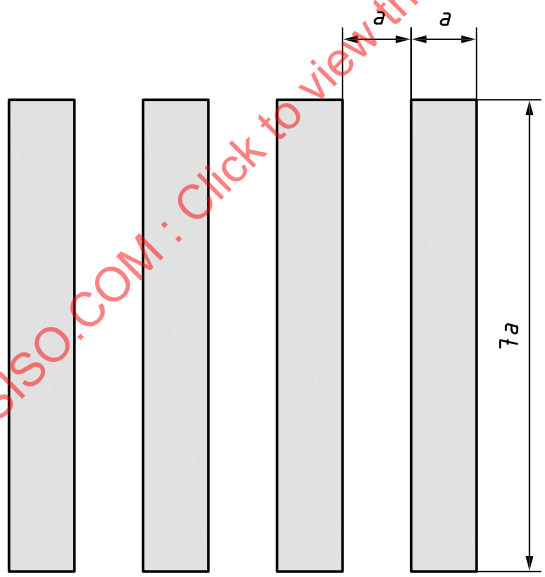


Figure D.1 — 4-bar test pattern for MTDP measurement

D.3 Measurement conditions

The observer shall have normal visual acuity (post-corrected effects less than ±0,25 diopters) and be experienced in this type of measurement.

The 4-bar-test pattern is positioned in front of a black body, the temperature of which can be varied giving positive and negative temperature differences, ΔT, between the bars and the background. The spatial frequency of the resolving power measurement targets shall be within ±5 % of the nominal value. The emissivities of the test pattern and the black body shall both be 0,95 or better. The black body shall make it possible to achieve temperature differences of at least ±10 K. The accuracy shall be