RUSSIAN MARITIME REGISTER OF SHIPPING

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# GUIDELINES

## ON EVALUATION OF MANOEUVRING CHARACTERISTICS OF INLAND NAVIGATION SHIPS (FOR EUROPEAN INLAND WATERWAYS)

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2011

The Guidelines on Evaluation of Manoeuvring Characteristics of Inland Navigation Ships (for European Inland Waterways) are based on the Administrative instruction No. 1 "Requirements relating to the capacity for taking evasive action and turning capacity" and Administrative instruction No. 2 "Requirements concerning prescribed (forward) speed, stopping capacity and capacity for going astern" of Commission Directive 2008/126/EC of December 19, 2008 amending Directive 2006/87/EC of the European Parliament and of the Council laying down technical requirements for inland waterway vessels.

These Guidelines have been approved in accordance with the established approval procedure and come into force since January 1, 2011.

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## 1 GENERAL

**1.1** The present Guidelines on Evaluation of Manoeuvring Characteristics of Inland Navigation Ships (for European Inland Waterways)[1] of the Russian Maritime Register of Shipping[2] specify the requirements for manoeuvring characteristics of inland navigation ships and convoys in compliance with the requirements of the Rules for the Classification and Construction of Inland Navigation Ships (for European Inland Waterways).

The Guidelines have been developed on the basis of Administrative instructions No. 1 and No. 2 of Commission Directive 2008/126/EC of December 19, 2008 (Directive 2008/126/EC) amending Directive 2006/87/EC of the European Parliament and of the Council laying down technical requirements for inland waterway vessels (Directive 2006/87/EC).

Fulfillment of the Guidelines requirements means that a ship has manoeuvring characteristics complying with the EC requirements.

**1.2** Manoeuvring characteristics of inland navigation ships are determined on the basis of the full-scale tests .

**1.3** Based upon results of manoeuvrability trials for compliance with the requirements of the Guidelines and the requirements of Ch.5, Directive 2006/87/EC and Administrative instructions No.1 and No.2 of Directive 2008/126/EC, the Report on Survey of the Ship (form 6.3.10) is issued to ships complying with the said requirements.

## 2 APPLICATION

**2.1** The Guidelines shall apply to the following inland navigation ships:

**.1** ships having a length (*L*) of 20 m or more;

**.2** ships for which the product of length (*L*), breadth (*B*) and draught (*T*) is a volume of 100 $m^3$ or more;

**.3** tugs and pushers intended for towing or pushing ships referred to in 2.1.1 or floating equipment by any method;

**.4** ships intended for passenger transport which carry more than 12 passengers in addition to the crew;

**2.2** The Guidelines do not apply to:

**.1** ferries;

**.2** warships;

**.3** sea-going ships, including sea-going tugs and pushers,
which:

**.3.1** operate or are based on tidal waters;

[1] Hereinafter referred to as "the Guidelines".
[2] Hereinafter referred to as "the Register".

**.3.2** operate temporarily on inland waterways, provided that they carry:

a certificate proving conformity with the International Convention for the Safety of Life at Sea, 1974 (SOLAS-74), or equivalent, a certificate proving conformity with the International Convention on Load Lines, 1966 (LL 66/68), or equivalent, and an international oil pollution prevention (IOPP) certificate proving conformity with the International Convention for the Prevention of Pollution from Ships, 1973 (MARPOL 73/78); or

in the case of passenger ships not covered by the above Conventions, a certificate issued in conformity with Council Directive 98/18/EC of 17 March 1998 on safety rules and standards for passenger ships; or

in the case of pleasure craft not covered by the above Conventions, a certificate of the country of which it carries the flag.

## 3 SCOPE OF TECHNICAL SUPERVISION

**3.1** If requirements of the Guidelines are applicable to a ship then the Register performs the following:

**.1** review and approval of technical documentation related to ship manoeuvring characteristics including execution of full-scale tests and reporting test results and calculations;

**.2** technical supervision of full-scale tests.

**3.2** An authorization to the Register from the ship's Flag Administration is a mandatory condition of the technical supervision.

**3.3** Full-scale test program shall be agreed with the Register Branch Office performing technical supervision of tests and approved by the Register Head Office[1].

**3.4** Test results are reported as a protocol and submitted to the Register for review. Upon satisfactory results of review the Register representative who performed technical supervision of tests signs the protocol and certifies it with his personal stamp. Copy of protocol together with the test report is forwarded to the RHO. Upon results of review of test report by the RHO the Register Branch Office issues the Report on Survey of the Ship specified in 1.3. The Report on Survey of the Series Ship may be issued on the basis of test results of a prototype ship provided that no changes were made during construction of a series ship which affect ship speed and manoeuvrability.

[1] Hereinafter referred to as "the RHO".

## 4 DEFINITIONS

**4.1** The following definitions shall apply in the Guidelines:

l e n g t h (*L*): the maximum length of the hull, in m, excluding rudder and bowsprit;

b r e a d t h (*B*): the maximum breadth of the hull, in m, measured to the outer edge of the shell plating (excluding paddle wheels, rub rails, and similar);

d r a u g h t (*T*): the vertical distance, in m, between the lowest point of the hull or the keel and the waterline.

## 5 GENERAL

**5.1** Ships and convoys shall display adequate speed and manoeuvrability.

Self-propelled ships and convoys shall meet the requirements set out in 5.2 to 5.10.

**5.2 Navigation tests.**

**5.2.1** Navigability and manoeuvrability shall be checked by means of navigation tests. Compliance with the requirements of 5.6 to 5.10 shall, in particular, be examined.

**5.3 Test area.**

**5.3.1** The navigation tests referred to in 5.2 shall be carried out on areas of inland waterways that have been designated by the competent authorities.

**5.3.2** Those test areas shall be situated on a stretch of flowing or standing water that is if possible straight, at least 2 km long, and sufficiently wide and is equipped with highly-distinctive marks for determining the position of the ship.

**5.3.3** It shall be possible to plot the hydrological data such as depth of water, width of navigable channel and average speed of the current in the navigation area as a function of the various water levels.

**5.4 Degree of loading of ships and convoys during navigation tests.**

During navigation tests, ships and convoys intended to carry goods shall be loaded to at least 70 per cent of their tonnage and loading, distributed in such a way as to ensure a horizontal attitude as far as possible. If the tests are carried out with a lesser load the approval for downstream navigation shall be restricted to that loading.

**5.5 Use of on-board facilities for navigation test.**

**5.5.1** During the navigation test, all of the equipment which may be actuated from the wheelhouse may be used, apart from anchors.

**5.5.2** However, during the test involving turning into the current referred to in 5.10, anchors may be used.

**5.6 Prescribed (forward) speed.**

**5.6.1** Ships and convoys shall achieve a speed in relation to the water of at least 13 km/h. That condition is not mandatory where tugs and pushers are operating solo.

**5.6.2** The Register may grant exemptions to ships and convoys operating solely in estuaries and ports.

**5.7 Stopping capacity.**

**5.7.1** Ships and convoys shall be able to stop facing downstream in good time while remaining adequately manoeuvrable.

**5.7.2** Where ships and convoys are not longer than 86 m and not wider than 22,90 m the stopping capacity may be replaced by turning capacity.

**5.7.3** The stopping capacity shall be proved by means of stopping manoeuvres carried out within a test area as referred to in 5.3 and the turning capacity by turning manoeuvres in accordance with 5.10.

**5.8 Capacity for going astern.**

**5.8.1** Where the stopping manoeuvre required by 5.7 is carried out in standing water it shall be followed by a navigation test while going astern.

**5.9 Capacity for taking evasive action.**

**5.9.1** Ships and convoys shall be able to take evasive action in good time. That capacity shall be proven by means of evasive manoeuvres carried out within a test area as referred to in 5.3.

**5.10 Turning capacity.**

**5.10.1** Ships and convoys not exceeding 86 m in length or 22,90 m in breadth shall be able to turn in good time.

That turning capacity may be replaced by the stopping capacity referred to in 5.7.

The turning capacity shall be proven by means of turning manoeuvres against the current.

**5.11 Navigation tests on convoys.**

**5.11.1** In order to authorise a tug/pusher or self-propelled ship to propel a rigid convoy, and to enter this on the Community certificate, the Register shall decide which formations are to be presented and shall conduct the navigation tests referred to in 5.2 with the convoy in the formation(s) applied for, which the Register regards to be the least favourable one(s). The requirements set out in 5.2 to 5.10 shall be met by this convoy. The Register shall check that the rigid connection of all ships in the convoy is maintained during the manoeuvres required by Section 5.

**5.11.2** If during the navigation tests referred to in 5.11.1 there are specific installations on board the ships that are being either pushed or propelled side-by-side, such as the steering system , propulsion units or manoeuvring equipment, or articulated couplings in order to meet the requirements set out in 5.2 to 5.10, the following shall be entered on the certificate for the ships propelling the convoy: formation, position, name and official number of those ships which are fitted with the specific installations used.

# 6 REQUIREMENTS RELATING TO THE CAPACITY FOR TAKING EVASIVE ACTION AND TURNING CAPACITY

**6.1 General.**

**6.1.1** According to 5.9, ships and convoys shall be able to take evasive action in good time and the capacity for such action shall be proved by evasive action manoeuvres in the test area in accordance with 5.3. This shall be proved by simulated evasive action manoeuvres to port and starboard.

During tests the requirements of 6.2 shall be complied with keeping a keel clearance of at least 20 per cent of the draught, but not less than 0,5 m.

**6.2 Evasive action test procedure and recording of data.**

**6.2.1** With the ship or convoy under way at a constant speed of $v_0$ = 13 km/h in relation to the water, at the start of the manoeuvre (time $t_0$ = 0 s, turning speed $r$ =0°/min, rudder angle $\delta_0$ = 0°, engine speed kept constant), evasive action to port or starboard shall be initiated by putting across the helm. The rudder shall be set to an angle δ, or the steering unit to an angle $\delta_a$ in the case of an active steering device, at the start of the manoeuvre, in accordance with the indications given in 6.2.3. The rudder angle δ (e.g. 20° to starboard) shall be maintained until the value r1 of the turning speed referred to in 6.2.2 for the corresponding dimensions of the ship or convoy is reached. When the turning speed $r_1$ is reached, the time $t_1$ shall be recorded and the rudder set to the same angle on the opposite side (e.g. 20° to port) so as to stop the turn and commence turning in the opposite direction, i.e., to reduce the turning speed to $r_2$ = 0 and let it to rise again to the value given in 6.2.2. When the turning speed $r_2$ = 0 is reached, the time $t_2$ shall be recorded. When the turning speed $r_3$ given in 6.2.2 is reached, the rudder shall be set in the opposite direction to the same angle δ, so as to stop the turning movement. The time $t_3$ shall be recorded. When the turning speed $r_4$ = 0 is reached, the time $t_4$ shall be recorded and the ship or convoy shall be returned to its original course.

Diagram of the evasive action manoeuvre is given in Fig. 6.2.1.

**6.2.2** The following limit values shall be complied with to reach turning speed $r_4$ depending on the dimensions of the ships or the convoys and on the water depth $h$:

The times $t_1$, $t_2$, $t_3$ and $t_4$ required to reach turning speeds $r_1$, $r_2$, $r_3$ and $r_4$ shall be recorded in the measurements report in Section 7. The $t_4$ values shall not exceed the limits given in Table 6.2.2.

**6.2.3** At least four evasive action manoeuvres shall be carried out, namely:

one to starboard with a rudder angle δ = 20°;

one to port with a rudder angle δ = 20°;

one to starboard with a rudder angle δ = 45°;

one to port with a rudder angle δ = 45°.

If necessary (e.g. in the case of uncertainty about the values measured or of unsatisfactory manoeuvres), the evasive action manoeuvres shall be repeated. The turning speeds given in 6.2.2 and the time limits shall be complied with.

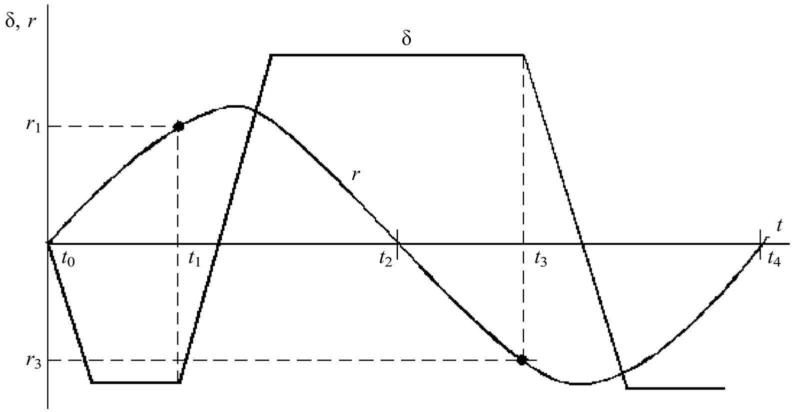


Fig. 6.2.1 Diagram of the evasive action manoeuvre:
$t_0$ — start of evasive action manoeuvre;
$t_1$ — time to reach turning speed $r_1$;
$t_2$ — time to reach turning speed $r_2 = 0$;
$t_3$ — time to reach turning speed $r_3$;
$t_4$ — time to reach turning speed $r_4 = 0$;
δ — rudder angle, (°);
$r$ — turning speed, (°/min)

Таблица 6.2.2

| No. | Dimensions of ships or convoys, $L \times B$, m | Required turning speed $r_1 = r_3$ (°/min) | | Limit values for the time $t_4$ (s) in shallow and deep water | | |
|---|---|---|---|---|---|---|
| | | δ = 20° | δ = 45° | $1{,}2 \leqslant h/T \leqslant 1{,}4$ | $1{,}4 < h/T < 2$ | $h/T > 2$ |
| 1 | All motor ships, single-in-line convoys, $\leqslant 110 \times 11{,}45$ | 20 °/min | 28 °/min | 150 s | 110 s | 110 s |
| 2 | Single-in-line convoys up to $193 \times 11{,}45$ or two-abreast convoys up to $110 \times 22{,}90$ | 12 °/min | 18 °/min | 180 s | 130 s | 110 s |
| 3 | Two-abreast convoys $\leqslant 193 \times 22{,}90$ | 8 °/min | 12 °/min | 180 s | 130 s | 110 s |
| 4 | Two-abreast convoys up to $279 \times 22{,}90$ or three-abreast convoys up to $193 \times 34{,}35$ | 6 °/min | 8 °/min | (*) | (*) | (*) |
| (*) In accordance with the decision of the Register surveyor. | | | | | | |

For active steering devices or special types of rudder, a position $\delta_a$ of the steering unit or rudder angle $\delta$ other than $\delta = 20°$ and $\delta = 45°$ may be selected, according to the Register surveyor's assessment, depending on the type of steering system.

**6.2.4** In order to determine the turning speed, a rate-of-turn indicator in accordance with Annex IX to Directive 2006/87/EC shall be on board.

**6.2.5** The load condition during the evasive action manoeuvre shall be between 70 and 100 per cent of the maximum deadweight. If the test is carried out with a smaller load, approval shall be restricted to that load limit.

**6.3 Turning capacity.**

**6.3.1** The turning capacity of ships and convoys whose length (*L*) does not exceed 86 m and breadth (*B*) does not exceed 22,9 m shall be considered sufficient, when during an upstream turning manoeuvre with an initial speed in relation to the water of 13 km/h, the limit values for stopping facing downstream established in Section 8 are complied with. The keel clearance conditions according to 6.1 shall be complied with.

**6.4 Other requirements.**

**6.4.1** Notwithstanding 6.1 to 6.3, the following requirements shall be met:

**.1** for manually controlled steering systems, a single turn of the wheel shall correspond to a rudder angle of at least 3°;

**.2** for powered steering systems, when the rudder is at maximum immersion, it shall be possible to achieve an average angular velocity of 4°/s over the rudder's entire turning range.

This requirement shall also be checked, with the ship at full speed, for moving the rudder over a range from 35° port to 35° starboard. In addition, it shall be checked whether the rudder keeps the position of maximum angle at maximum propulsion power. For active steering systems or special types of rudder, this provision applies taking into account their peculiarities.

**6.5 Recording of data and reports.**

**6.5.1** The measurements, reports and recording of data shall be carried out according to the procedure set out in Section 7.

# 7 REPORT ON EVASIVE ACTION MANOEUVRE AND TURNING CAPACITY

**7.1** Report on evasive action manoeuvre and turning capacity shall be drawn up in accordance with Table 7.1. The report shall be signed by the Register surveyor certified with his personal stamp.

Table 7.1

Inspection body: ____________________

Date: ____________________

Name: ____________________

Name of ship: ____________________

Shipowner: ____________________

Type of ship (or convoy): ____________________

$L \times B$, m: ____________________

$T_{test}$, m: ____________________

Test area: ____________________

Depth of water $h$, m; ____________________

$h/T$ (depth to draught ratio): ____________________

Speed of the current, m/s: ____________________

Load during test, t: ____________ % of maximum

Deadweight: ____________________

Rate-of-turn indicator

Type: ____________________

Type of rudder construction: normal construction/special construction (*)

Active steering system: yes/no (*)

Results of evasive action manoeuvres:

| Time $t_1$ to $t_4$ | Rudder angle $\delta$ or $\delta_0$ (*), at which evasive action commences and turning speed to be complied with $r_1 = r_3$ | | | | Com-ments |
|---|---|---|---|---|---|
| | $\delta = 20°$ STAR (*)<br>$\delta_a = \dots$ STAR (*) | $\delta = 20°$ PORT (*)<br>$\delta_a = \dots$ PORT (*) | $\delta = 45°$ STAR (*)<br>$\delta_a = \dots$ STAR (*) | $\delta = 45°$ PORT (*)<br>$\delta_a = \dots$ PORT (*) | |
| | $r_1 = r_3 = \dots$ °/min | | $r_1 = r_3 = \dots$ °/min | | |
| $t_1$, s | | | | | |
| $t_2$, s | | | | | |
| $t_3$, s | | | | | |
| $t_4$, s | | | | | |
| Limit value $t_4$ according to Table 6.2.2 | | | | | |

Turning capacity (if applicable) (*)
Geographic position at start of turning manoeuvre ________________________ km
Geographic position at end of turning manoeuvre ________________________ km
Steering apparatus
Type of operation: manual/powered (*)
Rudder angle for each turn of the wheel (*): ________________________ °
Angular velocity of the rudder over the whole range (*): ________________________ °/s
Angular velocity of the rudder over the range 35° PORT to 35° Starboard (*): ____________ °/s

(*) Delete as appropriate.

## 8 REQUIREMENTS CONCERNING PRESCRIBED (FORWARD) SPEED, STOPPING CAPACITY AND CAPACITY FOR GOING ASTERN

**8.1 Maximum prescribed (forward) speed.**

**8.1.1** The speed in relation to the water shall reach at least 13 km/h. During tests, the following conditions shall be met in the same way as for the stopping test:

**.1** the keel clearance set out in 8.2.1 shall be complied with;

**.2** the measuring, recording, registration and evaluation of test data shall be carried out.

**8.2 Stopping capacity and capacity for going astern.**

**8.2.1** Ships and convoys are deemed able to stop facing downstream in good time when this is proved during a test of stopping in relation to the ground facing downstream at an initial speed in relation to the water of 13 km/h, with a keel clearance equal to at least 20 per cent of the draught but not less than 0,5 m.

**8.2.1.1** In flowing water (current velocity of 1,5 m/s), stopping in relation to the water shall be demonstrated over a maximum distance measured in relation to the ground of:

550 m for ships and convoys of length $L > 110$ m or breadth $B > 11{,}45$ m,

or

480 m for ships and convoys of length $L \leqslant 110$ m and breadth $B \leqslant 11{,}45$ m.

The stopping manoeuvre is completed on coming to a stop in relation to the ground.

**8.2.1.2** In standing water (current velocity of less than 0,2 m/s), stopping in relation to the water shall be demonstrated over a maximum distance, measured in relation to the ground of:

350 m for ships and convoys of length $L > 110$ m or width $B > 11{,}45$ m,

or

305 m for ships and convoys of length $L \leqslant 110$ m and width $B \leqslant 11{,}45$ m.

In standing water, a test shall also be performed to demonstrate that a speed of not less than 6,5 km/h can be reached when going astern.

The measuring, recording and registration of the test data referred to in 8.2.1.1 or 8.2.1.2 shall be carried out in accordance with the procedure set out in Section 9.

Throughout the entire test, the ship or the convoy shall have adequate manoeuvrability.

**8.2.2** During the test, ships shall be loaded as far as possible to between 70 and 100 per cent of their deadweight. This load condition shall be evaluated in accordance with Section 10. When the ship or the convoy is loaded to less than 70 per cent at the time of the test, the permitted maximum displacement in downstream navigation shall be set in accordance with the actual load, provided that the limit values of 8.2.1 are complied with.

**8.2.3** If the actual values of the initial speed and current velocity at the time of the test do not meet the conditions set out in 8.2.1, the results obtained shall be evaluated according to the procedure described in Section 10.

The permitted deviation of the initial speed of 13 km/h shall be not more than +1 km/h, and the current velocity in flowing water shall be between 1,3 and 2,2 m/s, otherwise the tests shall be repeated.

**8.2.4** The permitted maximum displacement or the respective maximum load or the maximum immersed cross-section for ships and convoys in downstream navigation shall be determined on the basis of the tests and entered in the Report on Survey of the Ship.

## 9 MEASURING, RECORDING AND REGISTRATION OF DATA COLLECTED DURING STOPPING MANOEURVRE TESTS

**9.1 Stopping manoeuvre.**

**9.1.1** The ships and convoys shall carry out a test in flowing water or in standing water to prove that they are capable of stopping facing downstream only with their propulsion system without the use of anchors. The stopping manoeuvre shall be carried out in accordance with Fig. 9.1.1. It begins when the ship is traveling at a constant speed of as near as possible to 13 km/h in relation to the water by preserving the engines from "ahead" to "astern" (point A of the order "stop") and is completed when the ship is stationary in relation to the ground (point E: $\nu = 0$ in relation to the ground or point D = E: $\nu = 0$ in relation to the water and in relation to the ground if the stopping manoeuvre is carried out in standing water).

When stopping manoeuvres are carried out in flowing water, the position and the moment of stopping in relation to the water shall also be recorded (the ship moves at the speed of the current; point D: $\nu = 0$ in relation to the water).

The data measured shall be entered in a report as shown in the diagram of Table 9.2.2. Before the stopping manoeuvre is carried out, the unchanging data shall be entered at the top of the form.

The average current velocity ($\nu_{STR}$) in the fairway shall be determined, if available, based on the reading of an established water level gauge, or by measuring the movement of a floating body and shall be entered in the report.

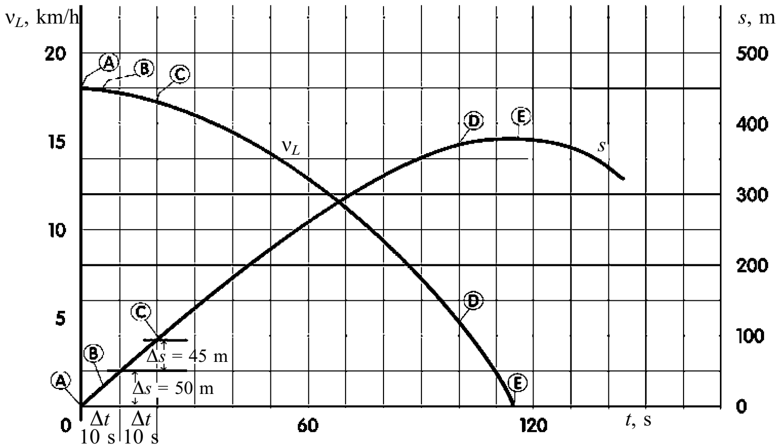


Fig. 9.1.1
Stopping manoeuvre:
A — "stop" order; B — propeller stopped; C — propeller in reverse; D — $v = 0$ in relation to the water; E — $v = 0$ in relation to the ground; $v$ — speed of vessel; $v_L$ — $v$ in relation to the ground; $s$ — distance covered in relation to the ground; $t$ — measured time

The use of current meters is permitted to determine the speed of the ship in relation to the water during the stopping manoeuvre, if it is possible to record the movement and the required data in accordance with the procedure above.

**9.2 Registration of the data measured and recording them in the report.**

**9.2.1** For the stopping manoeuvre, first of all the initial speed in relation to the water shall be determined. This can be done by measuring the time taken to travel between two markers on land. In flowing water, the average current velocity shall be taken into account.

The stopping manoeuvre is initiated by the order "stop" (point A in Fig. 9.1.1), given on passing a marker on land. Passing the land marker shall be recorded perpendicularly to the axis of the ship and shall be entered in the report. Passing all other land markers during the stopping manoeuvre shall be similarly recorded.

The values measured shall, if possible, be recorded at intervals of 50 m. In each case, note shall be taken of the time when points B and C — if possible — as well as when points D and E are reached and the respective position shall be estimated. The data concerning the engine speed need not be recorded in the report, but shall be noted to permit more accurate control of the initial speed.

**9.2.2** Report on stopping manoeuvre shall be drawn up in accordance with Table 9.2.2. The report shall be signed by the Register surveyor and certified with his personal stamp.

Table 9.2.2

**Report on stopping manoeuvre**

Inspection body: ______________________
Date: ______________________
Name: ______________________
Test run No.: ______________________
Type of craft or convoy: ______________________
$L \times B$, m: ______________________
$T$ at test, m: ______________________
Load at test, t: ______________________
% of maximum deadweight: ______________________
Power of propulsion engines $P_B$, kW: ______________________
Propulsion system according to Table 10.4-2: ______________________
Test area: ______________________
Water level gauge reading, m: ______________________
Water depth, m: ______________________
Gradient, m/km: ______________________
Average current velocity $v_{STR}$, km/h (m/s): ______________________
Maximum displacement, m: ______________________

| Position | Time, s | $\Delta s$, m | $\Delta t$, s | $v_{IL}$, km/h | Engine speed $n$, $min^{-1}$ | Observa-tions |
|---|---|---|---|---|---|---|
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |

**9.3 Description of the stopping manoeuvre.**

The stopping manoeuvre shall be presented in the form of a diagram (refer to Fig. 9.1.1). First of all, the time-traverse diagram shall be plotted using the measurements entered in the test report and points A to E shall be indicated. It will then be possible to determine the average speed between two measurement points and to plot the speed/time diagram in accordance with Fig. 9.1.1. By determining the quotient of the difference of position over the difference in time $\Delta s/\Delta t$, the average speed of the ship for this period can be calculated.

Example:

During the interval between 0 and 10 s, the distance from 0 to 50 m is covered.

$\Delta s/\Delta t$ = 50 m/10 s = 5,0 m/s = 18,0 km/h.

This value is entered as the average speed at the 5 s abscissa-position. During the second interval, from 10 to 20 s, a distance of 45 m is covered.

$\Delta s/\Delta t$ = 45 m/10 s = 4,5 m/s = 16,2 km/h.

At marker D, the ship has stopped in relation to the water i.e. current velocity is approximately 5 km/h.

## 10 EVALUATION OF THE RESULTS OF THE STOPPING MANOEUVRE

**10.1** On the basis of the values recorded during the stopping manoeuvre compliance with the limit values in accordance with Section 8 shall be verified. If the conditions for the stopping manoeuvre deviate substantially from the standard conditions, or if there are doubts as to the compliance with the limit values, the results shall be evaluated. To that end the following procedure may be applied for calculating stopping manoeuvres.

**10.2** Theoretical stopping distances are determined under the standard conditions ($S_{reference}$) of 8.2.1 and under stopping manoeuvre conditions ($S_{actual}$), and are compared with the stopping distances measured ($S_{measured}$). The corrected stopping distance of the stopping manoeuvre under standard conditions ($S_{standard}$) is calculated as follows:

$$S_{standard} = S_{measured} \cdot S_{reference}/S_{actual} \leqslant \text{limit value} \qquad (10.2)$$

(refer to 8.2.1.1 or 8.2.1.2).

When the stopping manoeuvre has been carried out with a load of 70 to 100 per cent of the maximum deadweight in order to calculate $S_{standard}$, the displacement ($D_{reference} = D_{actual}$) corresponding to the load at the time of the test shall be used for the determination of $S_{reference}$ and $S_{actual}$.

When in determining $S_{standard}$ according to the Formula (10.2) the limit value in question is exceeded or not reached, the value of $S_{reference}$ shall be reduced by variation of $D_{reference}$ so that the limit value is complied with ($S_{standard}$ = limit value). The maximum displacement permitted in downstream navigation shall be set accordingly.

**10.3** According to the limit values given in 8.2.1.1 and 8.2.1.2, only the stopping distances measured in:

Phase I ($S_{\mathrm{I}}$) — "Full ahead" reversed to "Full astern"; and

Phase II ($S_{\mathrm{II}}$) — end of reversal until ship stops in relation to the water - shall be calculated (refer to Fig. 10.3).

The total stopping distance is then:

$$S_{total} = S_{\mathrm{I}} + S_{\mathrm{II}}. \qquad (10.3)$$

**10.4** The particular stopping distances shall be calculated as follows:

$$S_{\mathrm{I}} = k_1 v_L t_1, \qquad (10.4\text{-}1)$$

$k_1$ — refer to Table 10.4-1;
$t_1 \leqslant 20$ s;

$$S_{\mathrm{II}} = k_2 v_{\mathrm{II}}^2 \frac{Dg}{k_3 F_{POR} + R_{Tm\mathrm{II}} - R_G} (k_4 + v_{STR}/v_{\mathrm{II}}), \qquad (10.4\text{-}2)$$

$k_2$, $k_3$, $k_4$ — refer to Table 10.4-1;

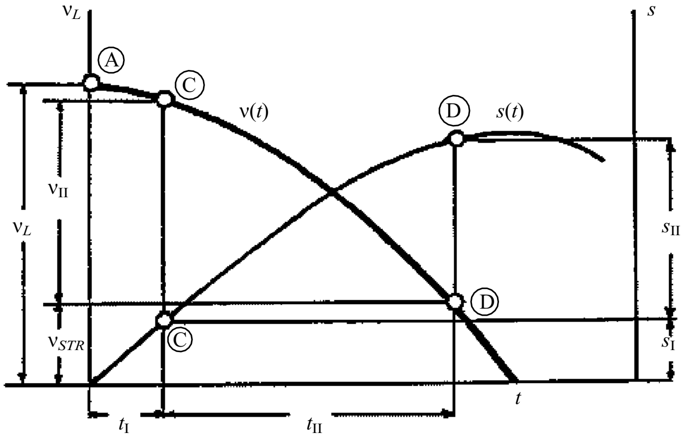


Fig. 10.3
Diagram of stopping manoeuvre

$$R_{Tm\mathrm{II}} = (R_T/v^2)(k_7 k_6(v_L - v_{STR}))^2, \qquad (10.4\text{-}3)$$

$k_6$, $k_7$ — refer to Table 10.4-1;
$R_t / v^2$ — refer to Fig. 10.4;

$$R_G = iD\rho g \cdot 10^{-6}; \qquad (10.4\text{-}4)$$

$$v_{\mathrm{II}} = k_6(v_L - v_{STR}), \qquad (10.4\text{-}5)$$

$k_6$ — refer to Table 10.4-1;

$$F_{POR} = fP_B, \qquad (10.4\text{-}6)$$

$f$ — refer to Table 10.4-2;

$$t_{\mathrm{II}} = \frac{S_{\mathrm{II}}}{v_{\mathrm{II}}(k_4 + v_{STR}/v_{\mathrm{II}})}, \qquad (10.4\text{-}7)$$

$k_4$ — refer to Table 10.4-1

where $v_L$ — speed in relation to the ground at the start of reversal, in m/s;
$t_{\mathrm{I}}$ — reversal time, in s;
$v_{\mathrm{II}}$ — speed in relation to the water at the end of reversal, in m/s;
$D$ — displacement, in $m^3$;
$F_{POR}$ — bollard pull in reverse, in kN;
$P_B$ — power of propulsion engine, in kW;
$R_{Tm\mathrm{II}}$ — average resistance during phase II, to be determined using the diagram for determining $R_T/v^2$, in kN;
$R_G$ — gradient resistance, in kN;
$i$ — gradient (if missing to be taken as 0,16), in m/km;
$v_{STR}$ — average current velocity, in m/s;

$g$ — acceleration due to gravity (9,81), in m/s$^2$;
ρ — density of water, ρ fresh water = 1000, in kg/m$^3$;
$T$ — maximum draught (of ship or convoy), in m;
$h$ — water depth, in m;
$B$ — breadth, in m;
$L$ — length, in m.

Table 10.4-1

***k* factors**

| Factor | Motor ships and single file convoys | Two-abreast convoys | Three-abreast convoys | Units |
|---|---|---|---|---|
| $k_1$ | 0,95 | 0,95 | 0,95 | — |
| $k_2$ | 0,115 | 0,120 | 0,125 | kg·s$^2$/m$^4$ |
| $k_3$ | 1,20 | 1,15 | 1,10 | — |
| $k_4$ | 0,48 | 0,48 | 0,48 | — |
| $k_6$ | 0,90 | 0,85 | 0,80 | — |
| $k_7$ | 0,58 | 0,55 | 0,52 | — |

Table 10.4-2

**Coefficient *f* for ratio between bollard pull in reverse and the power of the propulsion engines**

| Propulsion system | $f$ | Units |
|---|---|---|
| Modern nozzles with rounded rear edge | 0,118 | kN/kW |
| Old nozzles with sharp rear edge | 0,112 | kN/kW |
| Propellers without nozzles | 0,096 | kN/kW |
| Propellers with nozzles (generally sharp rear edge) | 0,157 | kN/kW |
| Rudder propellers without nozzles | 0,113 | kN/kW |

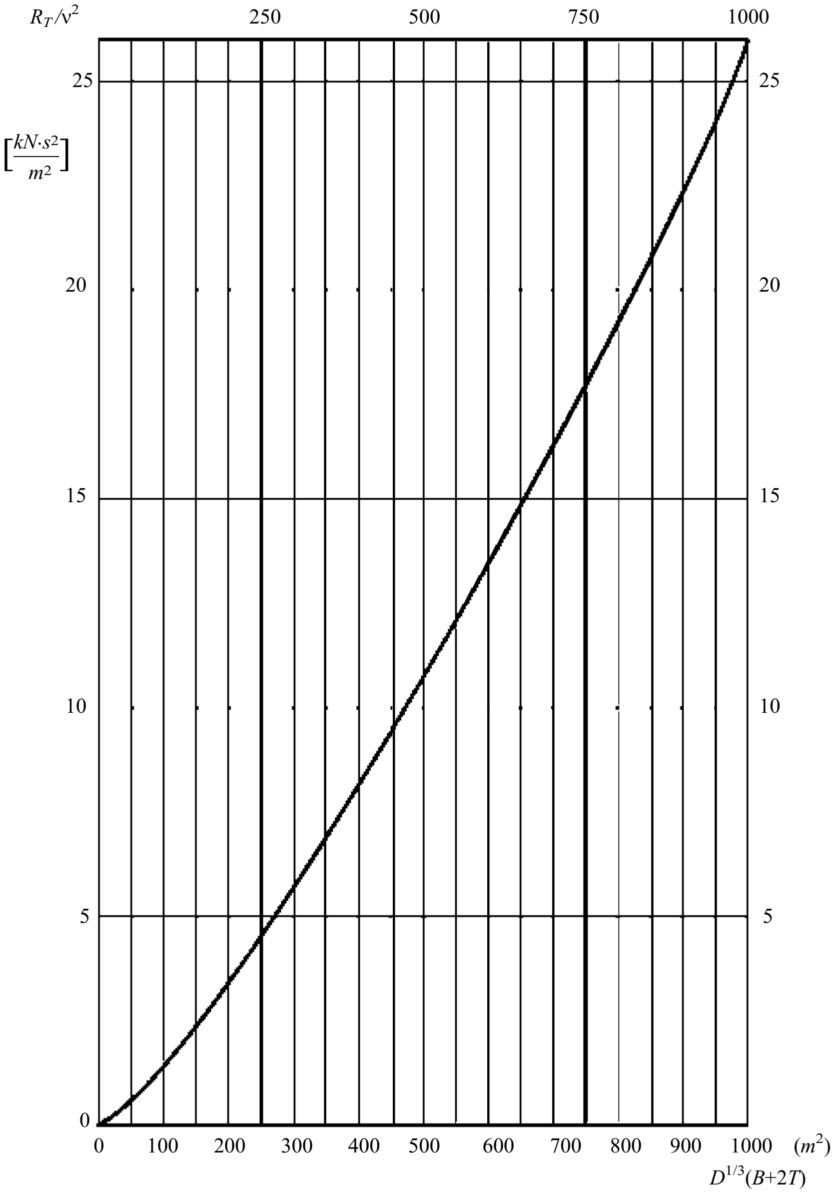


Fig. 10.4
Diagram concerning the calculation of resistance

## 11 EXAMPLES OF THE APPLICATION OF THE PROVISIONS OF SECTION 10 "EVALUATION OF THE RESULTS OF THE STOPPING MANOEUVRE"

**11.1 Example 1.**

**11.1.1 Data of ships and convoy.**

Formation: ordinary motor ship with a (Europa IIa) lighter coupled abreast.

| | $L$, m | $B$, m | $T_{max}$, m | $Dwt^{(*)}_{max}$, т | $D_{max}$, m$^3$ | $P_B$, kW |
|---|---|---|---|---|---|---|
| Motor ship | 110 | 11,4 | 3,5 | 2900 | 3731 | 1500 |
| Lighter | 76,5 | 11,4 | 3,7 | 2600 | 2743 | — |
| Convoy | 110 | 22,8 | 3,7 | 5500 | 6474 | 1500 |
| Propulsion system of the motor ship: modern nozzles with rounded rear edge.<br>(*) $Dwt$ = deadweight. | | | | | | |

**11.1.2 Values measured during the stopping manoeuvre.**

Current velocity: $v_{STR\ actual}$ = 1,4 m/s (5,1 km/h).

Speed of ship (in relation to the water): $v_{S\ actual}$ = 3,5 m/s (12,5 km/h).

Speed of ship (in relation to the ground): $v_{L\ actual}$ = 4,9 m/s (17,6 km/h).

Reversal time (measured) (point A to C): $t_{I}$ =16 s.

Stopping distance in relation to the water (point A to D): $S_{measured}$ = 340 m.

Load condition: $D_{actual}$ = 5179 m$^3$ = 0,8$D_{max}$.

Actual draught of convoy: $T_{actual} = 0{,}8T_{max}$ = 2,96 m.

**11.1.3 Limit value according to 8.2.1.1 or 8.2.1.2 to be compared with Sstandard.**

Since $B$ > 11,45 m and since the convoy is in flowing water, the following is applicable for this convoy under 8.2.1.1; the following is applicable to such a convoy:

$S_{standard}$ < 550 m.

**11.1.4 Determination of corrected stopping distance compared to standard conditions.**

Measured value (according to 9.2):

$S_{measured}$ = 340 m;

to be calculated:

$S_{actual}$ as the sum of $S_{I\ actual}$ (according to the Formula (10.4-1) with $v_{L\ actual}$) and $S_{II\ actual}$ (according to the Formulae (10.4-2) to (10.4-6) with actual speeds $v_{II\ actual}$, $v_{STR\ actual}$, $D_{actual}$),

$S_{reference}$ as the sum of $S_{I\ reference}$ (according to the Formula (10.4-1) with $v_{L\ reference}$) and $S_{II\ reference}$ (according to the Formulae (10.4-2) to (10.4-6) with the reference speeds according to 8.2.1 and given that the load condition is greater than 70 per cent of the maximum load (≈ 80 per cent): $D_{reference} = D_{actual}$ and $T_{reference} = T_{actual}$);

to be checked:

$S_{standard} = S_{measured}\,(S_{reference}/S_{actual}) \leqslant 550$ m.

**11.1.4.1** Coefficients for the calculation taken from Table 10.4-1:

for $S_{I\ actual}$ and $S_{I\ reference}$ $k_1 = 0{,}95$;
for $S_{II\ actual}$ and $S_{II\ reference}$ $k_2 = 0{,}12$;
$k_3 = 1{,}15$;
$k_4 = 0{,}48$;
$k_6 = 0{,}85$;
$k_7 = 0{,}55$.

According to Table 10.4-2 (for modern nozzles with rounded rear edge) $f = 0{,}118$.

**11.1.4.2** Calculation of $S_{actual}$.

**.1** $S_{I\ actual}$ with the values measured during the stopping manoeuvre (Formula (10.4-1)):

$S_{I\ actual} = k_1 \cdot v_{L\ actual} \cdot t_{I\ actual}$;

$S_{I\ actual} = 0{,}95 \cdot 4{,}9 \cdot 16 = 74{,}5$ m;

**.2** $S_{II\ actual} = k_2 v^2_{II\ actual} \dfrac{D_{actual}\,g}{k_3 F_{POR} + R_{TmII\ actual} - R_G} \left(k_4 + v_{STR\ actual}/v_{II\ actual}\right)$;

**.3** Calculation of $R_{TmII\ actual}$ according to Fig. 10.4 and Formula (10.4-3):

$D_{actual}^{1/3} = 5179^{1/3} = 17{,}3$ m;

$D_{actual}^{1/3}(B + 2T_{actual}) = 17{,}3(22{,}8 + 5{,}92) = 496{,}8$ m$^2$;

according to Fig. 10.4: $R_T/v^2 = 10{,}8$ kN·s$^2$/m$^2$;

$v_{L\ actual} - v_{STR\ actual} = 4{,}9 - 1{,}4 = 3{,}5$ m/s;

$R_{TmII\ actual} = (R_T/v^2)(k_7 k_6 (v_{L\ actual} - v_{STR\ actual}))^2 = 10{,}8(0{,}55 \cdot 0{,}85 \cdot 3{,}5)^2 = 28{,}8$ kN;

**.4** calculation of resistance to gradient $R_G$ according to the Formula (10.4-4):

$R_G = 10^{-6}(0{,}16 D_{actual} \cdot \rho \cdot g) = 10^{-6}(0{,}16 \cdot 5179 \cdot 1000 \cdot 9{,}81) = 8{,}13$ kN;

**.5** calculation of $v_{II\ actual}$ according to the Formula (10.4-5):

$v_{II\ actual} = k_6(v_{L\ actual} - v_{STR\ actual}) = 0{,}85 \cdot 3{,}5 = 2{,}97$ m/s;

$v^2_{II\ actual} = 8{,}85$ (m/s)$^2$;

**.6** calculation of $F_{POR}$ according to the Formula (10.4-6) and Table 10.4-2:

$F_{POR} = 0{,}118 \cdot 1500 = 177$ kN;

**.7** calculation of $S_{II\ actual}$ using the Formula (11.1.4.2.2) and the results of 11.1.4.2.3 to 11.1.4.2.6:

$S_{II\ actual} = 0{,}12 \cdot 8{,}85 \cdot 9{,}81(0{,}48 + 1{,}4/2{,}97)5179/(1{,}15 \cdot 177 + 28{,}8 - 8{,}13)$;

$S_{II\ actual} = 228{,}9$ m;

**.8** calculation of total distance according to the Formula (10.3):

$S_{actual} = 74{,}51 + 228{,}9 = 303{,}4$ m.

Note. The term $(R_{TmII} - R_G)$, which is a function of $D$, with an actual value of 20,76 kN is obviously relatively small compared to $k_3 \cdot F_{POR}$ with an actual value of 203,55 kN. So for simplification purposes, $S_{II}$ can be taken as proportional to $D$, i.e. $S_{II} = Constant \cdot D$.

**11.1.4.3** Calculation of $S_{reference}$.

Initial values:

$v_{STR\ reference}$ = 1,5 m/s = 5,4 km/h; $D_{reference} = D_{actual}$ = 5179 m$^3$;

$v_{S\ reference}$ = 3,6 m/s = 13 km/h; $T_{reference} = T_{actual}$ = 2,96 m;

$v_{L\ reference}$ = 5,1 m/s = 18,4 km/h.

**.1** $S_{I\ reference} = k_1 v_{L\ reference} \cdot t_I$;

$S_{I\ reference}$ = 0,95·5,1·16 = 77,50 m;

**.2** $$S_{II\ reference} = k_2 v^2_{II\ reference} \frac{D_{reference}\, g}{k_3 F_{POR} + R_{TmII\ reference} - R_G}\left(k_4 + \frac{v_{STR\ reference}}{v_{II\ reference}}\right);$$

**.3** calculation of $R_{TmII\ reference}$:

$R_T/v^2$ = 10,8 kN·s$^2$/m$^2$ (as in 11.1.4.2, since $B$, $D$ and $T$ are unchanged);

$v_{L\ reference} - v_{STR\ reference}$ = 3,6 m/s;

$R_{TmII\ reference} = (R_T/v^2)(k_7 k_6 (v_{L\ reference} - v_{STR\ reference}))^2 = 10{,}8(0{,}55 \cdot 0{,}85 \cdot 3{,}6)^2 = 30{,}99$ kN;

**.4** resistance due to gradient $R_G$ as in 11.1.4.2;

**.5** calculation of $v_{II\ reference}$:

$v_{II\ reference} = k_6(v_{L\ reference} - v_{STR\ reference}) = 0{,}85 \cdot 3{,}6 = 3{,}06$ m/s;

$v^2_{II\ reference}$ = 9,36 (m/s)$^2$;

**.6** $F_{POR}$ — as in 4.2;

**.7** calculation of $S_{II\ reference}$ using the Formula (11.1.4.3.2) and the result from 11.1.4.3.3 to 11.1.4.3.6;

$S_{II\ reference}$ = 0,12·9,36·9,81(0,48+1,5/3,06)5179/(1,15·177+30,99 – 8,13) =
= 0,0472·5179 = 244,5 m,

where 0,0472 = $Constan_{treference}$;

**.8** calculation of total distance:

$S_{reference} = S_{I\ reference} + S_{II\ reference}$ = 77,5 + 244,5 = 322 m.

**11.1.4.4** Verification of compliance with permissible stopping distance under standard conditions $S_{standard}$ according to the Formula (10.2).

$S_{standard} = S_{measured} S_{reference} / S_{actual}$ = 360,8 m < 550 m.

C o n c l u s i o n . The permissible limit value is far from being reached, i.e.:

admission to downstream navigation is possible without problems for the actual load condition (0,8$D_{max}$);

a higher load condition is possible and may be calculated according to 11.1.5.

**11.1.5 Possible increase of $D_{actual}$ in downstream navigation.**

$(S_{standard})_{Limit} = S_{measured}\,(S_{reference})_{Limit} / S_{actual}$ = 550 m;

$(S_{reference})_{Limit} = 550 S_{actual} / S_{measured}$ = 550·303,4/340 = 490,8 m.

With $S_{II\ reference} = Constant_{reference}\, D$ according to the Note under 11.1.4.2

$(S_{reference})_{Limit} = (S_{I\ reference} + S_{II\ reference})_{Limit} = S_{I\ reference} + 0{,}0472\,(D_{reference})_{Limit}$.

Hence

$(D_{reference})_{Limit} = ((S_{reference})_{Limit} - S_{I\ reference})/0{,}0472 = (490{,}8 - 77{,}5)/0{,}0472 = 8756$ m$^3$.

From this follows that: since $(D_{reference})_{Limit} > D_{max}$ (8756 > 6474) this formation (refer to 11.1.1) may be permitted in downstream navigation with full load.

**11.2 Example II.**

**11.2.1 Data of ships and convoy.**

Formation: large motor ship propelling 2 lighters side-by-side in front and 1 lighter coupled side-by-side.

| | $L$, m | $B$, m | $T_{max}$, m | $Dwt^{(*)}_{max}$, t | $D_{max}$, m$^3$ | $P_B$, kW |
|---|---|---|---|---|---|---|
| Motor ship | 110 | 11,4 | 3,5 | 2900 | 3731 | 1500 |
| Lighter | 76,5 | 11,4 | 3,7 | 2600 | 2743 | — |
| Convoy | 186,5 | 22,8 | 3,7 | 10700 | 11960 | 1500 |
| Propulsion system of the self-propelled ship: modern nozzles with rounded rear edge.<br>(*) *Dwt* = deadweight. | | | | | | |

**11.2.2 Values measured during the stopping manouevre.**

Current velocity: $v_{STR\ actual}$ = 1,4 m/s (5,1 km/h).

Speed of ship (in relation to the water): $v_{S\ actual}$ = 3,5 m/s (12,5 km/h).

Speed of ship (in relation to the bank): $v_{L\ actual}$ = 4,9 m/s (17,6 km/h).

Reversal time (measured) (point A to C): $t_I$ = 16 s.

Stopping distance in relation to the water (point A to D): $S_{measured}$ = 580 m.

Load condition: $D_{actual}$ = 9568 m$^3$ = $0{,}8D_{max}$.

Actual draught of convoy: $T_{actual}$ = 2,96 m = $0{,}8T_{max}$.

**11.2.3 Limit value according to 8.2.1.1 or 8.2.1.2 to be compared with $S_{standard}$.**

Since $B$ > 11,45 m and the convoy is in flowing water, the following applies to this convoy under 8.2.1.1:

$S_{standard} \leqslant 550$ m.

**11.2.4 Determination of the corrected stopping distance compared with standard conditions.**

Measured value: $S_{measured}$ = 340 m.

Calculation to be made:

$S_{actual}$ as the sum of $S_{I\ actual}$ (according to the Formula (10.4-1) with $v_{L\ actual}$) and $S_{II\ actual}$ (according to the Formulae (10.4-2) to (10.4-6) with real speeds $v_{L\ actual}$ (refer to 11.2.2 ) and $D_{actual}$);

$S_{reference}$ as the sum of $S_{I\ reference}$ (according to the Formula (10.4-1) with $v_{L\ reference}$) and $S_{II\ reference}$ (according to the Formulae (10.4-2) to (10.4-6) with reference speeds in conformity with 8.2.1, because the load condition > 70 per cent maximum, where $D_{reference} = D_{actual}$ and $T_{reference} = T_{actual}$).

To be verified:

$S_{standard} = S_{measured}(S_{reference}/S_{actual}) \leqslant 550$ m, otherwise the expression $S^*_{standard}$ = 550 m is applicable by reduction of $D_{actual}$ to $D^*$.

**11.2.4.1** Coefficients for the calculation specified in Table 10.4-1:

for $S_{\text{I}\ actual}$ and $S_{\text{I}\ reference}$ $k_1 = 0,95$;

for $S_{\text{II}\ actual}$ and $S_{\text{II}\ reference}$ $k_2 = 0,12$;

$k_3 = 1,15$;

$k_4 = 0,48$;

$k_6 = 0,85$;

$k_7 = 0,55$.

According to Table 10.4-2 (for modern nozzles with rounded rear edge) $f = 0,118$.

**11.2.4.2** Calculation of $S_{actual}$.

**.1** $S_{\text{I}\ actual}$ using the values measured during the stopping manoeuvre:

$S_{\text{I}\ actual} = k_1 \cdot \nu_{L\ actual} \cdot t_{\text{I}\ actual}$;

$S_{\text{I}\ actual} = 0,95 \cdot 4,8 \cdot 16 = 73$ m;

**.2** formula for $S_{\text{II}\ actual}$:

$$S_{\text{II}\ actual} = k_2 \nu^2_{\text{II}\ actual} \frac{D_{actual}\, g}{k_3 F_{POR} + R_{Tm\text{II}\ actual} - R_G} \left(k_4 + \frac{\nu_{STR\ actual}}{\nu_{\text{II}\ actual}}\right);$$

**.3** calculation of $R_{Tm\text{II}\ actual}$ according to Fig. 10.4 and Formula (10.4-3):

$D_{actual}{}^{1/3} = 9568^{1/3} = 21,2$ m;

$D_{actual}{}^{1/3}(B + 2T_{actual}) = 21,2(22,8 - 5,92) = 609$ m$^2$;

according to Fig. 10.4: $R_T/\nu^2 = 14$ kNs$^2$/m$^2$;

$\nu_{L\ actual} - \nu_{STR\ actual} = 4,8 - 1,4 = 3,4$ m/s;

$R_{Tm\text{II}\ actual} = (R_T/\nu^2)(k_7 k_6(\nu_{L\ actual} - \nu_{STR\ actual}))^2 = 14,0(0,55 \cdot 0,85 \cdot 3,4)^2 = 35,4$ kN;

**.4** calculation of resistance due to gradient $R_G$ according to the Formula (10.4-4):

$R_G = 10^{-6}(0,16 D_{actual} \cdot \rho \cdot g) = 10^{-6}(0,16 \cdot 9568 \cdot 1000 \cdot 9,81) = 15,02$ kN;

**.5** calculation of $\nu_{\text{II}\ actual}$ according to the Formula (10.4-5):

$\nu_{\text{II}\ actual} = k_6(\nu_{L\ actual} - \nu_{STR\ actual}) = 2,89$ m/s;

$\nu^2_{\text{II}\ actual} = 8,35$ (m/s)$^2$;

**.6** calculation of $F_{POR}$ according to the Formula (10.4-6) and Table 10.4-2:

$F_{POR} = 0,118 \cdot 1500 = 177$ kN;

**.7** calculation of $S_{\text{II}\ actual}$ using the Formula (11.2.4.2.2) and the results of 11.2.4.3 to 11.2.4.6:

$S_{\text{II}\ actual} = 0,12 \cdot 8,35 \cdot 9,81(0,48 + 1,4/2,89)9568 / (1,15 \cdot 177 + 35,4 - 15,02)$;

$S_{\text{II}\ actual} = 402$ m;

**.8** calculation of the total distance according to the Formula (10.3):

$S_{actual} = 73 + 402 = 475$ m.

**11.2.4.3** Calculation of $S_{reference}$.

Initial values:

$\nu_{STR\ reference} = 1,5$ m/s = 5,4 km/h; $D_{reference} = D_{actual} = 9568$ m$^3$;

$\nu_{S\ reference} = 3,6$ m/s = 13 km/h; $T_{reference} = T_{actual} = 2,96$ m;

$\nu_{L\ reference} = 5,1$ m/s = 18,4 km/h.

**.1** $S_{\text{I}\ reference} = k_1 \nu_{L\ reference} \cdot t_{\text{I}}$;

$S_{\text{I}\ reference} = 0,95 \cdot 5,1 \cdot 16 = 77,50$ m;

**.2** $S_{\text{II}\ reference} = k_2 v^2_{\text{II}\ reference} \dfrac{D_{reference}\, g}{k_3 F_{POR} + R_{Tm\text{II}\ reference} - R_G}\left(k_4 + \dfrac{v_{STR\ reference}}{v_{\text{II}\ reference}}\right)$;

**.3** calculation of $R_{Tm\text{II}\ reference}$:

$R_T/v^2$ = 14,0 kN·s$^2$/m$^2$ (according to 4.2, since *B*, *D* and *T* unchanged);

$v_{L\ reference} - v_{STR\ reference}$ = 3,6 m/s;

$R_{Tm\text{II}\ reference}$ = 14,0(0,55·0,85·3,6)$^2$ = 39,6 kN;

**.4** resistance due to gradient $R_G$ is calculated according to 4.2;

**.5** calculation of $v_{\text{II}\ reference}$:

$v_{\text{II}\ reference}$ = 0,85·3,6 = 3,06 m/s, $v^2_{\text{II}\ reference}$ = 9,36 (m/s)$^2$;

**.6** $F_{POR}$ is calculated according to 4.2;

**.7** calculation of $S_{\text{II}\ reference}$ using the Formula (11.2.4.3.2) and the results of 11.2.4.3.3 to 11.2.4.3.6:

$S_{\text{II}\ reference}$ = 0,12·9,36·9,81(0,48+1,5/3,06)9568/(1,15·177+39,6 – 15,02) =
= 0,04684·9568 = 448 m,

where 0,04684 = $Constant_{reference}$;

**.8** calculation of the total distance:

$S_{reference}$ = $S_{\text{I}\ reference}$ + $S_{\text{II}\ reference}$ = 77,5 + 448 = 525,5 m.

**11.2.4.4** Verification of compliance with permissible stopping distance under standard conditions $S_{standard}$ according to the Formula (10.2):

$S_{standard} = S_{measured} S_{reference} / S_{actual}$ = 580·525,5/475 = 641 > 550 m.

C o n c l u s i o n . The limit value has clearly been exceeded; admission to downstream navigation is possible only with a load restriction. This restricted load can be determined in conformity with 11.2.5.

**11.2.5 *D** permissible in downstream navigation according to 10.2.**

$S_{standard} = S_{measured} \cdot S^*_{reference} / S_{actual}$ = 550 m,

Therefore:

$S^*_{reference} = 550 S_{actual}/S_{measured} = S_{\text{I}\ reference} + S^*_{\text{II}\ reference}$;

$S^*_{\text{II}\ reference} = Constant_{reference} \cdot D^* = 0{,}04684 D^*$;

$D^*$ = (550(475/580) – 77,5)/0,04684 = 7950 m$^3$.

C o n s e q u e n c e . Since in downstream navigation the permissible displacement *D** is only 7950 m$^3$, the permissible deadweight (*perm. Dwt.*) in this formation is approximately:

*perm.Dwt*/max.*Dwt* = $D^*/D_{\max}$ = 7950/11960 = 0,66.

Permissible deadweight (refer to 11.2.1):

0,66·10700 = 7112 t.

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