Anchor loads and rate of turn M.S. Planet V

Part I: Study on anchor loads

Report No. : **26405-TM-01**
Date : **22 October 2012**

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MARIN order No. : 26405
Ordered by : Dutch Safety Board

Revision no.	Status	Date	Author	Reviewed by
0	Draft	21 September 2012	B.J. den Hollander	H.J.J. van den Boom
1	Final	22 October 2012	B.J. den Hollander	H.J.J. van den Boom

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1 INTRODUCTION

The Dutch Safety Board is investigating the accident of Motor Ship PLANET V on the Western Scheldt on May 26, 2012. The vessel experienced a full black out while overtaking a barge towed by MTS Vantage. The speed through the water at the moment of blackout was approximately 11 knots whereas the speed over ground was approximately 9 knots. After the blackout, the vessel turned to port in the direction of the tow. The crew made an attempt to avoid a collision by use of the port side bow anchor. The anchor winch brake however was not able to stop the running anchor chain. The anchor chain fully ran out and broke out of the chain locker fatally injuring a nearby standing crew-member. Also, the collision with the barge could not be avoided.

In her investigation of the accident, the Safety Board would like to find the answer to the following two questions:

First question: What is the magnitude of the loads on the anchor gear and the vessel when a vessel is stopped by the anchor? What are the main parameters and what loads can be expected for various scenarios?

Second question: What is the cause of the Rate of Turn of the vessel after the black-out and what could have prevented this Rate of Turn?

This report gives insight in the first question by answering the following sub questions:

a. What parameters influence the magnitude and direction of the loads on the anchor gear and vessel when the vessel is stopped by the anchor?
b. What are the regulatory requirements for the anchor gear of the Planet V?
c. What were the magnitude and direction of the loads on the anchor gear and vessel when the vessel was stopped by the anchor?
d. How do the magnitude and direction of the loads on the anchor gear and vessel relate to the regulatory requirements?
e. What is the influence of each of the individual parameters on the magnitude and direction of the loads on the anchor gear and vessel when the vessel is stopped by the anchor (i.e. a sensitivity analysis)?
f. What magnitude and direction of the loads on the anchor gear and vessel when the vessel is stopped by the anchor can be expected in various scenarios?
g. What was the magnitude and direction of the loads on the anchor winch brake?
h. How did the magnitude and direction of the loads on the anchor winch brake relate to the holding power of the anchor winch brake?

The answer to the second question is given in Part II of this report.

2 REGULATORY REQUIREMENTS ON ANCHOR GEAR PLANET V

2.1 Classification Planet V

As the anchor gear onboard ships are one of the safety devices, it is part of class regulation. In case of M.S. Planet V, the vessel and its equipment are build under Germanischer Lloyd regulations: GL Class GL 100 A5 E “Container Vessel”.

2.2 Rules and regulations on anchor gear

The classification rules and guidelines are public and can be found on the Germanischer Lloyd website. The anchor gear regulations that are applicable on Planet V are listed below and added to this report in Appendix I.

The equipment regulations, including the anchor gear regulations, can be found in: *Rules and Guidelines, I – Ship Technology, Part 1 – Seagoing Ships, Chapter I – Hull Structures, Section 18 – Equipment.*

Reading the note in the first paragraph of chapter A.1 of the named section, it becomes clear that the regulations exclude the intendancy to use the anchor gear as an emergency brake. This note states:

> *“The anchoring equipment required by this Section is intended of temporary mooring of a vessel within a harbour or sheltered area when the vessel is awaiting berth, tide, etc.*
>
> *The equipment is, therefore, not designed to hold a ship off fully exposed coasts in rough weather or to stop a ship which is moving or drifting. In this condition the loads on the anchoring equipment increase to such a degree that its components may be damaged or lost owing to the high energy forces generated, particularly in large ships.*
>
> *The anchoring equipment required by this Section is designed to hold a ship in good holding ground in conditions such as to avoid dragging of the anchor. In poor holding ground the holding power of the anchors will be significantly reduced.*
>
> *The equipment numeral formula for anchoring equipment required under this Section is based on an assumed current speed of 2.5 m/sec, wind speed of 25 m/sec and a scope of chain cable between 6 and 10, the scope being the ratio between length of chain paid out and water depth.*
>
> *It is assumed that under normal circumstances a ship will use only one bow anchor and chain cable at a time.”*

The next chapters will show what the extra forces are on the anchor gear for a sailing vessel in relation to the forces the regulations are based on.

2.3 Anchor gear design loads

Section 2.2 states that the anchor gear is designed to keep a vessel in steady position using one anchor at a maximum current speed of 2.5 m/s and maximum wind speed of 25 m/s.

Using wind and current drag coefficients, equilibrium in loads and yaw momentum can be calculated for a wind speed of 25 m/s and a current of 2.5 m/s. As for the Planet V these coefficients are unknown, standard, non-dimensionalised coefficients are used. For the wind coefficients, code number FRE0303BN from the University of Hamburg is used. For the current coefficients OCIMF coefficients [1] are used.

Formulas:

$Fx_{wind} = 0.5 * rho_{air} * V_{wind}^2 * Cx_{wind} * A_{lateral}$
$Fy_{wind} = 0.5 * rho_{air} * V_{wind}^2 * Cy_{wind} * A_{lateral}$
$M_{wind} = 0.5 * rho_{air} * V_{wind}^2 * Cn_{wind} * A_{lateral}$ * Vessel length

$Fx_{current} = 0.5 * rho_{water} * V_{current}^2 * Cx_{current}$ * Vessel length * draught
$Fy_{current} = 0.5 * rho_{water} * V_{current}^2 * Cy_{current}$ * Vessel length * draught
$M_{current} = 0.5 * rho_{water} * V_{current}^2 * Cn_{current} * A_{lateral}$ * Vessel length^2 * draught

Rho_{air} = 1.25 kg/m^3
Rho_{water} = 1023 kg/m^3
Cx/y/n = drag coefficients
Vessel length = 116.4 m
$A_{lateral}$ = 1204 m^2
Draught = 6.8 m
Vessel length = 116.4 m

Wind and current loads, as well as yaw momentums are calculated for angles 0-90 degrees (of the bow in steps of 10 degrees). To get the vessel in a stationary position behind the anchor, an equilibrium of wind and current yaw momentums must be achieved.

The 100 calculations made (10 wind angles times 10 current angles) show that an equilibrium is reached with a wind angle 50 degrees of one bow and a current angle 10 degrees of the other bow. The combined wind and current loads in x- and y-direction result in a horizontal (anchor chain) load of 306.8 kN; well below the Planet V anchor proof load of 580 kN.
Assuming a catenary anchor chain shape from anchor to vessel, the formulas in section 3.5 show that a horizontal load of 306.8 kN will result in a vertical chain load (= load on anchor brake) of 85 kN and a total chain load of 318 kN, being 22% of the chain break load.

3 ANCHOR GEAR LOADS

3.1 Anchor winch load parameters

Numerous parameters are of influence on the anchor winch loads and the stopping distance when the anchor is used to stop a sailing vessel. Parameters are:

- Displacement of the vessel
- Sailing speed over ground
- Wind exposed area
- Wind speed and direction
- Current speed and direction
- Anchor type
- Anchor weight
- Anchor chain type
- Anchor chain weight
- Anchor chain length (at seabed)
- Type of anchor soil at the anchor location
- Anchor winch brake power
- Anchor winch holding power

When a vessel, at relative high speed, has to be stopped by the anchor, dominant parameters are the holding power of the anchor, the drag of the chain over the seabed, the weight and elasticity of the anchor chain and the brake power of the anchor winch.

3.2 Planet V particulars on May 26, 2012

Lpp	= 107.8 m
B	= 19.2 m
$T_{forward}$	= 6.8 m
T_{aft}	= 6.8 m
Water depth	= 25 m
SOG	= 9.0 kn
Heading (initial)	= 248 deg
Current speed	= 2 kn
Current direction	= 074 deg (towards)
Wind speed	= 7 m/s
Wind direction	= 070 deg (coming from)

Anchor type	= SPEK
Anchor weight	= 4030 kg
Chain grade	= K3
Chain diameter	= 48 mm
Chain length	= 250 m
Breaking load	= 1814 kN
Holding load chain brake	= 80% chain breaking load = 1448 kN
Anchor ground	= Sand

3.3 Vessel kinetic energy

An object in motion represents kinetic energy. This energy can be calculated by using the following formula:

$E = 0.5 * m * v^2$

m = mass of the object [kg]
v = velocity of the object [m/s]

The mass of the vessel is calculated by:

$m = Lpp * B * T * Cb * rho * m_{added}$
= 107.8 * 19.2 * 6.8 * 0.7 * 1023 * 1.05
= 10,582,588 kg
= 10,583 tonnes

Cb = block coefficient
rho = water density Westerschelde kg/m^3
m_{added} = added mass. Typical 5% for a sailing vessel [2]

$E = 0.5 * m * v^2$
$= 0.5 * 10{,}582{,}588 * 4.63^2$
= 113,429 kJ

A sailing vessel represents a lot of kinetic energy. To stop a vessel without the use of the propeller, this energy needs to be absorbed in another way. A part of the energy is absorbed due to the resistance a vessel encounters by sailing through water and air. As this energy absorption is only small, the vessel will need an additional way to absorb the kinetic energy of the vessel: for example the anchor gear.

There are three basic ways to absorb this kinetic energy using the anchor gear:

1. Use the anchor chain as a spring.
2. Drag anchor and chain over the seabed which will result in a high resistance.
3. Use the anchor winch brake to absorb the kinetic energy. The absorbed energy will be transformed into heat.

In reality the energy will be absorbed by a combination of these three effects. In the first phase, the anchor and chain will drag over the seabed. When the anchor holds, the chain will stretch and the winch brake can be used to dissipate energy. When the chain is on the chain stopper, the catenary effect of the chain will act as a spring. For the analysis in this report, these effects are analysed separately.

3.4 Maximum holding force anchor

The holding force of an anchor is normally expressed as a linear function of the weight of the anchor and soil conditions. This holding force is calculated by:

$F_{hold} = C_{ground} * C_{anchor} * g * m_{anchor}$

C_{ground} = holding coefficient, depending on anchor ground
C_{anchor} = holding coefficient, depending on anchor type
g = earth gravity
m_{anchor} = anchor mass

The formula shows that the holding power of an anchor can be increased by:

1. Using an anchor with a larger weight
2. To anchor in grounds with larger C_{ground} (see Table 1)
3. Using new developed anchors with larger holding coefficients (see Table 2)

Table 1 holding coefficient anchor ground

Type anchor ground	C_{ground}
Clay	4
Heavy sand	3
Sand/ mud	2
Mud	1

Table 2 holding coefficient anchor type

Anchor type	C_{anchor}
Traditional (i.e. SPEK)	1
Improved anchor design	2 - 5

For the nature of the coefficients in Table 1 Table 2 reference is made to [3] and [4] of the literature list.

As the anchor of M.S. Planet V is a conventional type (SPEK) anchor, a holding coefficient of 1 is applied. The soil conditions at the location in the Western Scheldt are classified as “heavy sand” and therefore an anchor ground coefficient of 3 is applied [2]. This results in a maximum anchor holding load of:

$$F_{hold} = C_{ground} * C_{anchor} * g * m_{anchor}$$
$$= 3 * 1 * 9.81 * 4030$$
$$= 118.6 \text{ kN}$$

3.5 Catenary

At a force equilibrium, the anchor chain will follow the shape of a catenary (see Figure 1). Using the maximum holding force of the anchor, the following formulas give an insight in the chain forces and forces at the anchor chain fairlead.

X = (Fh/q*g) * arccosh((q * g * y/ Fh) + 1)
= (118,600/43.7 * 9.81) * arccosh ((43.7 * 9.81 * 27/118,600) +1)
= 121.25 m

S = (Fh/q*g) * sinh(q * g * x/ Fh)
= (118,600/43.7 * 9.81) * sinh(43.7 * 9.81 * 121.25/118,600)
= 125.17 m

Fh = horizontal force (holding force anchor)
q = weight of anchor chain submerged (kg/m)
g = earth gravity

The vertical chain force at the fairlead corresponds to the weight of the free hanging catenary:
Fv = S * q * g
= 53.66 kN

The tension at the top of the catenary is then found by combining the horizontal and vertical components:
Fl = $\sqrt{}$(Fh^2 + Fv^2)
= 130.17 kN

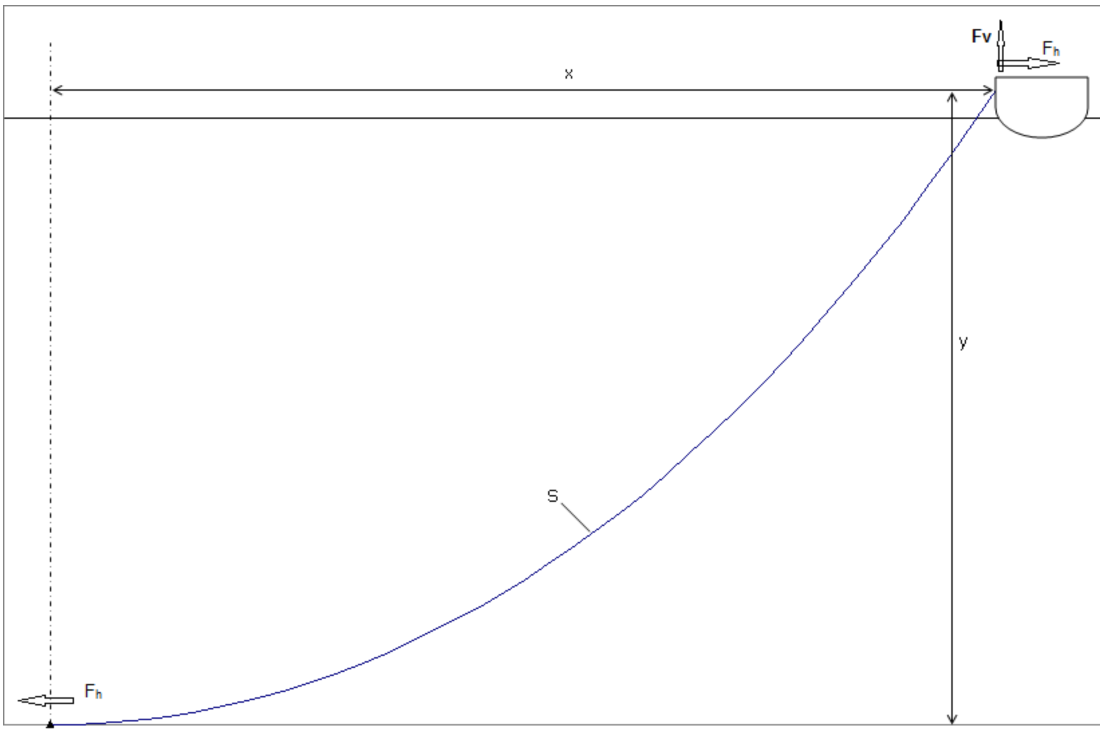

Figure 1 Catenary shape anchor chain

4 STOPPING SCENARIOS

Calculations on loads are done for three scenarios:
1. Chain on stopper, anchor holds.
2. Anchor holds and anchor winch at maximum chain brake load.
3. Anchor and chain drag over seabed.

These scenarios are simplified because exact angles and length of the anchor chain, the position of the anchor and the status of the vessel and the environmental reactions on it are unknown. Therefore in the calculations it is assumed that the vessel follows a straight course and the anchor chain is in the same vertical plane as the centre line of the vessel.

4.1 Scenario I: Chain on stopper, anchor holds

When the anchor chain is fixed at both ends, the anchor chain will act as a spring when a force is applied. Different lengths of anchor chain will give different chain spring stiffnesses and therefore different distances in which the vessels kinetic energy is absorbed. Using MARIN mooring calculation software, the force-elongation graphs for anchor chain lengths of 100, 175 and 250 meters are calculated (see Figure 2).

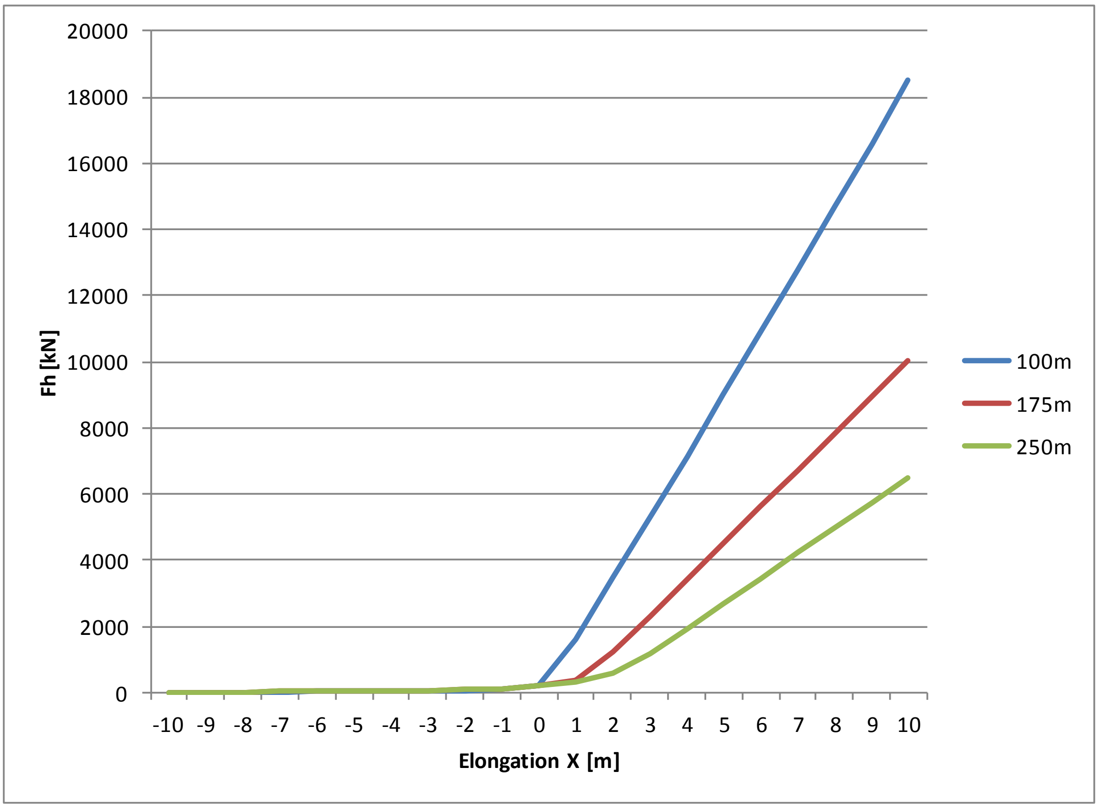

Figure 2 Force - elongation curve anchor chain

At a distance of zero meters, line forces are equal to the catenary line forces calculated in section 3.5. Negative distances are towards the anchor point and positive distances are away of the anchor point. When the chain is pre-tensioned, the load- elongation characteristic is nearly linear and can thus be approximated by a linear chain spring stiffness (see Table 3).

Table 3 Anchor chain spring stiffness

Anchor chain length	Anchor chain spring stiffness
100 m	1886 kN/m
175 m	1104 kN/m
250 m	965 kN/m

Using the formula for an equilibrium of energy, the distance can be calculated that is needed to absorb the vessels kinetic energy by the anchor chain. Assumption is that the anchor is at a fixed position on the seabed and that the catenary curve can be approximated by a linear spring stiffness.

Formulas:
Ship energy: $0.5 * m * v^2 = 113{,}429$ kJ
Absorbed energy: $0.5 * C * x^2$
Line force: $Fl = x * C$

m = mass vessel [kg]
v = vessel speed [m/s]
C = anchor chain spring stiffness [N/m]
x = stopping distance [m]

The stopping distance is found from the equilibrium of the ship energy and the absorbed energy. The travelled distances is the sum of the stopping distance and the distance travelled by dropping the different lengths of chain.

Table 4 Stopping distances and forces anchor chain as a spring

Energy vessel	113,429 kJ	113,429 kJ	113,429 kJ
Anchor chain length	100 m	175 m	250 m
Chain stiffness	1886 kN/m	1104 kN/m	965 kN/m
Stopping distance	10.97 m	14.33 m	15.33 m
Travelled distance	107.2 m	185.6 m	261.6 m
Line force	20,685 kN	15,826 kN	14,796 kN
Percentage chain break load	1140 %	870 %	820 %

The results in Table 4 show a high stiffness of the anchor chain, absorbing the vessels kinetic energy over very short distances. It should be noted that these stopping distances are from the location where the chain is already pre-tensioned and the mentioned anchor chain length is paid out. The short distances and high line forces are explained by the shallow water. At this water depth the catenary effect is small, the chain is fully stretched and only the material elasticity contributes to the anchor chain spring stiffness. The results also show that a longer chain length results in a lower chain spring stiffness, a larger stopping distance and therefore smaller line forces. The calculated line forces are much larger than the chain breaking load, resulting in breakage of the chain before the vessel is stopped. These line forces also show that the scenario of the vessel being stopped by the anchor chain acting as a spring is unrealistic. For M.S. Planet V the holding force of the anchor on the Western Scheldt is much smaller than the calculated line forces in this scenario. It is most likely that the anchor will be dragged along the seabed before the anchor chain acts as a spring to absorb the vessels kinetic energy.

4.2 Scenario II: Anchor holds and anchor winch at maximum chain brake load

To prevent the anchor chain loads from exceeding the chain breaking load, the anchor winch brake can be used to limit the chain loads and to absorb the vessels kinetic energy.

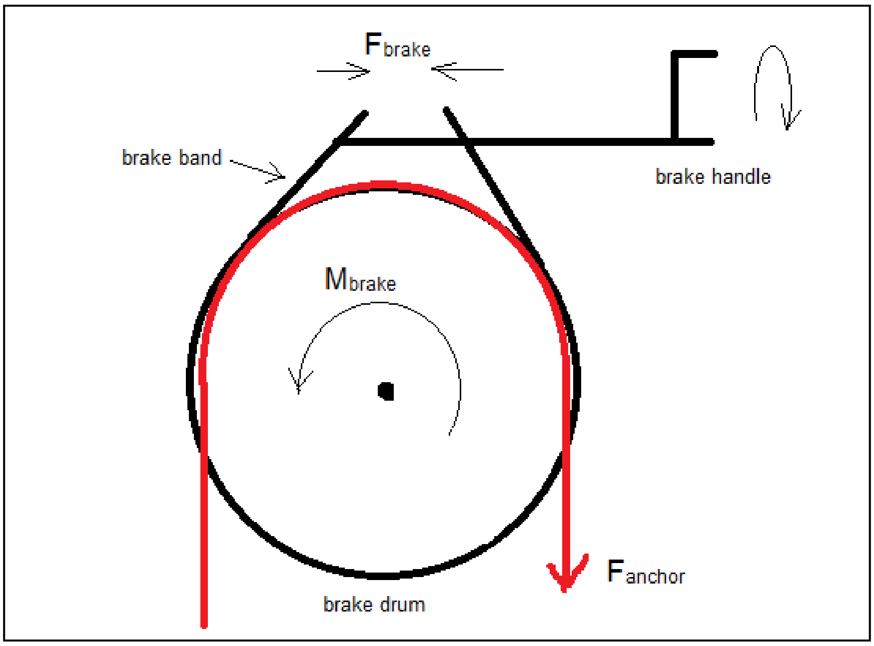

Figure 3 Anchor winch band brake

Figure 3 shows the working principle of an anchor winch band brake. The anchor chain force causes a turning momentum on the brake drum. Turning the brake handle will tighten the brake band around the brake drum. The friction between the brake band and the brake drum will result in a braking momentum, in opposite direction to the drum turning momentum. This brake momentum will slow down the turning rate of the brake drum i.e. slowing down the vessel.

Since the general arrangement drawing of the Planet V anchor winch only states the maximum holding load of the chain brake, it is assumed that the maximum braking force is 80% of the maximum holding load: 0.8 * 1448 kN = 1158.4 kN.

The maximum braking power that can be applied on the anchor chain depends on the angular velocity of the anchor winch brake drum. For this scenario it is assumed that the velocity at which the chain is dropped is equal to the vessels forward velocity.
Because the energy absorption by the anchor winch brake will slow down the vessel and therefore decrease the angular velocity of the anchor winch, resulting in decrease in braking power, MATLAB software is used to calculate the stopping distance. Time steps of 0.5 seconds are used. At t=0, the anchor chain follows a catenary shape and the anchor has reached its maximum holding force.

Formulas:

Kinetic energy vessel : $E = 0.5 * m * v^2$

Brake power : $P = M * \omega$

$M = F_{chain} * r_{brake\ drum}$

$\omega = 2\pi * n$

n = revolutions per second

Using the anchor winch brake to slow down the vessel results in a linear deceleration of the vessel (see plot 2 of Figure 4). After 40 seconds all kinetic energy will be absorbed, covering a distance of 97 meters Most of the energy the brake absorbs will be transferred into heat.

The results in this scenario are based on the assumption that the anchor holds immediately and will hold the chain loads. In practice most of the anchor holding force is produced by the lengths of chain on the sea bed, not by the anchor itself.
Most likely applying the maximum braking power in this scenario would have caused the anchor to drag over the seabed, reducing the effective braking power.

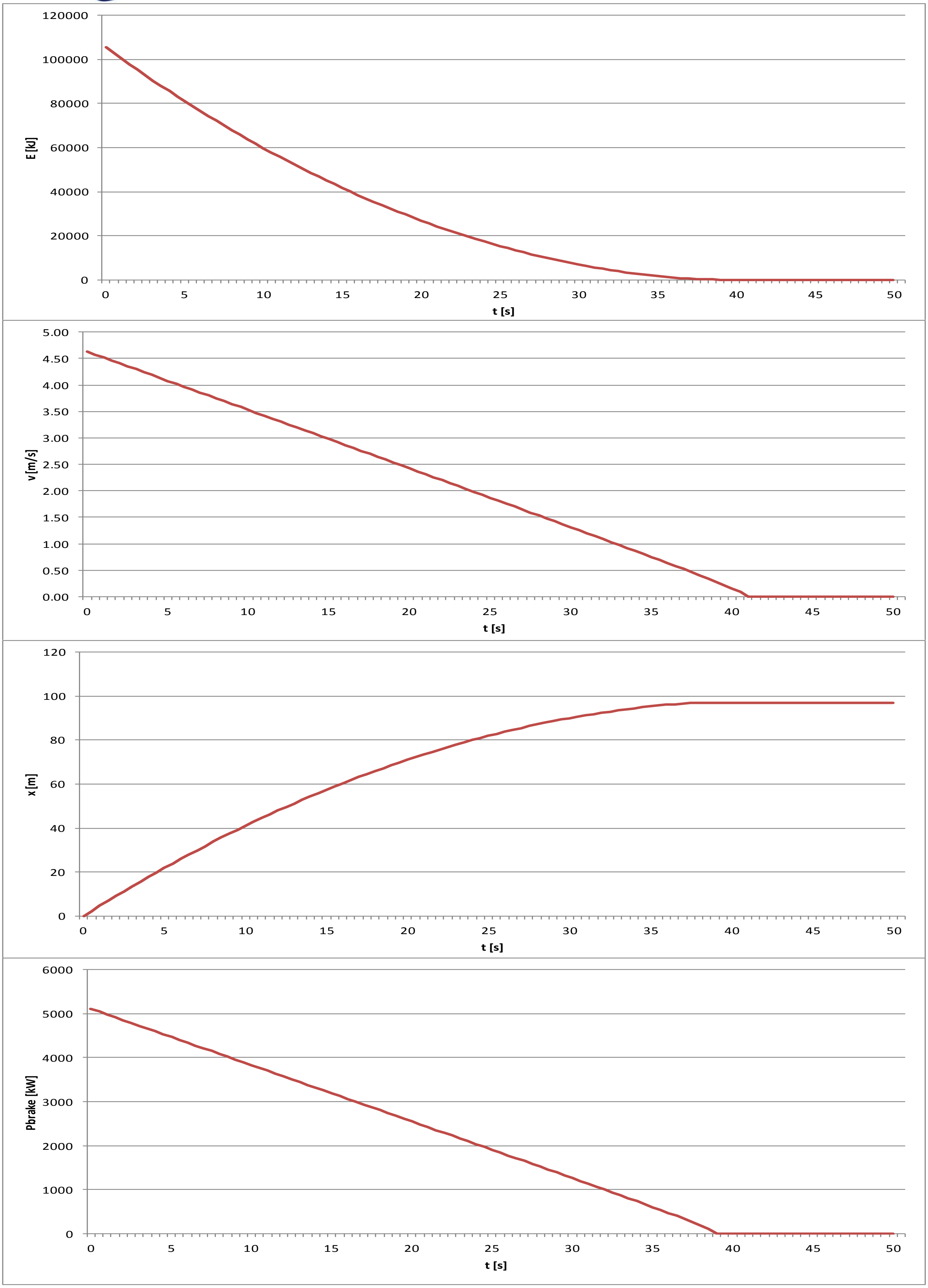

Figure 4 Stopping the vessel by applying maximum brake force

4.3 Scenario III: Anchor and chain drag over seabed

In this scenario different lengths of anchor chain will be dropped. Then the chain stopper will hold one end of the chain, causing the anchor and dropped chain to drag over the seabed. When more lengths of chain are dropped on the seabed, they will increase the friction resistance, increasing loads and decreasing the vessel stopping distance.

There is not much information about friction coefficients available. A friction coefficient of 0.74 is chosen for the anchor chain [5]. There is no information on dragging anchors available, therefore a friction coefficient of 0.8 is assumed for the anchor.
For calculation, lengths of 50, 100, 175 and 225 meters of anchor chain are used.

$Fw_{chain} = L * q * g * C_c$
Fw_{anchor} = 80% holding force = 94.88 kN
$F_{drag} = Fw_{chain} + Fw_{anchor}$

L = chain length on seabed [m]
q = chain mass submerged [kg/m]
g = earth gravity [m/s^2]
C_c = chain friction coefficient

$E_{ship} = F_{drag} * x$

Table 5 Stopping distances by dragging chain and anchor

Chain length	50 m	100 m	175 m	225 m
E_{ship}	113,429 kJ	113,429 kJ	113,429 kJ	113,429 kJ
F_{drag}	110.7 kN	126.6 kN	150.4 kN	174.2 kN
Stopping distance x	1025 m	896 m	754 m	651 m

The results in Table 5 show that the length of anchor chain on the seabed has a large contribution to the stopping power of the vessel.

5 DYNAMIC APPROACH

The described scenario's in the previous chapter give some insights in forces and stopping abilities of M.S. Planet V. In practice, the ability to stop the vessel is limited by the holding power of anchor and anchor chain.
In this chapter a more dynamic approach is presented, combining the three scenarios and adding the wind and water resistance which will add to the deceleration of the vessel. MATLAB is used as a simulation tool for this approach.

Because the real situation is unknown, some assumptions are made to simplify the calculations:

- At t=0, the anchor line has a catenary shape and the anchor has reached its maximum holding power.
- The dropped chain length is increased with the same velocity as the velocity of the vessel.
- The anchor winch brake force is limited to the anchor chain force, based on the maximum anchor holding force, the length of anchor chain on the seabed and the anchor chain in a catenary shape.
- Previous assumption implies that the anchor will not be dragged over the seabed.

Figure 5 on the next page shows the results of this dynamic approach.
Obvious is the limitation of anchor winch braking power when the bottom plot of Figure 5 is compared with the bottom plot of Figure 4. The holding power of anchor and lengths of chain on the seabed are not high enough to apply the maximum brake power on the anchor winch.

Using the dynamic approach, the maximum chain force is 285 kN, limiting the anchor winch brake power to a maximum of 728 kW. This is only 25% of the theoretical maximum brake power. The results of this dynamic simulation show that the stopping time is 130 seconds and the stopping distance is 330 m (from the moment the anchor holds). A stopping distance of 330 m from the point the anchor holds implies that M.S. Planet V was unable to stop before the anchor chain had reached its end.
When more brake power is applied, the anchor and anchor chain will drag over the seabed, but the vessel will continue to slow down and stop eventually.

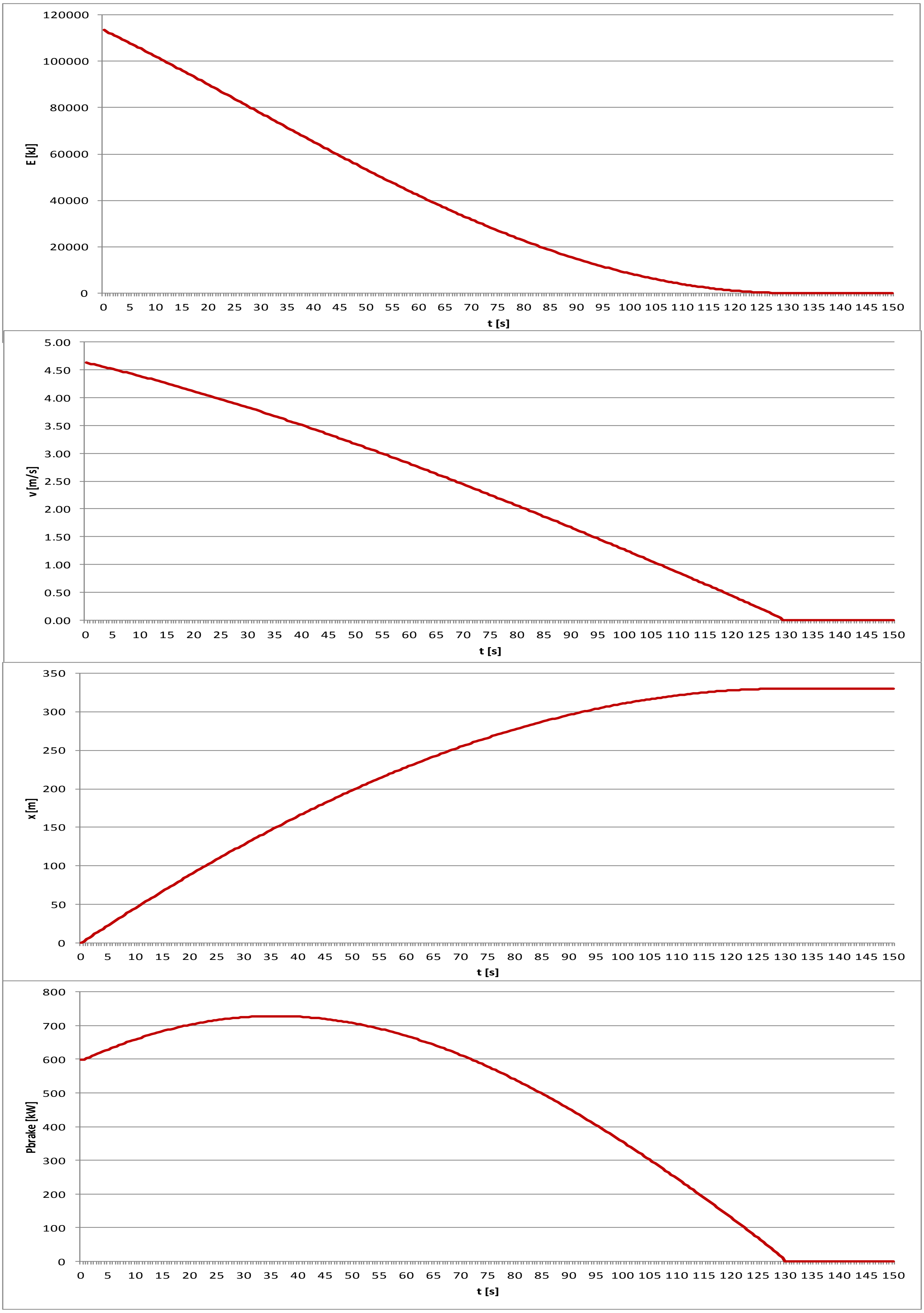

Figure 5 Stopping the vessel, dynamic approach

6 CONCLUSIONS

- M.S. Planet V was build under Germanischer Lloyd classification rules and regulations. There are rules and regulations for the hull, but also for the equipment onboard, including anchoring and mooring devices. Certificates prove that the anchor gear applied to these regulations.

- The anchor and anchor winch regulations are based on the assumption that they are designed to hold a ship using only one bow anchor, in good holding ground, in a sheltered environment with a maximum current speed of 2.5 m/s and a maximum wind speed of 25 m/s.

- Anchor type and weight, as well as anchor chain weight are important parameters in the maximum holding force of an anchor system.

- Although anchor and anchor winch are not designed to use as an emergency brake to stop the vessel, they can be used in that way to stop a vessel.

- Limitation of the stopping abilities is the maximum holding force of the anchor and chain on the seabed and the available chain length. Applying a higher brake power on the anchor chain will result in the anchor a chain being dragged over the seabed.

- The maximum load in the anchor gear can easily exceed the maximum winch brake load in case the anchor is fixed. Under normal conditions however, the anchor will drag when the load exceeds the anchor holding force of 119 kN. This corresponds to a winch brake load of 130 kN.

- Calculations, using a dynamic approach, on the stopping abilities of M.S. Planet V show that only 25% of the theoretical braking power of the anchor winch can be applied to slow down the vessel. Applying more brake power will result in the anchor being dragged over the seabed.

- Limitations on the stopping power of the vessel imply a longer stopping distance. This increases the risk of reaching the end of the anchor chain and breaking of the fastening of the anchor chain to the vessels structure as the breaking load of this fastening is limited between 15% and 30% of the rated breaking load of the anchor chain. In case of Planet V the breaking load of the chain end fastening is regulatory between 272.1 kN and 544.2 kN.

- Using the dynamic approach, the stopping distance of M.S. Planet V at an initial speed of 9.0 knots over ground is estimated at 330 meters.

- A stopping distance of 330 m (from the point the anchor holds) is more than the M.S. Planet V anchor chain length of 250 m. When more brake power is applied, the anchor will drag over the sea bed, but the vessel will continue to slow down and stop eventually.

Wageningen, October 2012
MARITIME RESEARCH INSTITUTE NETHERLANDS

Ir. H.J.J. van den Boom
Manager MARIN Trials & Monitoring

APPENDIX I: GERMANISCHER LLOYD RULES AND REGULATIONS

Section 18

Equipment

A. General

1. The equipment of anchors and chain cables as well as the recommended equipment of wires and ropes is to be determined from Table 18.2 in accordance with the equipment numeral Z_1 or Z_2, respectively.

Note

The anchoring equipment required by this Section is intended of temporary mooring of a vessel within a harbour or sheltered area when the vessel is awaiting berth, tide, etc.

The equipment is, therefore, not designed to hold a ship off fully exposed coasts in rough weather or to stop a ship which is moving or drifting. In this condition the loads on the anchoring equipment increase to such a degree that its components may be damaged or lost owing to the high energy forces generated, particularly in large ships.

The anchoring equipment required by this Section is designed to hold a ship in good holding ground in conditions such as to avoid dragging of the anchor. In poor holding ground the holding power of the anchors will be significantly reduced.

The equipment numeral formula for anchoring equipment required under this Section is based on an assumed current speed of 2,5 m/sec, wind speed of 25 m/sec and a scope of chain cable between 6 and 10, the scope being the ratio between length of chain paid out and water depth.

It is assumed that under normal circumstances a ship will use only one bow anchor and chain cable at a time.

2. Every ship is to be equipped with at least one anchor windlass.

Windlasses and chain stoppers, if fitted, are to comply with the GL Rules for Machinery Installations (I-1-2), Section 14, D.

For the substructures of windlasses and chain stoppers, see Section 10, B.5.

For the location of windlasses on tankers, see Section 24, A.9.

3. For ships having the navigation notation **RSA(20)** or **RSA(50)** affixed to their character of classification, the equipment may be determined as for one numeral range lower than required in accordance with the equipment numeral Z_1 or Z_2, respectively.

4. When determining the equipment for ships having the navigation notation **RSA(SW)** affixed to their character of classification, the provisions of Section 30, E. are to be observed.

5. When determining the equipment for tugs, Section 25, G. is to be observed.

When determining the equipment of barges and pontoons, Section 31, G. is to be observed.

6. Ships built under survey of GL and which are to have the mark ✠ stated in their Certificate and in the Register Book shall be equipped with anchors and chain cables complying with the Rules for Materials and having been tested on approved machines in the presence of a Surveyor.

7. For ships having three or more propellers, a reduction of the weight of the bower anchors and the chain cables may be considered.

Note

Seagoing ships navigating on inland waters and rivers are to have anchor equipment also complying with the Regulations of the competent authorities; e.g for ships navigating on the inland waterways of the Federal Republic of Germany with the exception of the river Rhine and river Danube the "Binnenschiffs-Untersuchungsordnung" is to be observed. For navigation on the river Rhine, the "Rheinschiffs-Untersuchungsordnung" and for navigation on the river Danube, the "Verordnung über die Untersuchung der Donauschiffe" are to be observed.

B. Equipment numeral

1. The equipment numeral Z_1 for anchors and chain cables is to be calculated as follows:

$$Z_1 = D^{2/3} + 2\,h\,\mathbf{B} + \frac{A}{10}$$

D = moulded displacement [t] in sea water having a density of 1,025 t/m^3 to the summer load waterline

h = effective height from the summer load waterline to the top of the uppermost house

$= a + \Sigma h_i$

a = distance [m], from the summer load waterline, amidships, to the upper deck at side

Σh_i = sum of height [m] of superstructures and deckhouses on the upper deck, measured on the centreline of each tier having a breadth greater than **B**/4. Deck sheer, if any, is to be ignored. For the lowest tier, "h" is to be measured at centreline from the upper deck or from a notional deck line where there is local discontinuity in the upper deck.

A = area [m^2], in profile view of the hull, superstructures and deckhouses, having a breadth greater than **B**/4, above the summer load waterline within the length **L** and up to the height h

Where a deckhouse having a breadth greater than **B**/4 is located above a deckhouse having a breadth of **B**/4 or less, the wider house is to be included and the narrow house ignored.

Screens of bulwarks 1,5 m or more in height are to be regarded as parts of houses when determining h and A, e.g. the area shown in Fig. 18.1 as A_1 is to be included in A. The height of the hatch coamings and that of any deck cargo, such as containers, may be disregarded when determining h and A.

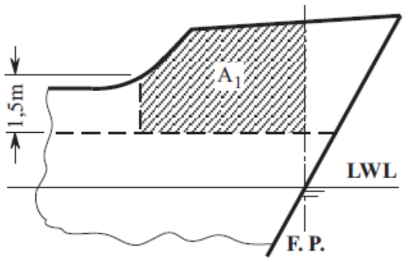

Fig. 18.1 Effective area A_1 of bulwark

2. The equipment numeral Z_2 for the recommended selection of ropes as well as for the determination of the design load for shipboard towing and mooring equipment and supporting hull structure is to be calculated as follows:

$$Z_2 = D^{2/3} + 2\,h\,\mathbf{B} + \frac{A}{10}$$

D = moulded displacement [t] in sea water having a density of 1,025 t/m^3 to the summer load waterline

h = effective height from the summer load waterline to the top of the uppermost house

= a + Σh_i

a = distance [m], from the summer load waterline, amidships, to the upper deck at side

Σh_i = sum of height [m] of superstructures and deckhouses on the upper deck, measured on the centreline of each tier. Deck sheer, if any, is to be ignored. For the lowest tier, "h" is to be measured at centreline from the upper deck or from a notional deck line where there is local discontinuity in the upper deck.

A = area [m^2], in profile view of the hull, superstructures and deckhouses above the summer load waterline within the length **L**.

Screens of bulwarks, hatch coamings and deck equipment, e.g., masts and lifting gear, as well as containers on deck have to be observed for the calculation of A.

C. Anchors

1. The number of bower anchors is to be determined according to column 3 of Table 18.2. Two of the rule bower anchors are to be connected to their chain cables and positioned on board ready for use.

It is to be ensured that each anchor can be stowed in the hawse and hawse pipe in such a way that it remains firmly secured in seagoing conditions. Details have to be coordinated with the owner.

Where in column 3 of Table 18.2 two bow anchors are required, a stream anchor shall be on board as a third anchor. Its mass shall be according to column 5 of the table. Length and breaking load of chain or stream wire respectively are to be as given in columns 10 and 11.

Where in column 3 of Table 18.2 three bower anchors are required, the third anchor is intended as a spare bower anchor. Installation of the spare bower anchor on board is not required.

The spare anchor is not required as a condition of classification and, with owner's consent, may be dispensed with.

Note

National regulations concerning the provision of a spare anchor, stream anchor or a stern anchor may need to be observed.

A stern anchor in the sense of these Rules is named a stream anchor of small seagoing ships, i.e. up to and including the equipment numeral of Z_1 = 205.

2. Anchors shall be of approved design. The mass of the heads of patent (ordinary stockless) anchors, including pins and fittings, is not to be less than 60 per cent of the total mass of the anchor.

3. For stock anchors, the total mass of the anchor, including the stock, shall comply with the values in Table 18.2. The mass of the stock shall be 20 per cent of this total mass.

4. The mass of each individual bower anchor may vary by up to 7 per cent above or below the required individual mass provided that the total mass of all the bower anchors is not less than the sum of the required individual masses.

5. Where special anchors approved as "High Holding Power Anchors" are used, the anchor mass may be 75 per cent of the anchor mass as per Table 18.2.

"High Holding Power Anchors" are anchors which are suitable for ship's use at any time and which do not require prior adjustment or special placement on the sea bed.

For approval as a "High Holding Power Anchor", satisfactory tests are to be made on various types of bottom and the anchor is to have a holding power at least twice that of a patent anchor ("Admiralty Standard Stockless") of the same mass. The mass of anchors to be tested should be representative of the full range of sizes intended to be manufactured. The tests are to be carried out on at least two sizes of anchors in association with the chain cables appropriate to the weight. The anchors to be tested and the standard stockless anchors should be of approx. the same mass.

The chain length used in the tests should be approx. 6 to 10 times the depth of water.

The tests are normally to be carried out from a tug, however, alternative shore based tests (e.g. with suitable winches) may be accepted.

Three tests are to be carried out for each anchor and type of bottom. The pull shall be measured by means of a dynamometer or recorded by a recording instrument. Measurements of pull based on rpm/bollard pull curve of the tug may be accepted.

Testing by comparison with a previously approved HHP anchor may be accepted as a basis for approval. The maximum mass of an anchor thus approved may be 10 times the mass of the largest size of anchor tested.

The dimensioning of the chain cable and of the windlass is to be based on the undiminished anchor mass according to the Tables.

6. Where stern anchor equipment is fitted, such equipment is to comply in all respects with the rules for anchor equipment. The mass of each stern anchor shall be at least 35 per cent of that of the bower anchors. The diameter of the chain cables and the chain length are to be determined from the Tables in accordance with the anchor mass. Where a stern anchor windlass is fitted the requirements of the GL Rules for Machinery Installations (I-1-2), Section 14, are to be observed.

7. Where a steel wire rope is to be used for the stern anchor instead of a chain cable the following has to be observed:

7.1 The steel wire rope shall at least be as long as the required chain cable. The strength of the steel wire rope shall at least be of the value for the required chain of grade K1.

7.2 Between anchor and steel wire rope a shot of 12,5 m in length or of the distance between stowed anchor and windlass shall be provided. The smaller length has to be taken.

7.3 A cable winch shall be provided according to the requirements for windlasses in the GL Rules for Machinery Installation (I-1-2), Section 14, B.

D. Chain Cables

1. The chain cable diameters given in the Tables apply to chain cables made of chain cable materials specified in the GL Rules for Metallic Materials (II-1), for the following grades:

– Grade K1 (ordinary quality)

– Grade K2 (special quality)

– Grade K3 (extra special quality)

2. Grade K1 material used for chain cables in conjunction with "High Holding Power Anchors" shall have a tensile strength R_m of not less than 400 N/mm^2.

3. Grade K2 and K3 chain cables shall be post production quenched and tempered and purchased from recognized manufacturers only.

4. The total length of chain given in Table 18.2 is to be divided in approximately equal parts between the two bower anchors.

5. Either stud link or short link chain cables may be used for stream anchors.

6. For connection of the anchor with the chain cable approved Kenter-type anchor shackles may be chosen in lieu of the common Dee-shackles. A forerunner with swivel is to be fitted between anchor and chain cable. In lieu of a forerunner with swivel an approved swivel shackle may be used. However, swivel shackles are not to be connected to the anchor shank unless specially approved. A sufficient number of suitable spare shackles are to be kept on board to facilitate fitting of the spare anchor at any time. On owner's request the swivel shackle may be dispensed with.

7. The attachment of the inboard ends of the chain cables to the ship's structure is to be provided with means suitable to permit, in case of emergency, an easy slipping of the chain cables to sea operable from an accessible position outside the chain locker.

The inboard ends of the chain cables are to be secured to the structures by a fastening able to withstand a force not less than 15 % nor more than 30 % of the rated breaking load of the chain cable.

Table 18.2 Anchor, Chain Cables and Ropes

No. for Reg.	Equipment numeral Z_1 or Z_2	Stockless anchor			Stud link chain cables						Recommended ropes				
		Bower anchor		Stream anchor	Bower anchors				Stream wire or chain for stream anchor		Towline		Mooring ropes		
		Number [1]	Mass per anchor		Total length	Diameter d_1	Diameter d_2	Diameter d_3	Length	Br. Load [2]	Length	Br. Load [2]	Number	Length	Br. Load [2]
			[kg]		[m]	[mm]	[mm]	[mm]	[m]	[kN]	[m]	[kN]		[m]	[kN]
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
101	up to 50	2	120	40	165	12,5	12,5	12,5	80	65	180	100	3	80	35
102	50 – 70	2	180	60	220	14	12,5	12,5	80	65	180	100	3	80	35
103	70 – 90	2	240	80	220	16	14	14	85	75	180	100	3	100	40
104	90 – 110	2	300	100	247,5	17,5	16	16	85	80	180	100	3	110	40
105	110 – 130	2	360	120	247,5	19	17,5	17,5	90	90	180	100	3	110	45
106	130 – 150	2	420	140	275	20,5	17,5	17,5	90	100	180	100	3	120	50
107	150 – 175	2	480	165	275	22	19	19	90	110	180	100	3	120	55
108	175 – 205	2	570	190	302,5	24	20,5	20,5	90	120	180	110	3	120	60
109	205 – 240	3	660		302,5	26	22	20,5			180	130	4	120	65
110	240 – 280	3	780		330	28	24	22			180	150	4	120	70
111	280 – 320	3	900		357,5	30	26	24			180	175	4	140	80
112	320 – 360	3	1020		357,5	32	28	24			180	200	4	140	85
113	360 – 400	3	1140		385	34	30	26			180	225	4	140	95
114	400 – 450	3	1290		385	36	32	28			180	250	4	140	100
115	450 – 500	3	1440		412,5	38	34	30			180	275	4	140	110
116	500 – 550	3	1590		412,5	40	34	30			190	305	4	160	120
117	550 – 600	3	1740		440	42	36	32			190	340	4	160	130
118	600 – 660	3	1920		440	44	38	34			190	370	4	160	145
119	660 – 720	3	2100		440	46	40	36			190	405	4	160	160
120	720 – 780	3	2280		467,5	48	42	36			190	440	4	170	170
121	780 – 840	3	2460		467,5	50	44	38			190	480	4	170	185
122	840 – 910	3	2640		467,5	52	46	40			190	520	4	170	200
123	910 – 980	3	2850		495	54	48	42			190	560	4	170	215
124	980 – 1060	3	3060		495	56	50	44			200	600	4	180	230
125	1060 – 1140	3	3300		495	58	50	46			200	645	4	180	250
126	1140 – 1220	3	3540		522,5	60	52	46			200	690	4	180	270
127	1220 – 1300	3	3780		522,5	62	54	48			200	740	4	180	285
128	1300 – 1390	3	4050		522,5	64	56	50			200	785	4	180	305
129	1390 – 1480	3	4320		550	66	58	50			200	835	4	180	325
130	1480 – 1570	3	4590		550	68	60	52			220	890	5	190	325
131	1570 – 1670	3	4890		550	70	62	54			220	940	5	190	335
132	1670 – 1790	3	5250		577,5	73	64	56			220	1025	5	190	350
133	1790 – 1930	3	5610		577,5	76	66	58			220	1110	5	190	375
134	1930 – 2080	3	6000		577,5	78	68	60			220	1170	5	190	400
135	2080 – 2230	3	6450		605	81	70	62			240	1260	5	200	425
136	2230 – 2380	3	6900		605	84	73	64			240	1355	5	200	450
137	2380 – 2530	3	7350		605	87	76	66			240	1455	5	200	480
138	2530 – 2700	3	7800		632,5	90	78	68			260	1470	6	200	480
139	2700 – 2870	3	8300		632,5	92	81	70			260	1470	6	200	490
140	2870 – 3040	3	8700		632,5	95	84	73			260	1470	6	200	500
141	3040 – 3210	3	9300		660	97	84	76			280	1470	6	200	520
142	3210 – 3400	3	9900		660	100	87	78			280	1470	6	200	555
143	3400 – 3600	3	10500		660	102	90	78			280	1470	6	200	590
144	3600 – 3800	3	11100		687,5	105	92	81			300	1470	6	200	620
145	3800 – 4000	3	11700		687,5	107	95	84			300	1470	6	200	650
146	4000 – 4200	3	12300		687,5	111	97	87			300	1470	7	200	650
147	4200 – 4400	3	12900		715	114	100	87			300	1470	7	200	660
148	4400 – 4600	3	13500		715	117	102	90			300	1470	7	200	670
149	4600 – 4800	3	14100		715	120	105	92			300	1470	7	200	680
150	4800 – 5000	3	14700		742,5	122	107	95			300	1470	7	200	685
151	5000 – 5200	3	15400		742,5	124	111	97			300	1470	8	200	685
152	5200 – 5500	3	16100		742,5	127	111	97			300	1470	8	200	695
153	5500 – 5800	3	16900		742,5	130	114	100			300	1470	8	200	705
154	5800 – 6100	3	17800		742,5	132	117	102			300	1470	9	200	705
155	6100 – 6500	3	18800		742,5		120	107			300	1470	9	200	715
156	6500 – 6900	3	20000		770		124	111			300	1470	9	200	725
157	6900 – 7400	3	21500		770		127	114			300	1470	10	200	725
158	7400 – 7900	3	23000		770		132	117			300	1470	11	200	725
159	7900 – 8400	3	24500		770		137	122			300	1470	11	200	735
160	8400 – 8900	3	26000		770		142	127			300	1470	12	200	735
161	8900 – 9400	3	27500		770		147	132			300	1470	13	200	735
162	9400 – 10000	3	29000		770		152	132			300	1470	14	200	735
163	10000 – 10700	3	31000		770			137			300	1470	15	200	735
164	10700 – 11500	3	33000		770			142			300	1470	16	200	735
165	11500 – 12400	3	35500		770			147			300	1470	17	200	735
166	12400 – 13400	3	38500		770			152			300	1470	18	200	735
167	13400 – 14600	3	42000		770			157			300	1470	19	200	735
168	14600 – 16000	3	46000		770			162			300	1470	21	200	735

d_1 = Chain diameter Grade K1 (Ordinary quality)
d_2 = Chain diameter Grade K2 (Special quality)
d_3 = Chain diameter Grade K3 (Extra special quality)
} See also D.

[1] see C.1.
[2] see F.1.2

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