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ANCHOR WINDLASS AND CHAIN STOPPERS

NR626 - NOVEMBER 2022

RULE NOTE

BUREAU VERITAS

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RULES, RULE NOTES AND GUIDANCE NOTES

NR626 DT R04 November 2022 takes precedence over previous revision. Unless otherwise specified, these rules apply to anchor windlass and chain stoppers for which an application for certification is dated on or after November 1, 2022, or to anchor windlass and chain stoppers installed on new ships for which contract for construction is signed on or after November 1, 2022. The Society may refer to the contents hereof before November 1, 2022, as and when deemed necessary or appropriate.

The PDF electronic version of this document available at the Bureau Veritas Marine & Offshore website https://marine-offshore.bureauveritas.com/ is the official version and shall prevail if there are any inconsistencies between the PDF version and any other available version.

These rules are provided within the scope of the Bureau Veritas Marine & Offshore General Conditions, enclosed at the end of Part A of NR467, Rules for the Classification of Steel Ships. The current version of these General Conditions is available at the Bureau Veritas Marine & Offshore website.

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NR626

ANCHOR WINDLASS AND CHAIN STOPPERS

Section 1 Anchor Windlass and Chain Stoppers

November 2022

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SECTION 1 Anchor Windlass and Chain Stoppers

Symbols

R_{eH} : Minimum specified yield stress of the steel considered, in N/mm²

R'_{lim} : Minimum yield stress of the aluminium alloy considered, in N/mm², to be taken equal to the minimum value, in welded condition, between $R'_{p0,2}$ (proof stress) and 0,7 R'_m (tensile strength), where $R'_{p0,2}$ and R'_m are defined in NR561 Hull in Aluminium Alloys, Design Principles, Construction and Survey.

1 General

1.1 Application

1.1.1 The anchor windlasses of ships covered by Rules and Rule Notes listed in Tab 1 are to comply with the requirements of the present Note.

Table 1 : Reference Rules

NR467	Rules for the classification of steel ships
NR483	Rules for the classification of naval ships
NR500	Rules for classification and certification of yachts
NR600	Hull structure and arrangement for the classification of cargo ships less than 65 m and non cargo ships less than 90 m

1.1.2 In addition, the design, construction and testing of windlasses are to comply with a recognized standard or code of practice.

The following recognized standards are given as examples:

- SNAME T & R Bulletin 3-15: 2018 - Guide to the Design and Testing of Anchor Windlasses for Merchant Ships
- ISO 7825: 2017 - Deck machinery general requirements
- ISO 4568: 2006 - Shipbuilding - Sea-going vessels - Windlasses and anchor capstans
- JIS F6714: 1995 - Windlasses

Standards not listed above may be considered by the Society on a case-by-case basis.

To be considered acceptable, the standard or code of practice is to specify criteria for stresses, performance and testing.

1.2 Definitions

1.2.1 Windlass

A windlass is a winch designed to wind or unwind chains of ships anchors.

1.2.2 Cable lifter

A cable lifter is a special socketed wheel fitted on the windlass, designed to receive and drive the anchor chain. It should have at least five snugs and be declutchable from the drive.

1.2.3 Chain stopper

A chain stopper is a device, generally a hook, that secure the chain cable and take the strain from the windlass.

1.3 Main particulars

1.3.1 The windlass is to be power driven and suitable for the size of chain cable and the mass of the anchors.

1.3.2 The windlass is to be fitted in a suitable position in order to ensure an easy lead of the chain cables to and through the hawse pipes.

1.3.3 For each chain cable, a chain stopper is normally fitted, arranged between windlass and hawse pipe.

1.4 Case of smaller ships

1.4.1 In mechanically propelled ships of less than 200 GT, a hand-operated windlass or one of the cargo winches may be accepted, provided the requirements relative to the brake capacity and strength (see [2.5] and [2.8]) are satisfied, and that the hoisting power and speed are demonstrated to be sufficient and suitable for the mass of the associated chain and anchor.

2 Performances and strength

2.1 General

2.1.1 The windlass is to achieve the following minimum performances in order to efficiently and safely conduct its main functions.

2.2 Continuous duty pull

2.2.1 The windlass prime mover is to be able to exert for at least 30 minutes a continuous duty pull, Z_{cont}, in kN, corresponding to the grade and diameter, d, in mm, of the chain cables as follows:

- for anchorage depth D,jbi in m, not greater than 82,5m, Z_{cont} is to be taken equal to Z_{cont1}, as given in Tab 2
- for anchorage depth D, in m, greater than 82,5m, Z_{cont} is to be taken equal to:

  $Z_{cont} = Z_{cont1} + (D - 82,5)\ 2,7.10^{-4}\ d^2$

Note 1: The value of Z_{cont} is based on the hoisting of one anchor at a time, with the effects of buoyancy and hawse pipe efficiency (taken equal to 70%) accounted for.

Table 2 : Continuous duty pull

Grade of chain	Z_{cont1}
Q1	$0,0375\ d^2$
Q2	$0,0425\ d^2$
Q3	$0,0475\ d^2$

2.3 Temporary overload

2.3.1 The windlass prime mover is to be able to provide the necessary temporary overload for breaking out the anchor. This temporary overload or “short term pull” is to be at least 1,5 times the continuous duty pull Z_{cont} applied for at least 2 minutes.

2.4 Hoisting speed

2.4.1 The mean speed of the chain cable during hoisting of the anchor and cable is to be at least 0,15 m/s. For testing purposes, the speed is to be measured over two shots of chain cable and initially with at least three shots of chain (82,5 m in length) and the anchor submerged and hanging free.

2.5 Brake capacity (Holding Load) HL

2.5.1 A windlass brake is to be provided with sufficient capacity (holding load HL) to stop the anchor and the chain cable when paying out, and during all other stages of mooring maneuvers.

2.5.2 The capacity of the windlass brake HL, in kN, is to be sufficient to withstand the loads as defined in:

- NR467, Pt B, Ch 12, Sec 4, [2.5]
- NR483, Pt B, Ch 9, Sec 4, [3.6]
- NR500, Pt B, Ch 7, Sec 1, [4.2]
- NR600, Ch 5, Sec 4, [4.1.2]

as applicable.

2.5.3 Alternatively, at the request of the interested parties, if duly justified, other values of windlass brake capacity may be accepted by the Society on a case by case basis. HL is to be therefore verified by test and/or calculations at the satisfaction of the Society and this acceptance is to be formally documented on an memorandum to the Classification certificate.

2.5.4 HL is to be assessed, among other performances to be reached, either during workshop/facilities tests or by calculations.

2.6 Prime mover system brake

2.6.1 The prime mover system of the windlass is to be capable of withstanding, without slipping, a static load exerted on the cable-lifter equal to 1,3 times the continuous duty pull Z_{cont}, when the control drive system is in the neutral position (off), and/or when the power supply has been cut-off. Thus, electric windlasses are to be provided with an automatic brake control system.

2.7 Chain stoppers

2.7.1 Where a chain stopper is fitted, it is to be able to withstand a pull of 80% of the breaking load of the chain, without any permanent deformation of the stressed parts.

2.7.2 The strength of the chain stopper may be verified by means of workshop testing according to [7.2.7].

2.7.3 A chain stopper designed to a recognized national or international standard may be accepted provided its service experience is considered satisfactory by the Society.

2.8 Strength

2.8.1 In general, the stress level in each load-bearing part of a windlass under continuous duty pull (see [2.2]) is not to exceed 40% of R_{eH} or R'_{lim}, as applicable.

2.8.2 The stress level in each load-bearing part of a windlass loaded at brake capacity (see [2.5]) is not to exceed R_{eH} or R'_{lim}, as applicable (no permanent deformation allowed).

2.8.3 The design of the drive train, including prime mover, reduction gears, bearings, clutches, shafts, cable lifter, keyways, bolting and other stress raisers is to consider the dynamic effects of sudden stopping and starting of the prime mover or chain cable so as to limit inertial load.

3 Materials and welding

3.1 General

3.1.1 The characteristics of the materials to be used in the construction of windlass, the general requirements relevant to fabrication by welding and the qualification of welding procedures are to comply with the applicable requirements of NR216 Materials and Welding.

3.1.2 Windlass and chain stoppers may be cast components or fabricated from plate materials. The material in cast components shall be cast steel or nodular cast iron with elongation at break not less than 18%. Plate material in welded parts shall be of grade as given in Tab 3.

Table 3 : Steel grades for plates

Plate thickness t, in mm	Normal strength structural steel	High strength structural steel
t < 20	A	AH
20 < t < 25	B	AH
25 < t < 40	D	DH
40 < t < 150	E	EH
Note 1: For plates above 40mm joined with fillet / partial penetration welds, grade D will normally be accepted.		

3.2 Cable lifters

3.2.1 Cable lifter shafts and cable lifters with couplings shall be made from materials as stated in Tab 4.

Table 4 : Cable lifters

	Chain cable diameter < 46 mm	Chain cable diameter > 46 mm
Cable lifters and couplings	Nodular cast iron or special iron	Cast steel
Cable lifter shaft	Forged or rolled steel, cast steel	

4 Powering systems

4.1 Hydraulic systems

4.1.1 Hydraulic systems, when employed for driving windlasses, are to comply with the provisions of

- NR467, Pt C, Ch 1, Sec 10, [14]
- NR483, Pt C, Ch 1, Sec 10, [13]

as applicable.

4.2 Electrical systems

4.2.1 Electrical systems, when employed for driving windlasses, are to comply with the provisions of:

- NR467, Pt C, Ch 2, Sec 4
- NR483, Pt C, Ch 2, Sec 4

as applicable.

4.2.2 Rotating machines of 100 kW and over are to be type approved or case-by-case approved and surveyed by the Society during testing and, if appropriate, during manufacturing. Tested machines are to be individually certified by the Society.

4.2.3 Where gears are fitted, they are to comply with the provisions of:

- NR467, Pt C, Ch 1, Sec 6
- NR483, Pt C, Ch 1, Sec 6

as applicable, and those rated 100 KW and over are to be certified by the Society.

5 Operational safety

5.1 Protection of mechanical components

5.1.1 To protect mechanical parts including component housings, a suitable protection system is to be fitted to limit the speed and torque at the prime mover. Consideration is to be given to a means to contain debris consequent to a severe damage of the prime mover due to over-speed in the event of uncontrolled rendering of the cable, particularly when an axial piston type hydraulic motor forms the prime mover.

5.2 Couplings

5.2.1 Windlasses are to be fitted with couplings which are capable of disengaging between the cable lifter and the drive shaft. Hydraulically or electrically operated couplings are to be capable of being disengaged manually.

6 Attachment to deck

6.1 Deck reinforcement under windlass and chain stopper

6.1.1 General

Local reinforcement of deck structure is to be provided in way of windlass and chain stopper considering the criteria defined in [6.1.2] and [6.1.3] and the following design loads:

- windlass: Brake capacity as defined in [2.5],
- chain stopper: Design load as defined in [2.7].

6.1.2 Permissible stresses for steel or aluminium structure

The stresses resulting from anchoring design loads induced in the net supporting hull structure are not to be greater than the following permissible values:

a) For strength assessment by means of beam theory or grillage analysis:
   - normal stress: 1,00 ReH or 1,0 R'lim, as applicable
   - shear stress: 0,6 ReH or 0,6 R'lim, as applicable.

   The normal stress is the sum of bending stress and axial stress. The shear stress to be considered corresponds to the shear stress acting perpendicular to the normal stress. No stress concentration factors are to be taken into account.

b) For strength assessment by means of finite element analysis:

Von Mises stress: 1.0 ReH or 1,0 R'lim, as applicable

For strength assessment by means of finite element analysis the mesh is to be fine enough to represent the geometry as realistically as possible. The aspect ratios of elements are not to exceed 3. Girders are to be modelled using shell or plane stress elements. Symmetric girder flanges may be modelled by beam or truss elements. The element height of girder webs is not to exceed one-third of the web height. In way of small openings in girder webs, the web thickness is to be reduced to a mean thickness over the web height. Large openings are to be modelled. Stiffeners may be modelled using shell, plane stress, or beam elements. The mesh size of stiffeners is to be fine enough to obtain proper bending stress. If flat bars are modelled using shell or plane stress elements, dummy rod elements are to be modelled at the free edge of the flat bars and the stresses of the dummy elements are to be evaluated. Stresses are to be read from the centre of the individual element. For shell elements the stresses are to be evaluated at the mid plane of the element.

Note 1: The stresses are to be based on net thicknesses obtained by deducting the corrosion addition t_c given in the applicable Society's rules.

6.1.3 Permissible stresses for composites materials structure

The stresses resulting from the application of the design loads defined in [6.1.1] and acting on the supporting hull structures of windlass and chain stopper are to comply with the safety coefficient as defined in:

- NR500, Pt B, Ch 7, Sec 1, [4.2.3]
- NR600, Ch 5, Sec 4, [4.4]

as applicable.

6.1.4 As far as practicable, deck reinforcements are to be in line with the windlass frame, for proper load transmission.

6.2 Additional requirements for windlasses located on fore deck

6.2.1 General

Additional requirements provided under this sub-article apply only to windlasses located within the forward quarter length of the ship.

These requirements apply to all ship types of sea going service of length 80 m or more, where the height of the exposed deck in way of the item is less than 0,1 L or 22 m above the summer load waterline, whichever is the lesser.

Where mooring winches are integral with the anchor windlass, they are to be considered as part of the windlass.

The strength of deck framing and hull structure supporting the windlass and its securing bolt loads as defined in [6.2.2] is to be checked according to relevant criteria in:

- NR467, Pt B, Ch 7, Sec 4 or NR467, Pt B, Ch 7, Sec 5 or NR467, Pt B, Ch 7, Sec 6
- NR483, Pt B, Ch 7, Sec 1 or NR483, Pt B, Ch 7, Sec 2 or NR483, Pt B, Ch 7, Sec 3

as applicable.

6.2.2 Loading

The following pressures and associated areas are to be applied (see Fig 1):

- 200 kN/m² normal to the shaft axis and away from the forward perpendicular, over the projected area in this direction
- 150 kN/m² parallel to the shaft axis and acting both inboard and outboard separately, over the multiple of f times the projected area in this direction, where:

  f = 1 + B / H, without being greater than 2,5

  B : Width of windlass measured parallel to the shaft axis

  H : Overall height of windlass.

Forces in the bolts, chocks and stoppers securing the windlass to the deck are to be calculated. The windlass is supported by N bolt groups, each containing one or more bolts, see Fig 2.

The axial force R_i in bolt group (or bolt) i, positive in tension, may be calculated from:

$R_{xi} = (P_x\ h\ x_i\ A_i) / I_x$

$R_{yi} = (P_y\ h\ y_i\ A_i) / I_y$

$R_i = R_{xi} + R_{yi} - R_{si}$

where:

A_i : Cross sectional area of all bolts in group i, in cm²

h : Shaft height above the windlass mounting, in cm

I_x : $\sum A_i\ x_i^2$ for N bolt groups

I_y : $\sum A_i\ y_i^2$ for N bolt groups

P_x : Force, in kN, acting normal to the shaft axis

P_y : Force, in kN, acting parallel to the shaft axis, either inboard or outboard whichever gives the greater force in bolt group i

R_{si} : Static reaction at bolt group i, due to weight of windlass

x_i, y_i : x and y coordinates of bolt group i from the centroid of all N bolt groups, positive in the direction opposite to that of the applied force, in cm.

Shear forces F_{xi}, F_{yi} applied to the bolt group i, and the resultant combined force F_i may be calculated from:

$F_{xi} = (P_x - \alpha\ g\ M) / N$

$F_{yi} = (P_y - \alpha\ g\ M) / N$

$F_i = (F_{xi}^2 + F_{yi}^2)^{0,5}$

Where:

α : Coefficient of friction, taken equal to 0,5

g : Gravity acceleration, taken equal to 9,81 m/s^2

M : Mass of windlass, in tonnes

N : Number of bolt groups.

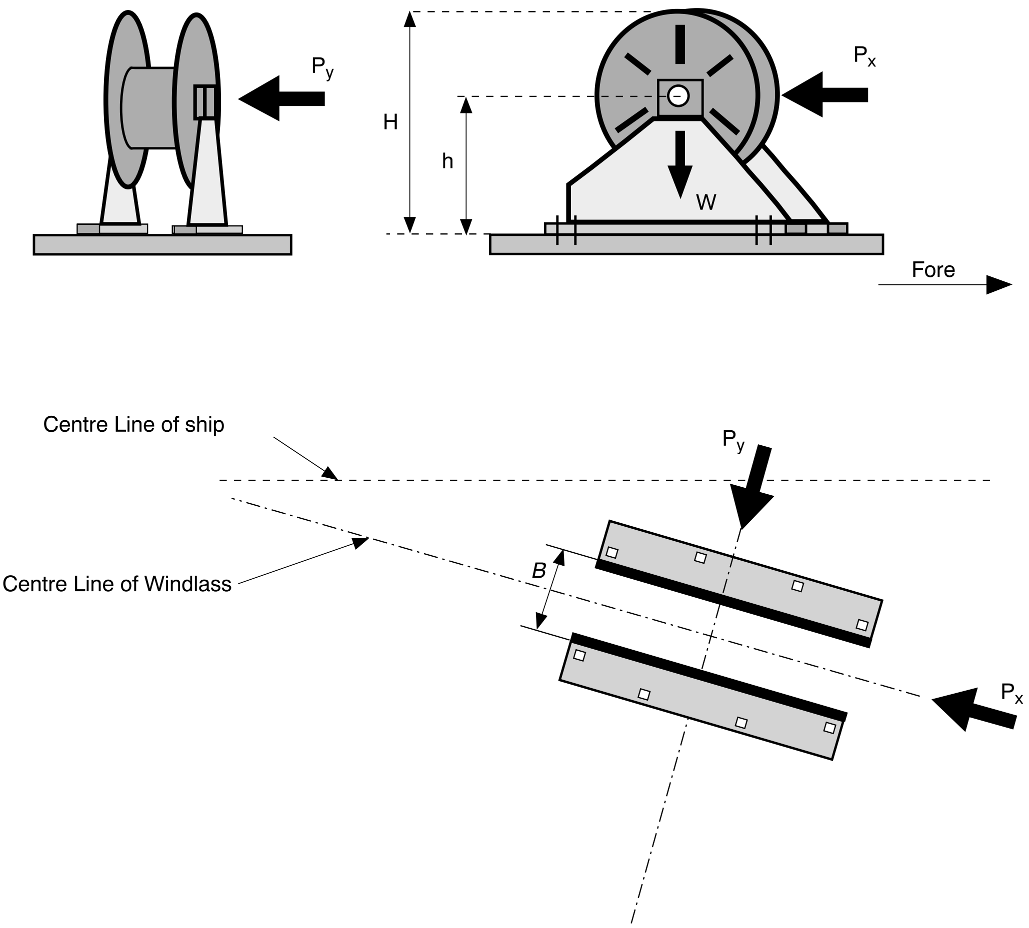
The design of the supporting structure are to take also into account the axial tensile and compressive forces R_{xi}, R_{yi}, R_i, and lateral forces F_{xi}, F_{yi}, F_i, calculated for bolt groups according to formulae above.

6.2.3 Strength requirements

Tensile axial stresses in the individual bolts in each bolt group i are to be calculated. The horizontal forces Fxi and Fyi are normally to be reacted by shear chocks. Where "fitted" bolts are designed to support these shear forces in one or both directions, the von Mises equivalent stresses in the individual bolts are to be calculated, and compared to the stress under proof load. Where pour-able resins are incorporated in the holding down arrangements, due account is to be taken in the calculations.

The safety factor against bolt proof strength is to be not less than 2,0.

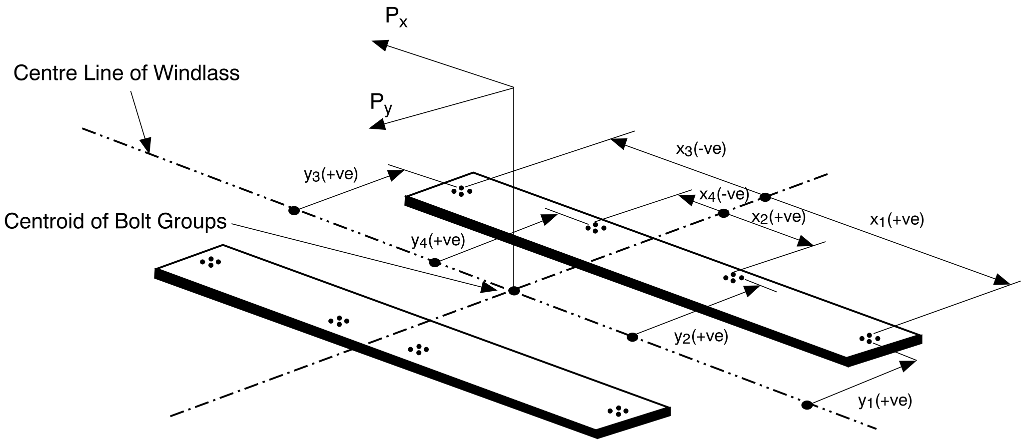
Figure 1 : Direction of forces and weight



Note that P_y is to be examined from both inboard and outboard directions separately - see [6.2.2].

The sign convention for y_i is reversed when P_y is from the opposite direction as shown.

Figure 2 : Sign convention



Coordinates x_i and y_i are shown as either positive (+ve) or negative (–ve).

7 Approval procedure

7.1 Plans and particulars to be submitted for review

7.1.1 The following plans showing the design specifications, the standard of compliance, engineering analyses and details of construction, as applicable, are to be submitted to the Society for evaluation:

- Windlass technical specifications; anchor and chain cable particulars (diameter and steel grade); main performances; design anchorage depth; standard of compliance
- Windlass arrangement plan showing all of the components of the anchoring/mooring system such as the prime mover, shafting, cable lifter, anchors and chain cables; mooring winches, wires and fairleads, if they form part of the windlass machinery; brakes; controls; etc
- Dimensions, materials, welding details, as applicable, of all torque-transmitting components (shafts, gears, clutches, couplings, coupling bolts, etc.) and all load bearing components (shaft bearings, cable lifter, sheaves, drums, bed-frames, etc.) of the windlass and of the winch, where applicable, including brakes, chain stopper (if fitted) and foundations
- Hydraulic piping system diagram along with system design pressure, safety valves arrangement and setting, material specifications for pipes and equipment, typical pipe joints, technical data and details of hydraulic motors, as applicable
- Electric one line diagram along with cable specification and size; motor controller; protective device rating or setting; as applicable
- Control, monitoring and instrumentation arrangements
- Engineering analyses for torque-transmitting and load-bearing components demonstrating their compliance with recognized standards or codes of practice. Analyses for gears are to be in accordance with a recognized standard
- Windlass foundation structure, including under deck supporting structures, and holding down arrangements
- Plans and data for windlass electric motors including associated gears rated 100 kW (135 hp) and over
- Calculations demonstrating that the windlass prime mover is capable of attaining the hoisting speed, the required continuous duty pull, and the overload capacity are to be submitted if the workshop load test is not carried out according to [7.2.5]
- Operation and maintenance procedures for the anchor windlass are to be incorporated in the vessel operations manual.

7.2 Workshop inspection and testing

7.2.1 General

Windlasses are to be inspected during fabrication at the manufacturers' facilities by a Surveyor for compliance with the approved plans.

7.2.2 Material

Material certificates of the main structural parts, including main shaft and brake are to be available.

7.2.3 Prime mover

Each prime mover is to be tested at the shop to verify its ability to meet the power, speed and braking capacity, as required in [2.2], [2.3], [2.4] and [2.6].

For electric motors of more than 50 kW, Type Approval certificates must be available.

For hydraulic windlass, the hydraulic system is to be tested at 1,5 times the maximum working pressure. In addition to the hydraulic motor, the hydraulic pump is also to be tested at the shop. During the testing, the input/output torque, speed, delivery pressures and flow rates of the pump and the hydraulic motor are to be measured, as appropriate.

7.2.4 No-load test

The windlass is to be run without load at nominal speed in each direction for a total of 30 minutes. If the windlass is provided with a gear change, additional run in each direction for 5 minutes at each gear change is required.

7.2.5 Load test

The windlass is to be tested to verify that the continuous duty pull, temporary overload and hoisting speed as specified in [2.2], [2.3] and [2.4] can be attained.

Where the manufacturer’s shop does not have adequate facilities to perform these tests, the following procedure is to be followed:

- The windlass manufacturer is to submit calculations to the Society for review in order to demonstrate the windlass performances and strength. For the purpose of these calculations the stresses in each torque-transmitting component are not to exceed 40% of ReH or R'lim, as applicable, under duty pull loading condition (see [2.2]), or 60% of ReH or R'lim, as applicable, under temporary overload condition (see [2.3])
- The load tests, including the adjustment of the overload protection, are to be carried out on board ship.

In this case, functional testing at the manufacturer's shop is to be performed under no-load conditions as per [7.2.4].

7.2.6 Brake capacity test

The holding Load of the brake is to be verified through testing, by applying for 2 min the required load, as defined in [2.5], on the cable-lifter.

During testing, the cable-lifter is to be disengaged from the prime mover system.

Upon testing, a visual inspection is to be carried out to check that there is no permanent deformation on the windlass structural and mechanical parts.

Where this test cannot be performed for practical reasons, the windlass manufacturer is to submit calculations to the Society for review. See details and guidance in [8].

7.2.7 Chain stoppers

The design load defined in [2.7.1] is to be applied on the chain stopper for 2 min.

Upon testing, a visual inspection is to be carried out to check that there is no permanent deformation on the chain stopper.

Where this test cannot be performed for practical reasons, the chain stopper manufacturer is to submit calculations to the Society for review considering the strength criteria defined in [8.4.1].

7.3 On-board working test of windlass

7.3.1 General

The working test of the windlass is to be carried out on board in the presence of a Surveyor to demonstrate satisfactory operation.

Each unit is to be independently tested for braking, clutch functioning, lowering and hoisting of chain cable and anchor, proper riding of the chain over the chain lifter, proper transit of the chain through the hawse pipe and the chain pipe, and proper stowage of the chain and anchor.

It is to be confirmed that anchors properly seat in the stored position and that chain stoppers function as designed if fitted.

The test is to demonstrate that the windlass complies with the requirements of [2] and, in particular, that it works adequately and has sufficient power to weigh the bower anchor at the required speed (excluding the housing of the anchor in the hawse pipe) when suspended to the maximum practicable length of chain cable.

The braking capacity is to be tested by intermittently paying out and holding the chain cable by means of the application of the brake. Where the available water depth is insufficient, the proposed test method will be specially considered.

Where a double windlass or two windlasses are fitted, the tests are to be performed on both sides.

7.4 Type approval

7.4.1 Windlass

At the request of the manufacturers, windlass produced in series may be Type Approved.

To achieve type approval procedure, a windlass specimen is to be fully approved as per the present Rule Note requirements, including the load and brake tests. For each produced windlass, the following points will have to be checked by the Surveyor before certification can be granted individually:

- consistency with approved drawings (materials, design)
- tests at workshop listed in [7.2.3], [7.2.4] and [7.2.5]
- check of material certificates (main shaft, casing, drum, guide roller and guide pins).

7.4.2 Chain stoppers

At the request of the manufacturers, chain stoppers produced in series may be Type Approved.

To achieve type approval procedure, a chain stopper specimen is to be fully approved as per the present Rule Note requirements, including the test under design load. For each produced chain stopper, the following points will have to be checked by the Surveyor before certification can be granted individually:

- consistency with approved drawings (materials, scantlings and welding)
- test at workshop as described in [7.2.7]
- check of material certificate.

7.5 Marking

7.5.1 Windlass shall be permanently marked with the following information:

- nominal size of the windlass (e.g. 100/3/45 is the size designation of a windlass for 100 mm diameter chain cable of grade 3, with a holding load of 45% of the breaking load of the chain cable)
- maximum anchorage depth, in metres.

8 Alternative method to brake capacity test at workshop

8.1 General

8.1.1 Where the brake capacity test is not possible or practical at the workshop, the manufacturer is to submit calculations to the Society for review, demonstrating that the windlass is capable of attaining the required performances listed in [2.5], including a strength assessment of every load bearing component.

8.1.2 Assessment of actual minimum brake capacity

The actual minimum brake capacity is to be assessed as defined in [8.2] to [8.4]. Additional calculations to assess the strength of internal structure of the brake may be required to be submitted.

8.2 Minimum torque calculation

8.2.1 The minimum braking torque t_{min}, in kN.m, to be achieved by the windlass brake in order to withstand the requested load HL defined in [2.5] can be expressed as follow in the case of ordinary drum brake design:

$$t_{min} = HL\ 0,5 d_{cl}$$

where:

d_{cl} : Diameter of the cable-lifter, in m.

8.3 Achieved torque

8.3.1 General

The maximum torque achieved by the windlass brake, t_{actu}, in kN.m, is to be at least equal to t_{min} as defined in [8.2], so that:

$$t_{actu} \geq t_{min}$$

The achieved maximum torque may be calculated as follow:

$$t_{actu} = E\ 0,5\ d_d$$

where:

d_d : Brake drum diameter, in m

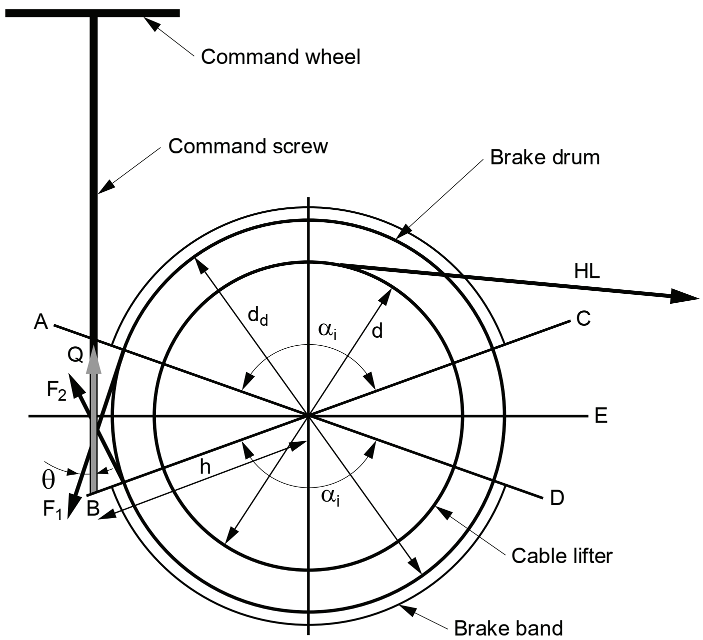
E : Force tangential to the brake drum, in kN.

The calculation of E is proposed in [8.3.2] to [8.3.4] for the following typical drum brakes arrangements:

- fixed in one point (in point A on Fig 3)
- with two pivots (in points C and D on Fig 3)
- with one pivot (in point E on Fig 3)
- with a rod link (in point A on Fig 3).

For any other brake arrangement, the torque is to be calculated using an appropriate standard.

Figure 3 : Brake arrangement



α	:	Total angle, in radian, of brake band coverage, taken as the sum of α_i
h	:	Distance, in m, from the center of the brake drum to the command screw
θ	:	Angle, in degree, between the command screw and the direction of F_1 force. May generally be taken equal to half the angle between points A and B.

8.3.2 Calculations for brake arrangement with one fixed point

The loads in the various parts of the brake system may be calculated according to the formulae given in Tab 5.

8.3.3 Calculations for brake arrangement with one or two pivots

The loads in the various parts of the brake system may be calculated according to the formulae given in Tab 7.

8.3.4 Calculations for brake arrangement with a rod link

The loads in the various parts of the brake system may be calculated according to the formulae given in Tab 6.

Table 5 : Brake system with one fixed point

Tangential force E, in kN	$E = F_1 - F_2$
Larger force F_1, in kN **(1)**	$F_1 = F_2 \cdot e^{\alpha\rho}$
Smaller force F_2, in kN **(1)**	$F_2 = \dfrac{Q \cdot \cos\theta \cdot h}{0,5 \cdot d_d}$
Force in the command screw Q, in kN **(1)**	$Q = \dfrac{2M_W \cdot (1 - \tan\beta \cdot f_s)}{d_s \cdot (\tan\beta + f_s)}$
Torque in the command wheel M_w, in kN.m	$M_w = F_c \cdot d_w$

(1) See Fig 3.
Note 1: See Fig 3 for definition of θ, h and α

β	:	Angle, in degree, of the command screw thread
d_s	:	Command screw mean diameter, in m, taken at the middle of the thread
d_w	:	Command wheel diameter, in m
F_c	:	Force applied on each side of the command wheel, in kN. In case of manual command, this force is to be taken not more than 0,1 kN
f_s	:	Friction coefficient of the command screw, taken equal to 0,15 unless otherwise justified
ρ	:	Friction coefficient between the brake band and the brake drum, taken equal to 0,25 unless otherwise justified by testing

Table 6 : Brake system with a rod link

Tangential force E, in kN	$E = F_1 - F_2$
Larger force F_1, in kN **(1)**	$F_1 = F_2 \cdot e^{\alpha\rho}$
Smaller force F_2, in kN **(1)**	$F_2 = \dfrac{Q \cdot \cos\theta \cdot h}{0,5 \cdot d_d \cdot r}$
Force in the command screw Q, in kN **(1)**	$Q = \dfrac{2M_W \cdot (1 - \tan\beta \cdot f_s)}{d_s \cdot (\tan\beta + f_s)}$
Torque in the command wheel M_w, in kN.m	$M_w = F_c \cdot d_w$

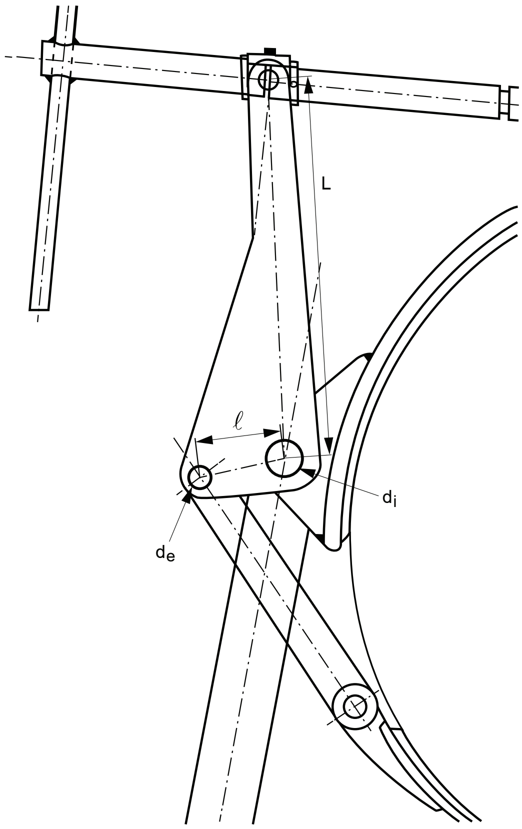
(1) See Fig 3.
Note 1: See Fig 3 for definition of θ, h and α
See Tab 5 for definition of ρ, β, f_s, d_s, d_w and F_c
See Fig 4 for definition of d_i, and d_e
f_t : Friction coefficient of the rod link toe, taken equal to 0,15 unless otherwise justified
r : Ratio ℓ/L of the rod link, as shown on Fig 4

Table 7 : Brake system with one or two pivots

Tangential force E, in kN	$E = \dfrac{Q \cdot \cos\theta \cdot h}{0,5 \cdot d_d}$
Larger force F_1, in kN **(1)**	$F_1 = E \cdot \dfrac{e^{\alpha\rho}}{e^{\alpha\rho} - 1}$
Smaller force F_2, in kN **(1)**	$F_2 = F_1 \cdot E$
Force in the command screw Q, in kN **(1)**	$Q = \dfrac{2M_W \cdot (1 - \tan\beta \cdot f_s)}{d_s \cdot (\tan\beta + f_s)}$
Torque in the command wheel M_w, in kN.m	$M_w = F_c \cdot d_w$

(1) See Fig 3.
Note 1: See Fig 3 for definition of θ, h and α
See Tab 5 for definitions of ρ, β, f_s, d_s, d_w and F_c

Figure 4 : Rod dimensions



d_e : Diameter, in m, of the rod link external pivot
d_i : Diameter, in m, of the rod link internal pivot
L, ℓ : Dimension, in m, of the rod link.

8.4 Strength assessment

8.4.1 General

The maximum load in each part of the windlass is to be deduced from the maximum achieved torque tactu, in order to check that the stress is nowhere greater than the following admissible values:

$$\sigma_{all} = R_{eH}$$

$$\tau_{all} = \frac{R_{eH}}{\sqrt{3}}$$

A special attention is to be paid to pad eyes and pins and to the structures and frames they are welded to, to ensure proper structural continuity.

8.4.2 Brake band pressure

In general, the pressure pb, in kN/m², between the brake band and the brake drum is not to exceed the allowable pressure according to the band lining manufacturer's specification.

The value of pb at maximum braking capacity is taken equal to:

$$p_b = \frac{E}{(\rho \cdot S_b)}$$

where:

E : Force tangential to the drum, as defined in [8.3.1]

ρ : Friction coefficient between the brake band and the brake drum, as defined in Tab 5

S_b : Contact surface, in m², between the brake band and the brake drum, taken equal to:

$$S_b = \frac{\alpha \cdot d_d \cdot b_b}{2}$$

where:

α : Total angle of brake band coverage, as defined in Tab 5

b_b : Band breadth, in m

d_d : Brake drum diameter, in m.

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