vryhof • anchor manual 2005

THE DIGITAL VERSION

vryhof

anchor manual 2005

Vryhof anchors
p.o. box 105, 2920 AC krimpen ad yssel, the netherlands
www.vryhof.com   vryhof@vryhof.com

Vryhof, Stevin, Stevpris, Stevshark, Stevtensioner and Stevmanta are registered trade marks.

Vryhof reserves all intellectual and industrial property rights such as any and all of their patent, trademark, design, manufacturing, reproduction, use and sales rights thereto and to any article disclosed therein.

All information in this manual is subject to change without prior notice. Vryhof anchors is not liable and/or responsible in any way for the information provided in this manual.

First edition published 1984. Print run 7,500 copies.
Second edition published 1990. Print run 7,500 copies.
Reprint second edition print run 5,000 copies.
Third edition published 2000. Print run 2,500 copies.
Reprint third edition print run 1,500 copies.
Second reprint third edition print run 1,000 copies.
First print fourth edition print run 1,000 copies.

Introduction

A stone and something that looked like a rope. For millennia this was the typical anchor. Over the last 25 years of more recent history, vryhof has brought the art to a more mature status. They have grown into a world leader in engineering and manufacturing of mooring systems for all kinds of floating structures. In doing so the company has secured numerous anchor and ancillary equipment patents, and shared its experience with others.

The company understands that the needs of the industry can not be satisfied by the supply of standard hard-ware only. Universal and tailored solutions rooted in proven engineering should be based on long practical experience. Vryhof has been and will be introducing new and original anchor designs well into the 21st century. With their products, advice and this manual, it shares this knowledge with those who are daily faced with complex mooring situations.

This manual is intended as a means of reference for all who purchase, use, maintain, repair or are in any way involved with anchors. Though written from one anchor manufacturer's standpoint, the information contained herein is applicable to many types of anchors. Total objectivity is, of course, impossible.

It is hoped this manual will contribute to the work and success of all who work with anchors. They are the only fixed reference point for many of the floating structures on the world's often turbulent waters.

1

General

Mooring systems

Mooring systems have been around just as long as man has felt the need for anchoring a vessel at sea. These systems were used, and are still used, on ships and consisted of one or more lines connected to the bow or stern of the ship. Generally the ships stayed moored for a short duration of time (days).

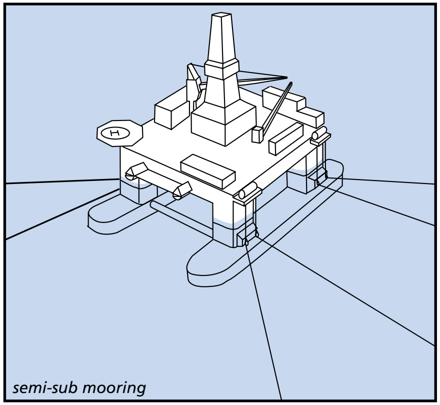
When the exploration and production of oil and gas started offshore, a need for more permanent mooring systems became apparent. Numerous different mooring systems have been developed over the years, of which a short selection is presented here.

Semi-submersible drilling rig - generally the semi-submersibles are moored using an eight point mooring. Two mooring lines come together at each of the columns of the semi-submersible.

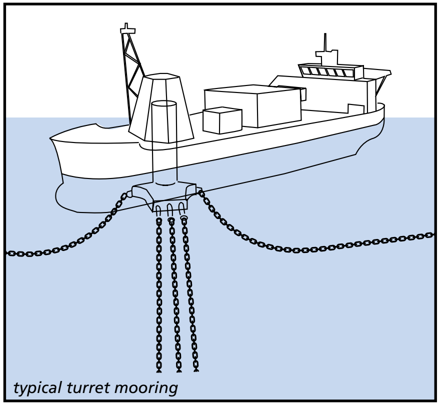
CALM buoy - generally the buoy will be moored using four or more mooring lines at equally spaced angles. The mooring lines generally have a catenary shape. The vessel connects to the buoy with a single line and is free to weathervane around the buoy.

SALM buoy - these types of buoys have a mooring that consists of a single mooring line attached to an anchor point on the seabed, underneath the buoy. The anchor point may be gravity based or piled.

Turret mooring - this type of mooring is generally used on FPSOs and FSOs in more harsh environments. Multiple mooring lines are used, which come together at the turntable built into the FPSO or FSO. The FPSO or FSO is able to rotate around the turret to obtain an optimal orientation relative to the prevailing weather conditions.



semi-sub mooring



typical turret mooring

Spread mooring - generally used on FPSOs and FSOs in milder environments. The mooring lines are directly connected to the FPSO or FSO at both the stern and bow of the vessel.

When oil and gas exploration and production was conducted in shallow to deep water, the most common mooring line configuration was the catenary mooring line consisting of chain or wire rope. For exploration and production in deep to ultra-deep water, the weight of the mooring line starts to become a limiting factor in the design of the floater. To overcome this problem new solutions were developed consisting of synthetic ropes in the mooring line (less weight) and/or a taut leg mooring system *(fig. 1-01 and fig. 1-02).*

The major difference between a catenary mooring and a taut leg mooring is that where the catenary mooring arrives at the seabed horizontally, the taut leg mooring arrives at the seabed at an angle. This means that in a taut leg mooring the anchor point has to be capable of resisting both horizontal and vertical forces, while in a catenary mooring the anchor point is only subjected to horizontal forces. In a catenary mooring, most of the restoring forces are generated by the weight of the mooring line. In a taut leg mooring, the restoring forces are generated by the elasticity of the mooring line.

An advantage of a taut leg mooring over the catenary mooring is that the footprint of the taut leg mooring is smaller than the footprint of the catenary mooring, i.e. the mooring radius of the taut leg mooring will be smaller than the mooring radius of a catenary mooring for a similar application.

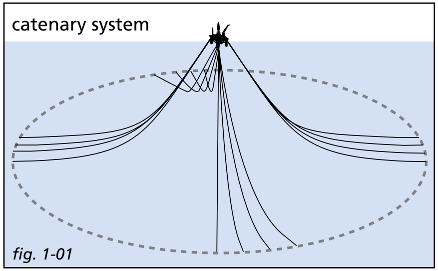


fig. 1-01

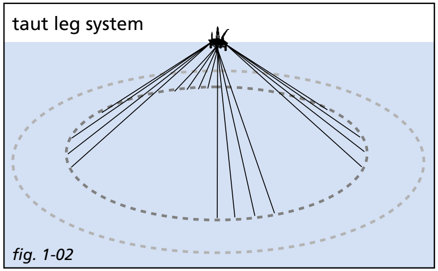


fig. 1-02

A typical mooring system can be divided in three different components, the mooring line, the connectors and the anchor point.

Mooring line

Chain

The most common product used for mooring lines is chain which is available in different diameters and grades. Two different designs of chain are used frequently, studlink and studless chain. The studlink chain is most commonly used for moorings that have to be reset numerous times during their lifetime, for instance semi-submersibles, while studless link chain is often used for permanent moorings (FPSOs, buoys, FSOs). A chain mooring line can be terminated in either a common link or an end link *(fig. 1-03).*

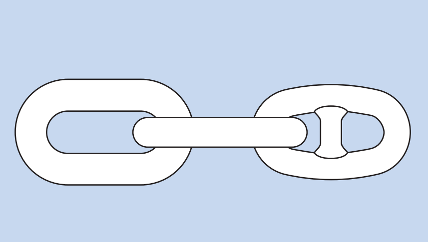


fig. 1-03

Wire rope

When compared to chain, wire rope has a lower weight than chain, for the same breaking load and a higher elasticity. Common wire ropes used in offshore mooring lines are six strand and spiral strand. The wire rope is terminated with a socket (for instance open spelter, closed spelter, CR) for connection to the other components in the mooring system. Generally wire rope is more prone to damage and corrosion than chain *(fig. 1-04).*

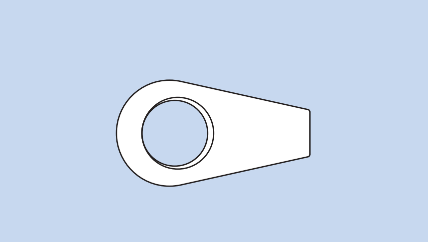


fig. 1-04

Synthetic fibre rope

A recent development is the use of synthetic fibre ropes as mooring line. Typical materials that can be used are polyester and high modulus polyethylene (Dyneema). The major advantage of synthetic fibre ropes is the light weight of the material and the high elasticity. The synthetic fibre rope is generally terminated with a special spool and shackle for connection to the other components in the mooring system.

Connectors

Shackles

The shackle is a connector that is very common in the offshore industry. It consists of a bow, which is closed by a pin. Many different types of shackles are available, depending on the application. The shackle can be used in both temporary and permanent moorings *(fig. 1-05).*

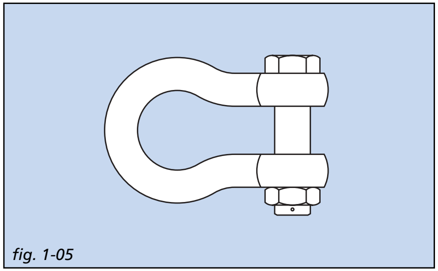


fig. 1-05

Connecting link kenter type

The connecting link kenter type is most commonly used for the connection of two pieces of chain mooring line, where the terminations of the two pieces have the same dimensions. The connecting link kenter type has the same outside length as a chain link of the same diameter. Generally connecting links kenter type are not used in permanent mooring systems, as they have a shorter fatigue life than the chain *(fig. 1-06).*

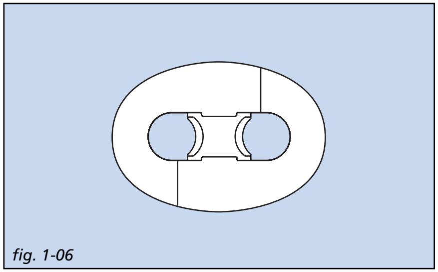


fig. 1-06

Connecting link pear shaped

The pear shaped connecting link is similar to the connecting link kenter type, except that it is used for the connection of two pieces of mooring line with terminations that have different dimensions. Like the connecting link kenter type, the pear shaped connecting links are not used in permanent mooring systems *(fig. 1-07).*

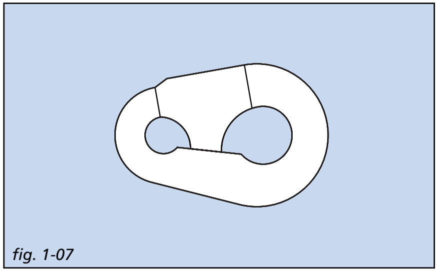


fig. 1-07

Connecting link c type

Like the connecting link kenter type, the connecting link c type is used for the connection of two pieces of mooring line with terminations that have the same dimensions. The major difference between the kenter type and the c type is the way that the connector is opened and closed. This connector is generally not used in permanent moorings *(fig. 1-08).*

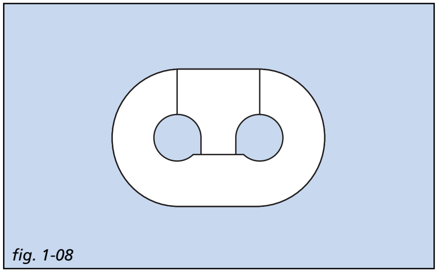


fig. 1-08

Swivels

A swivel is used in a mooring system, generally of a temporary type, to relieve the twist and torque that builds up in the mooring line. The swivel is often placed a few links from the anchor point, although it can also be placed between a section of chain and a section of wire rope. There are many different types of swivels available, although a disadvantage of most common swivels is that they may not function while under load, which is caused by high friction inside the turning mechanism. A new development is swivels that are capable of swivelling under load, due to special bearing surfaces inside the mechanism *(fig. 1-09).*

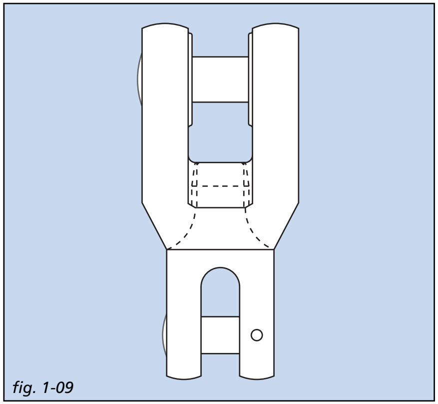


fig. 1-09

Anchoring point

Dead weight

The dead weight is probably the oldest anchor in existence. The holding capacity is generated by the weight of the material used and partly by the friction between the dead weight and the seabed. Common materials in use today for dead weights are steel and concrete *(fig. 1-10).*

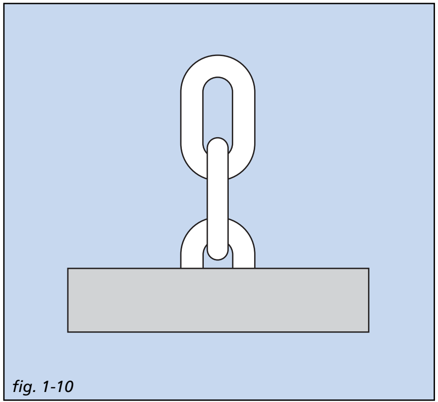


fig. 1-10

Drag embedment anchor

This is the most popular type of anchoring point available today. The drag embedment anchor has been designed to penetrate into the seabed, either partly of fully. The holding capacity of the drag embedment anchor is generated by the resistance of the soil in front of the anchor. The drag embedment anchor is very well suited for resisting large horizontal loads, but not for large vertical loads although there are some drag embedment anchors available on the market today that can resist significant vertical loads *(fig. 1-11).*

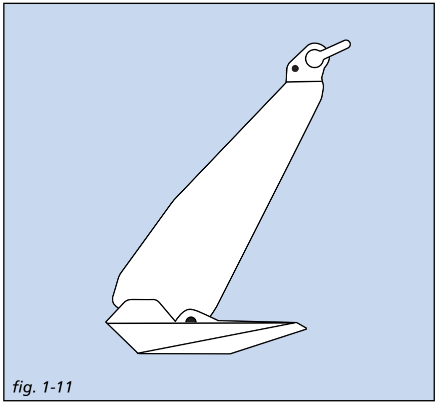


fig. 1-11

Pile

The pile is a hollow steel pipe that is installed into the seabed by means of a piling hammer or vibrator. The holding capacity of the pile is generated by the friction of the soil along the pile and lateral soil resist-ance. Generally the pile has to be installed at great depth below seabed to obtain the required holding capacity. The pile is capable of resisting both horizontal and vertical loads *(fig. 1-12).*

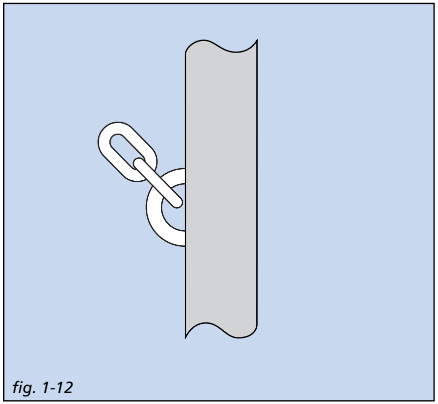


fig. 1-12

Suction anchor

Like the pile, the suction anchor is a hollow steel pipe, although the diameter of the pipe is much larger than that of the pile. The suction anchor is forced into the seabed by means of a pump connected to the top of the pipe, creating a pressure difference. When pressure inside the pipe is lower than outside, the pipe is sucked into the seabed. After installation the pump is removed. The holding capacity of the suction anchor is generated by the friction of the soil along the suction anchor and lateral soil resistance. The suction anchor is capable of withstanding both horizontal and vertical loads *(fig. 1-13).*

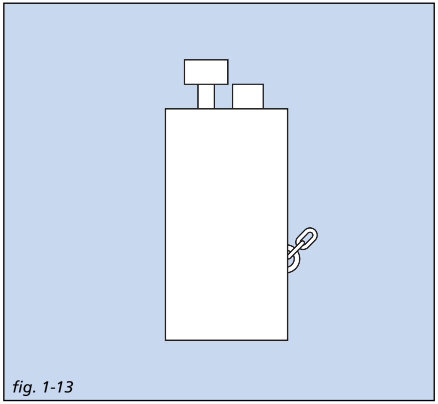


fig. 1-13

Vertical load anchor

A new development is the vertical load anchor (VLA). The vertical load anchor is installed like a conventional drag embedment anchor, but penetrates much deeper. When the anchor mode is changed from the installation mode to the vertical (normal) loading mode, the anchor can withstand both horizontal and vertical loads *(fig. 1-14).*

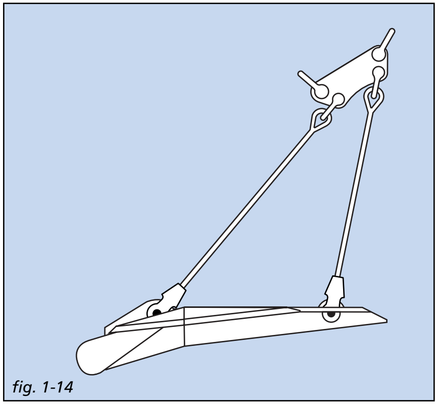


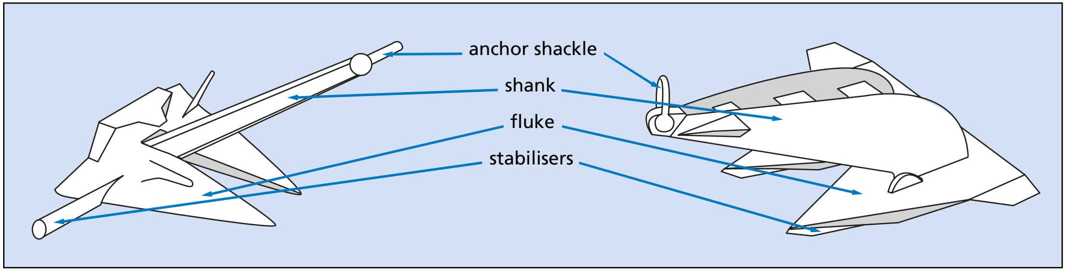
fig. 1-14

History of drag embedment anchors

History traces the use of anchors to China as far back as 2,000 BC, though it is quite probable that they were used prior to this. At that time the general tendency was to use large stones, baskets of stones, bags of sand or even logs of wood loaded with lead which were then fastened to lines. It was this weight as well as a certain degree of friction on the bottom which secured a vessel in position.

With the introduction of iron into anchor construction, teeth or flukes were built on the anchor, allowing penetration into the seabed, thus offering additional stability. Yet these primitive anchors were of poor construction and often broke under pressure. Curved arms were introduced in 1813, and from 1852, the so-called ‘Admiralty Anchor’ was used for ships of the Royal Navy. Another refinement in the 19th century was the elimination of the stock, the crosspiece at the top of an anchor which ensured that the positioning of the anchor would allow the flukes to penetrate the soil. A stockless anchor was invented in 1821 and became popular, primarily as a result of the ease of handling and stowing, qualities still valued today.

A large number of anchor types has been designed and commercialised over the years. Some have prospered, others not. The most recent designs are the results of vast experience and extensive testing, and are far more efficient than their historical predecessors. A short overview of the anchors in use today, is presented on the following pages.

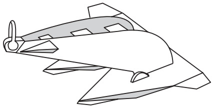


Characteristics of anchor types

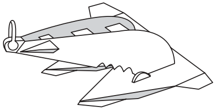
Based upon certain charateristics such as fluke area, shank, stabilisers, it is possible to classify the various anchor types. To allow a rough comparison of anchor type efficiency, an indication (*) is provided for a 10 t anchor as (HOLDING CAPACITY = WEIGHT * EFFICIENCY).

Class A efficiency range *33 to 55
slender anchors with ultra-penetration.

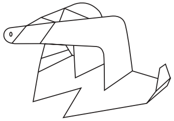
Class A



Stevpris



Stevshark

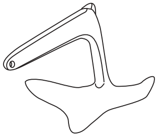


FFTS

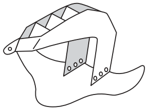
Characteristics of anchor types

Class B efficiency range *17 to 25
anchors with ‘elbowed’ shank, allowing for improved penetration.

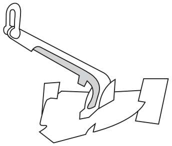
Class B



Bruce SS



Bruce TS

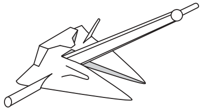


Hook

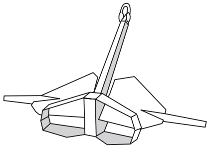
Class C efficiency range *14 to 26

anchors with open crown hinge near the centre of gravity and relatively short shank and stabilisers or built-in stabilisers.

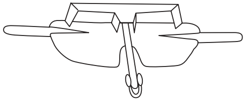
Class C



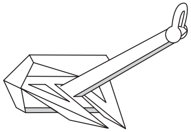
Stevin



Stevfix



Stevmud



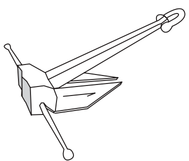
Flipper Delta

Characteristics of anchor types

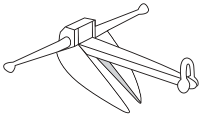
Class D efficiency range *8 to 15

anchors with hinge and stabilisers at the rear and relatively long shanks and stabilisers.

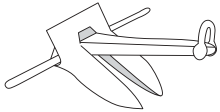
Class D



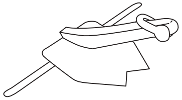
Danforth



LWT



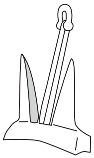
Moorfast - Stato - Offdrill

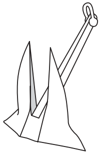


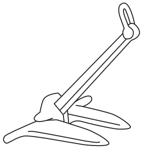
Boss

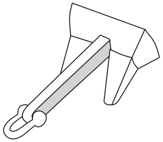
Class E efficiency range *8 to 11
anchors with very short, thick stabilisers; hinge at the rear and a relatively short, more or less square-shaped shank.

Class E


AC14


Stokes

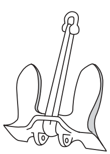

Snugstow


Weldhold

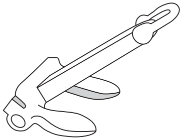
Class F efficiency range *4 to 6

anchors with square shank, no stock stabilisers. The stabilising resistance is built-in the crown.

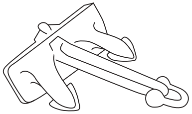
Class F



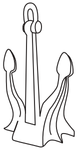
US Navy Stockless



Beyers



Union

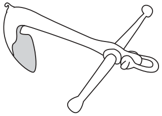


Spek

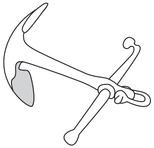
Characteristics of anchor types

Class G efficiency range *<6
anchors with small fluke area and stabilisers at the front of the shank.

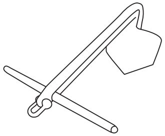
Class G



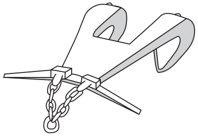
Single Fluke Stock



Stock



Dredger

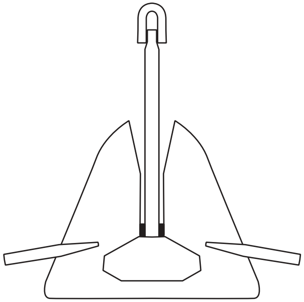


Mooring Anchor

History of vryhof anchor designs

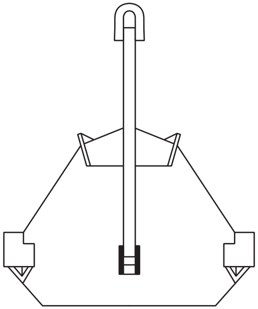
A brief chronological summary of the types of anchors vryhof has designed for use in the offshore and dredging industries:

- 1972 - The **Stevin** anchor: The original design. The wing was not yet enlarged. The anchor had a square shank. It is no longer manufactured.



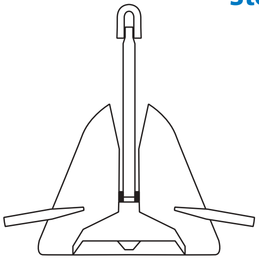
Stevin

- 1974 - The **Hook** anchor: originally designed for permanent moorings. This design was surpassed in 1980 by the Stevpris design and is no longer manufactured.



Hook

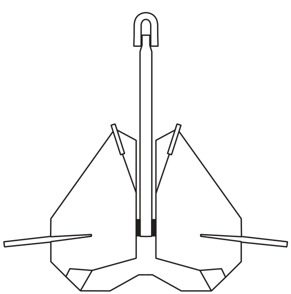
- 1977 - The **Stevin Mk3** anchor: is the improved version of the original Stevin anchor. It was equipped with an enlarged crown and fluke area and a streamlined shank for more efficient penetration. This anchor is still manufactured and in use in offshore and dredging activities. It has all classification societies approvals.



Stevin Mk3

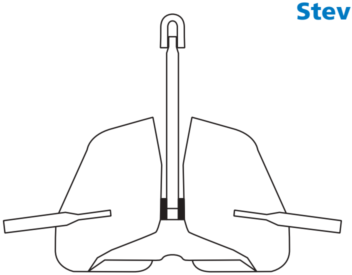
- 1978 - The **Stevfix** anchor: this anchor was designed with special fluke points for harder soils and a larger fluke area than the Stevin, but has been surpassed by the Stevpris anchor. It is no longer manufactured.

Stevfix



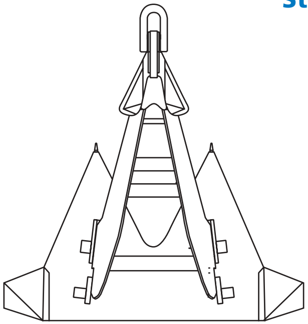
- 1979 - The **Stevmud** anchor: the Stevmud is essentially the Stevin anchor with a considerably enlarged fluke area. This anchor type was also surpassed by the Stevpris anchor and is no longer manufactured.

Stevmud

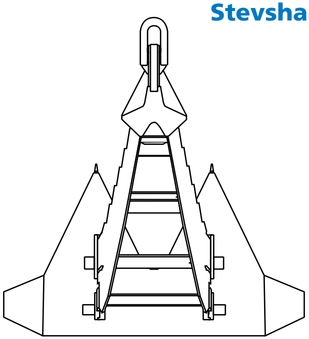


- 1980 - The introduction of the Stevpris and Stevshark anchors. The **Stevpris** anchor is a deep penetrating anchor with a plough shaped shank, surpassing the performance of all earlier designs in the vryhof range, and incorporating the latest experience, research and knowledge of the anchor designer. The Stevshark anchor is a specially reinforced Stevpris anchor, equipped with a serrated shank and cutter-teeth for better penetration in hard soils, such as coral types or sandstone. The fluke points are specially reinforced to withstand high point loads.

Stevpris

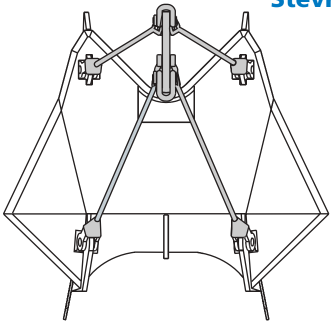


Stevshark Mk5

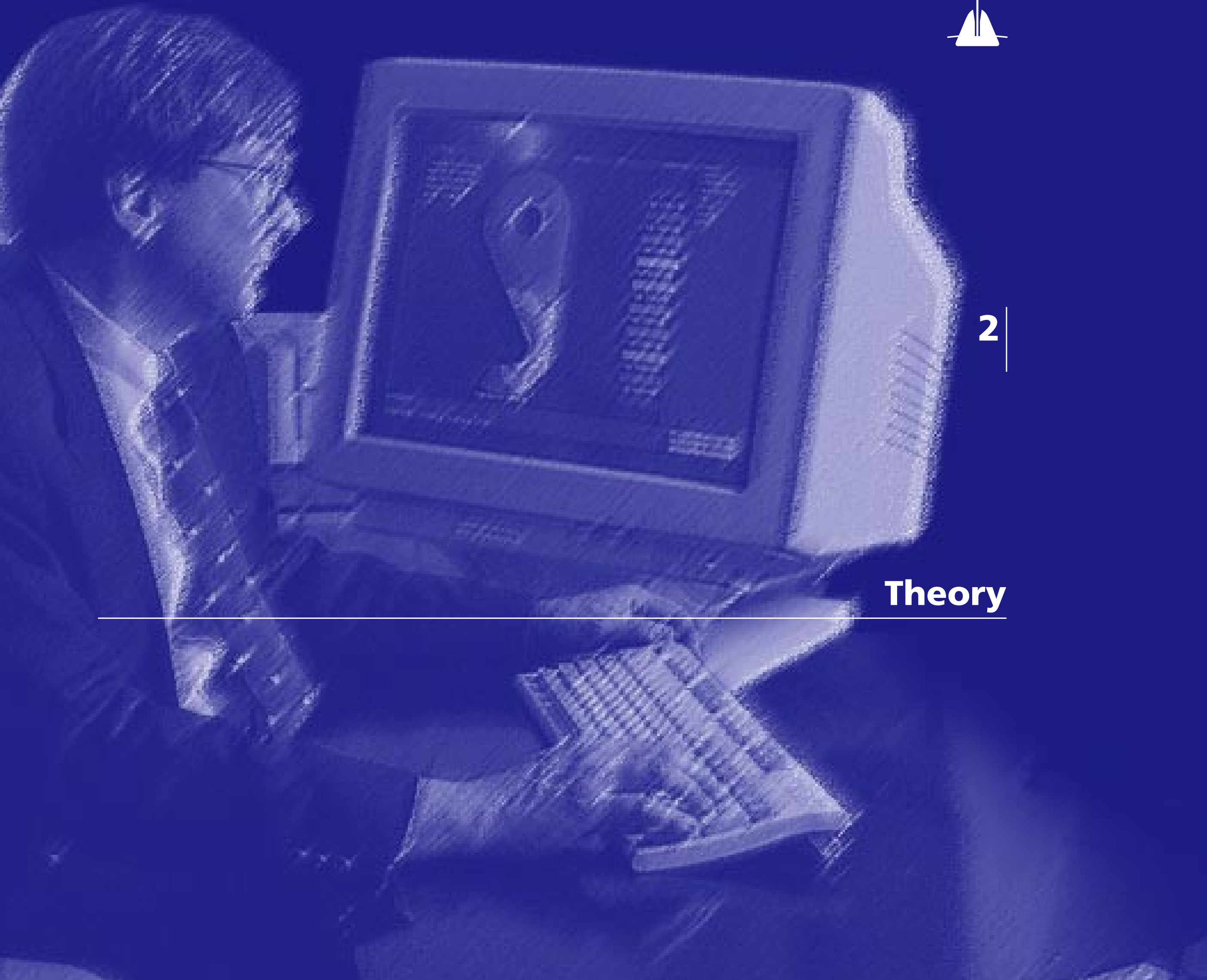


- 1990 - The **Stevpris Mk5** and **Stevshark Mk5** were introduced. The improved versions of the original Stevpris and Stevshark anchors. Improvements have concentrated on two features: higher holding capacity and easier handling.

Stevmanta



- 1996 - Introduction of the **Stevmanta VLA** (Vertical Load Anchor). Based on industry demand for an anchor that could withstand vertical loads, the Stevmanta VLA was developed. The Stevmanta VLA is a new design in which a traditionally rigid shank has been replaced by a system of wires connected to a plate. The anchor is designed to accept vertical (or normal) loads and is installed as a conventional drag embedment anchor with a horizontal load to the mudline to obtain the deepest penetration possible. By changing the point of pulling at the anchor, vertical (or normal) loading of the fluke is obtained thus mobilising the maximum possible soil resistance. As a VLA is deeply embedded and always loaded in a direction normal to the fluke, the load can be applied in any direction. Consequently the anchor is ideal for taut-leg mooring systems.



2

Theory

Theory

Anchor design used to be based on practical experience of the anchor manufacturer only. Nowadays, science has become a major factor in the design process, complementing the experience of the anchor manufacturer. Based on test results, both in the laboratory and in the field, a much better understanding of anchor behaviour has been achieved.

The performance of an anchor is influenced by many different parameters, of which the following are only a few: fluke area and design, shank design, soil conditions, load conditions, type of mooring line.

This chapter presents a short overview of how these parameters influence the performance of the anchor. It is by no means complete, but it will give a better understanding of how an optimal anchor design can be achieved. In the last part of this chapter, a few relevant test results are presented.

Criteria for anchor holding capacity

The holding capacity of an anchor is governed by the following parameters:

- The fluke area, which is limited by the strength of the anchor design.
- The penetration of the anchor. The penetration of the anchor is governed by the soil type (deep penetration in very soft clay and shallow penetration in sand), the anchor type (design), the type of mooring line that is used (chain or wire rope) and the applied load.

An increase in fluke area or an increase in the penetration depth of the anchor results in a higher holding capacity.

In the following paragraphs, the influences on the anchor penetration are further clarified.

Streamlining of the anchor

A streamlined anchor is very important for optimal penetration in the soil. As can be seen in *fig. 2-01* and *fig. 2-02*, an anchor which has protruding parts will encounter much more soil resistance and consequently will not penetrate as deep as a more streamlined anchor with the same fluke area.

Shank shape

A square shank, which is common for most older type single shank anchors, will cause penetration resist-ance due to the fact that the soil can not pass easily past the shank. A clod of soil will form underneath the shank, effectively increasing the resistance of the soil *(fig. 2-03)*. Bevelling the shank allows deeper penetration.When the single shank is replaced by a twin shank construction (for instance Stevpris, FFTS), usually two thin parallel steel plates, the soil can more easily pass through and past the shank, and consequently the twin shank anchor can penetrate deeper *(fig. 2-04)*.

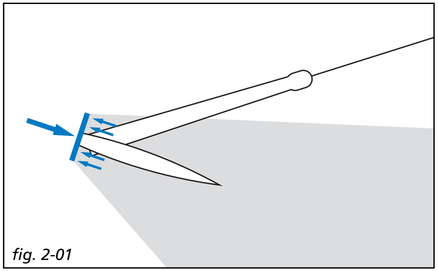


fig. 2-01

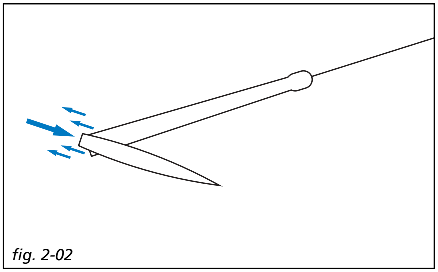


fig. 2-02

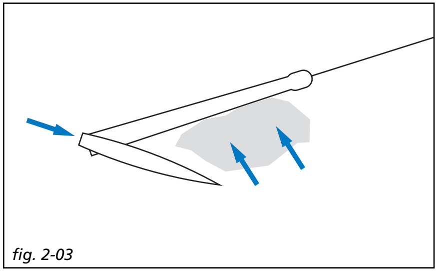


fig. 2-03

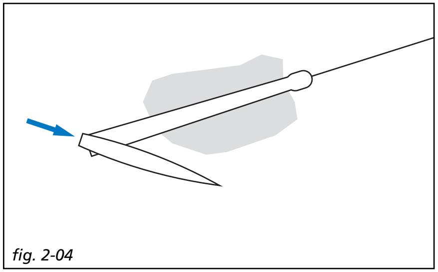


fig. 2-04

Mooring line

An anchor connected to a wire rope mooring line will penetrate deeper than the same anchor connected to a chain mooring line *(fig. 2-05 and fig. 2-06)*. This is caused by the higher lateral resistance (penetration resistance) along the chain mooring line. This effect is noticeable in all soil conditions, but especially in very soft clay where very deep penetration can be obtained. The holding capacity of a chain mooring line, due to friction in and on the seabed, is larger than the holding capacity of a wire rope mooring line.

When an anchor reaches its ultimate holding capacity, i.e. it will not resist any higher loads, at shallow penetration a wedge shaped piece of soil (in front and above the anchor) will fail. The holding capacity of the anchor can then be described as a combination of the following parameters *(fig. 2-07 and fig. 2-08)*:

- The weight of the anchor (A).
- The weight of the soil in the failure wedge (B).
- The friction of the soil in the failure wedge along fracture lines (C).
- Friction between fluke surface and soil (fluke area) (D).
- The bearing capacity of shank and mooring line (E).
- The friction of the mooring line in and on the soil (E).

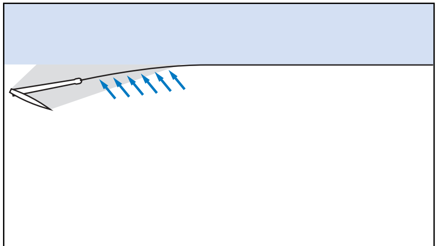


fig. 2-05

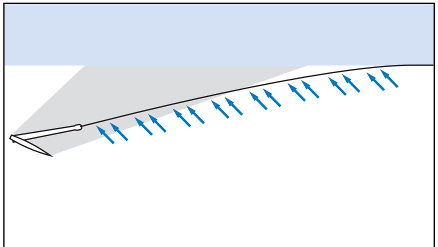


fig. 2-06

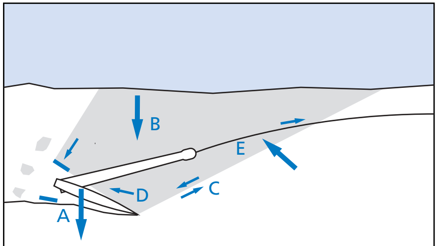


fig. 2-07

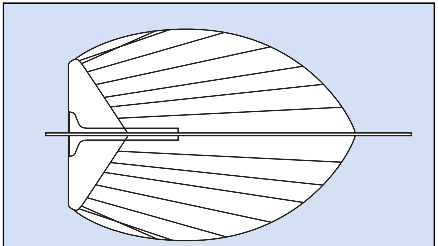


fig. 2-08

Criteria for good anchor design

Anchor parameters can be scaled from geometrically proportional anchors using the scale rules in *table A*.

There are several attributes of an anchor which are crucial in assuring its effective performance:

- The anchor must offer a high holding capacity; a result of the fluke area and shank design in combination with penetration and soil type.
- The design of the anchor should be such that the anchor is capable of being used successfully in practically all soil conditions encountered over the world, ranging from very soft clay to sand, corals and calcarenites.
- The fluke/shank angle of the anchor should be easily adjustable, allowing the anchor to be quickly deployed in different soil conditions.
- The design must be so conceived and produced that the high loads common in practice can be resisted and that the anchor can be easily handled, installed, retrieved and stored.
- The penetration of an anchor depends upon its shape and design. Obstructing parts on the anchor should be avoided as much as possible.
- The stability of an anchor encourages its penetration and, consequently, its holding capacity. Efficient stabilisers are an integral part of a good anchor design.
- The shank must permit passage of the soil.
- The surface area of an anchor fluke is limited by the required structural strength of the anchor.
- The anchor design must have optimal mechanical strength to fulfil requirements and stipulations of the classification societies.
- The anchor should be designed to ensure an optimum between structural strength of the anchor and holding capacity.
- The anchor should be streamlined for low penetration resistance.

Scale influence

	Model	**Reality**	**Related to Weight**
Length	L	n	$W^{1/3}$
Fluke area	A	n^2	$W^{2/3}$
Weight	W	n^3	W
Penetration	P	n	$W^{1/3}$
Moment	M	n^4	$W^{4/3}$
Moment of inertia	I	n^4	$W^{4/3}$
Section Modulus	S	n^3	W
Bending stress	M/S	$n^4/n^3=n$	$W^{1/3}$
Shear strength	F/A	$n^3/n^2=n$	$W^{1/3}$

table A

Aspects of soil mechanics in anchor design

Until the nineteen seventies anchor design was largely an empirical process. There was not much science involved, more use of experience. It is not easy, for instance, to calculate the Ultimate Holding Capacity (UHC) of an anchor from the commonly known soil mechanics formulas. The main problem is the prediction of the volume of soil mobilised by the anchor. To a large degree, it is this volume which determines the UHC. Detailed understanding of soil characteristics and behaviour is essential in the anchor design process and of increasing benefit in handling at sea. It is this understanding which is the hallmark of a competent anchor designer and builder.

For anchor design and installation, the availability of good soil data is of utmost importance as the soil is of great influence on anchor behaviour. The following are influenced by the soil conditions encountered:

Anchor type - some anchors are more suited for soft soil conditions (soft clay), while others are more suited for hard soils (sand and hard clays), although there are a number of anchor types on the market that are suited for most soil conditions encountered.

Holding capacity - in hard soil like sand and hard clay, the maximum attainable ultimate holding capacity with a certain anchor type and size is higher than the attainable ultimate holding capacity in very soft clay.

Penetration and drag - in very soft clay the anchor will penetrate deeper than in harder soil like sand. As a consequence, the drag length of the anchor will also be longer in very soft clay than in hard soil.

Retrieval forces - when an anchor is installed in very soft clay, the required retrieval forces will be higher than in hard soil like sand. For example, in very soft clay the required retrieval force of an anchor can be equal to 80%-90% of the installation load while in hard soil (sand) the retrieval force might only be 20%-30% of the installation load.

Soil classification

Soil strength is generally expressed in terms of the shear strength parameters of the soil. The soil type is classified mainly by grain size distribution.

Grain size	**Soil description**
< - 2 µm	Clay
2 - 6 µm	Fine Silt
6 - 20 µm	Medium Silt
20 - 60 µm	Coarse Silt
60 - 200 µm	Fine Sand
200 - 600 µm	Medium Sand
0.6 - 2 mm	Coarse Sand
2 - 6 mm	Fine Gravel
6 - 20 mm	Medium Gravel
20 - 60 mm	Coarse Gravel
60 - 200 mm	Cobbles
> - 200 mm	Boulders

IIn general, the soil types encountered in anchor design are sand and clay (Grain diameter from 0.1 µm to 2 mm). However, mooring locations consisting of soils with grain sizes above 2 mm, such as gravel, cobbles, boulders, rock and such, also occur. Clay type soils are generally characterised by the undrained shear strength, the submerged unit weight, the water content and the plasticity parameters. The consistency of clays is related to the undrained shear strength. However, American (ASTM) and British (BS) standards do not use identical values (*table B)*.

The undrained shear strength values S_u can be derived in the laboratory from unconfined unconsolidated tests (UU).

Undrained Shear Strength (kPa)

Consistency of Clay	**ASTM D-2488**	**BS CP-2004**
Very soft	0 - 13	0 - 20
Soft	13 - 25	20 - 40
Firm	25 - 50	40 - 75
Stiff	50 - 100	75 - 150
Very stiff	100 - 200	150 - 300
Hard	200 - 400	300 - 600
Very hard	> 400	> 600

table B

Soil classification

On site the values can be estimated from the results of the Standard Penetration Test (SPT) or Cone Penetrometer Test (CPT). An approximate relation between shear strength and the test values are shown in *table C*.
The mechanical resistance of sandy soils is predominantly characterised by the submerged unit weight and the angle of internal friction, φ. These parameters are established in the laboratory. An approxim-ate correlation between the angle φ and the relative density of fine to medium sand is given in *table D*. The undrained shear strength of clayey soil can also be estimated based on manual tests.

- In soft clay the thumb will easily penetrate several inches, indicating an undrained shear strength smaller than 25 kPa.
- In firm (medium) clay the thumb will penetrate several inches with moderate effort, indicating an undrained shear strength between 25 kPa and 50 kPa.
- Stiff clay will be easily indented with the thumb but penetration will require great effort, indicating an undrained shear strength between 50 kPa and 100 kPa.
- Very stiff clay is easily indented with the thumbnail, indicating an undrained shear strength between 100 kPa and 200 kPa.
- Hard clay is indented with difficulty with the thumbnail, indicating an undrained shear strength larger than 200 kPa.

The rock strength can generally be described by its compressive strength *(table E)*.

A classification system for soil based on the carbonate content and grain size of the soil (Clark and Walker), is shown on the laste page of this chapter.

S_u kPa	UU kPa	SPT N	CPT MPa
0 - 13	0 - 25	0 - 2	0.0 - 0.2
13 - 25	25 - 50	2 - 4	0.2 - 0.4
25 - 50	50 - 100	4 - 8	0.4 - 0.7
50 - 100	100 - 200	6 - 15	0.7 - 1.5
100 - 200	200 - 400	15 - 30	1.5 - 3.0
> 200	> 400	>-30	>3.0

table C

Descriptive term	Relative Density	Angle φ	SPT N	CPT MPa
Very loose	< 0.15	< 30	0- 4	0 - 5
Loose	0.15 - 0.35	30 - 32	4 - 10	5 - 10
Medium dense	0.35 - 0.65	32 - 35	10 - 30	10 - 15
Dense	0.65 - 0.85	35 - 38	30 - 50	15 - 20
Very dense	> 0.85	> 38	> 50	> 20

table D

Descriptive term	Compressive strength q_u [MPa]
Very weak	< 1.25
Weak	1.25 – 5
Moderately weak	5 – 12.5
Moderately strong	12.5 – 50
Strong	50 – 100
Very strong	100 – 200
Extremely strong	> 200

table E

Fluke/shank angle

The penetration of an anchor into a certain soil type is greatly influenced by the selected fluke/shank angle. For hinging anchor types (Stevin, Danforth etc.) the fluke/shank angle is the angle between the anchor shackle, the hinge and the fluke tip. The method for measuring the fluke/shank angle for fixed shank anchors (Stevpris, FFTS, etc.) is not well defined. Often it is the angle between the anchor shackle, the rear of the fluke and the fluke tip, but not all anchor manufacturers use the same definition.

The recommended fluke/shank angles for different soil conditions are presented in *table F*.

Some modern anchors, like the Stevpris Mk5, have an additional intermediate fluke/shank angle of 41°, which can be used in intermediate or more complex soil conditions. For instance at a location where the anchor has to pass through a layer of soft clay before penetrating into a layer of sand.
If an anchor is used with an incorrect fluke/shank angle, it will negatively influence performance. This is the case for all anchor types.

In hard soil, an anchor with a fluke/shank angle of 32^0 will give the highest holding power. If an anchor is used with the fluke/shank angle set at 50^0, the anchor will fail to penetrate into the seabed and will begin to trip, fall aside and slide along the seabed *(Fig. 2-9 and 2-10)*.

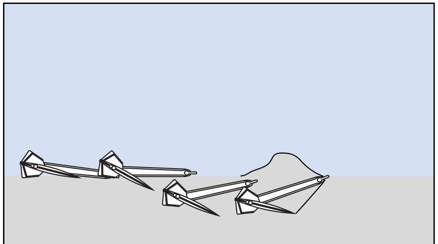


fig. 2-09

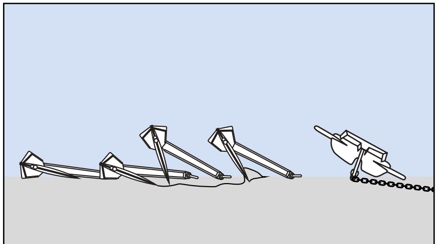


fig. 2-10

Soil type	**Approximate fluke/shank angle**
Very soft clay	50°
Medium clay	32°
Hard clay and sand	32°

table F

Fluke/shank angle

If an anchor is used in very soft clay (mud) with the fluke/shank angle set at 32°, the anchor will penetrate into the seabed, however the penetration will be less than when a fluke/shank angle of 50° is used. Consequently the holding capacity will be lower when the fluke/shank angle is set at 32°, and the drag length longer *(Fig. 2-11)*.

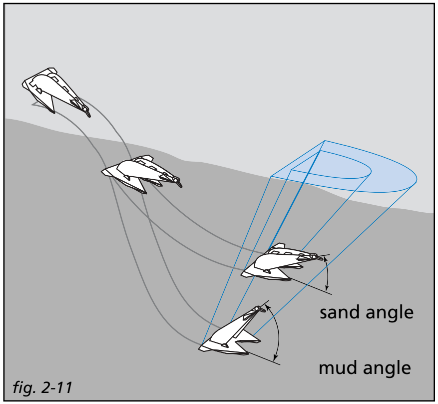


fig. 2-11

Fluke area

Because the fluke area of an anchor is of great influence on the holding capacity, it can be useful to compare the fluke area of different anchor types that are available on the market today. In general, it can be stated that two anchors of the same weight but of different type (for instance a Stevin anchor and a Stevpris Mk5 anchor), do not necessarily have the same fluke area. Consequently, two anchors of the same weight but different type, will have different holding capacities.

Some examples:

Fig. 2-12 shows a Stevpris Mk5 anchor and a Moorfast anchor, both of identical weight. It demonstrates that in spite of being the same weight, the fluke areas differ substantially. The ultimate holding capacity of the Stevpris Mk5 anchor is 4 to 8.5 times higher than that of the same weight Moorfast anchor.

Fig. 2-13 illustrates the difference in fluke area of the Stevpris Mk5 anchor in comparison with the Bruce FFTS Mk4 anchor, both of which have identical weight.

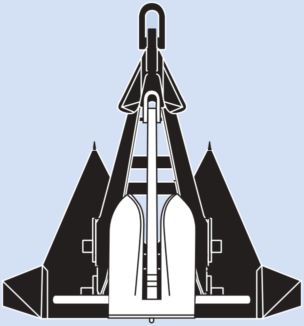


fig. 2-12

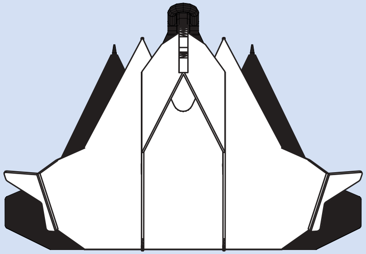


fig. 2-13

Strength of an anchor design

Anchors should be designed to withstand the loads applied on them in the different loading situations. Typical loading situations and areas of special attention for anchors are:

- During the proof loading of the anchors in the factory, after construction has been completed. On basis of the proof load results, the classification societies issue the approval certificate.

While embedded in the seabed

- Depending on the soil conditions, different loading situations can occur on the anchor. In sands and clays, the load tends to be spread equally over the anchor, which generally presents no problems. Retrieval is also very simple, without excessive loads placed on the anchor.
- In very hard soils, the anchor has to be able to withstand the load with only one or two of the fluke tips buried in the soil, as penetration in very hard soil conditions is generally shallow.
- In very soft clays (mud) penetration of the anchor is uncomplicated. However, recovery of the anchor can cause high loads, sometimes exceeding the load that was used to install the anchor.
- Sidewards forces on the top of (shallow) buried anchors can be so extreme that no anchor is capable of resisting them.

During anchor handling

- Care should be taken during the handling of the anchors, as the loads exerted by the winches, vessels and chain can sometimes exceed the structural strength of the anchor and cause damage. Anchor designers attempt to design the anchors for these high loads, however this is not always possible due to variations in the magnitude of the loads during handling operations.

- Large forces can be exerted on the anchor when high winch power is used, the anchor is caught on the anchor rack or caught behind the stern roller of the AHV.
- The use of an improper anchor/chaser combination. When a chaser is used that is either too small or too large, the chaser could jam on the shank of the anchor and cause damage.

The strength of the Stevpris anchor is now more closely examined in the light of the remarks made before.

Strength of the shank

The prismatic shape of the Stevpris anchor not only ensures optimal penetration of the soil but also guarantees maximum strength. Although the Stevpris design also has limitations, it is one of the better designs to withstand sideward forces on the shank, a frequent occurrence in practice. When using an anchor in very soft clay (mud), the bending moment on the shank is low during the installation and when the anchor is in the soil. However, during the breaking out of the anchor, high bending moments could be introduced in the shank due to the high retrieval forces required in very soft clay. In extremely sticky soils, the breaking out force of the anchor can rise to 80% or 90% of applied anchor load; in certain instances, it can even exceed 100%. To reduce these forces the breaking out procedure is undertaken at low speed to allow time for the anchor to break out.

Strength of the fluke

The strength of the fluke and especially the fluke points of an anchor are very important when working in extremely hard soils such as coral, limestone and other rock types. It is possible in such instances that the total holding capacity of the anchor will have to be sustained by the fluke points alone. This means the structure must be strong enough to withstand extreme bending forces. Loading in normal soil conditions is not a problem due to the fact that the load is equally spread over the fluke.

In *fig. 2-14*, the different force points are shown for varying soil conditions. The location on the fluke where the proofload is applied, is also indicated.

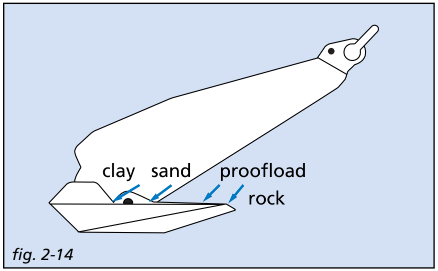


fig. 2-14

Strength in extremely hard soils

In very hard soils such as calcarenite, coral and limestone, an anchor will not penetrate very deeply. Consequently the load applied to the anchor has to be held by the fluke tips of the anchor and a small portion of the fluke. This means that extremely high loads will be applied to the fluke tips, compared to normal soil conditions such as sand and clay.

For use in very hard soil conditions, vryhof has designed the Stevshark anchor, a modified version of the Stevpris anchor. To create the Stevshark, the Stevpris anchor has been strengthened, consequently a Stevshark anchor having the same outside dimensions and holding capacity as a Stevpris anchor will be heavier.

Strength calculations of the Stevshark design have been made to guarantee sufficient strength in the fluke points. The Stevshark anchor is designed to withstand the application of the main part of the load on just its fluke tips.

To promote penetration, the Stevshark anchor has a serrated shank and can be provided with cutter points on the fluke tips. Ballast weight can also be added inside the hollow flukes of the anchor, up to 35% of the anchor weight. This is important when working in very hard soil, where the anchor weight pressing on the fluke tips promotes penetration, i.e. increased bearing pressure.

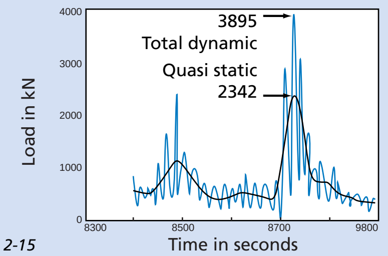


fig. 2-15

The loads in a mooring system are caused by the wind, waves and current acting on the floater. Depending on the location of the floater in the world, different metocean conditions will prevail. In the table below, some extreme metocean conditions are presented for different areas.

The loads induced in the mooring system can be divided into quasi-static loads and total dynamic loads. The quasi static load is the load due to the swell, wind, current and the frequency of the system. For quasi-static loads, the systems tend to move at a low frequency, generally with a period of 140 to 200 seconds.

On top of this quasi-static load there are the individ-ual wave forces causing a high frequency motion. The high frequency motion causes dynamic shock loads with a period of 10 to 14 seconds due to the rolling of the vessel and the movements of the anchor lines through the water. The quasi-static load plus the individual wave forces is called the total dynamic load. Generally the quasi-static loads will be equal to 50% to 90% of the total dynamic load. See *Fig. 2-15* for an example of the difference between the quasi-static load and the total dynamic load.

Location	**Waveheight m**	**Wave period s**	**Windspeed m/s**	**Current m/s**
Campos Basin	8 – 10	12 - 15	25	1
Gulf of Mexico	11	14	44 - 48	1
Northern North Sea	15 - 16	15 - 17	38 - 39	0.9– 1.2
Porcupine Basin	16 - 18	16 - 20	39 - 41	1.0 – 1.5
Vorine Basin	14 - 15	16 - 17	37 - 39	1.0 – 1.5
West of Africa	4 - 6	10 - 16	20	0.3 – 0.6
West of Shetlands	15 - 17	16 - 19	39 - 41	1.0 – 3.0

The quasi-static and total dynamic loads are generally calculated for the intact and damaged load condition. The intact load condition is the condition in which all the mooring lines are intact. The damaged load condition is the condition in which one of the mooring lines has broken.

From the quasi-static load and the total dynamic load, the required holding capacity of the anchor can be calculated. This is called the ultimate holding capacity (UHC) for drag embedment anchors and the ultimate pull-out capacity (UPC) for VLAs. The required holding capacity is calculated by applying the factors of safety specified by the classification societies.

In the *tables G and H*, the factors of safety are presented for the different load conditions for drag embedment anchors (for instance the Stevpris Mk5 anchor), according to API RP 2SK. The factors of safety used by the major classification societies are generally similar to those given in API RP 2SK (2nd edition, 1996).

For VLAs, the recently used factors of safety suggested by ABS, are presented in *table I*.

The factors of safety for VLAs are higher than the factors of safety required for drag embedment anchors, due to the difference in failure mechanisms. When a drag embedment anchor reaches its ultimate holding capacity, it will continuously drag through the soil without generating additional holding capacity, i.e. the load will stay equal to the UHC. When a VLA exceeds its ultimate pullout capacity, it will slowly be pulled out of the soil.

In *table J* the safety factors according to API RP 2SK for the mooring line are presented for comparison purposes.

Permanent mooring	**Quasi-static load**	**Total dynamic load**
Intact load condition	1.8	1.5
Damaged condition	1.2	1.0

table G

Temporary mooring	**Quasi-static load**	**Total dynamic load**
Intact load condition	1.0	0.8
Damaged condition	Not required	Not required

table H

VLA	**Total dynamic load**
Intact load condition	2.0
Damaged condition	1.5

table I

Mooring line safety factors	**Quasi-static load**	**Dynamic load**
Intact load condition	2.00	1.67
Damaged load condition	1.43	1.25
Transient load condition	1.18	1.05

table J

Drag embedment anchors

Drag embedment anchors are generally installed by applying a load equal to the maximum intact load. For permanent mooring systems the installation load should be held for the period specified by the classification societies (see *table K*). The anchor will then have penetrated to a certain depth, but will still be capable of further penetration because the ultimate holding capacity has not been reached. The anchor will also have travelled a certain horizontal distance, called the drag length. After installation the anchor is capable of resisting loads equal to the installation load without further penetration and drag. When the installation load is exceeded, the anchor will continue to penetrate and drag until the soil is capable of providing sufficient resistance or the ultimate holding capacity has been reached. However, there are certain effects which allow the anchor to withstand forces larger than the installation load without further penetration and drag. These are:

The set-up and consolidation effect

Set-up and consolidation mainly occur in clayey soils. The penetrating anchor disturbs the soil and the soil temporarily loses strength. With time, the disturbed clay reconsolidates to its initial shear strength, this takes from a few hours up to 1 month, depending on the soil type. Because not all the soil around the anchor is disturbed, the set-up effect factor is less than the sensitivity index indicates. The disturbance mainly reduces the soil resistance parallel to the fluke. On reloading, the parallel soil resistance gains strength, it takes a larger load to move the anchor again. Equilibrium dictates that also the normal load, i.e. the bearing soil resistance to the fluke, increases; consequently the load at the shackle increases also with the set-up factor. Observations on anchors for drilling rigs and theoretical considerations for a 3 to 4 week consolidation time demonstrate a typical set-up effect factor =1.5.

Classification society	**Required duration of maintaining tension**
Lloyd's Register of Shipping	20 minutes
American Bureau of Shipping	30 minutes
Det Norske Veritas (NMD)	15 minutes

table K

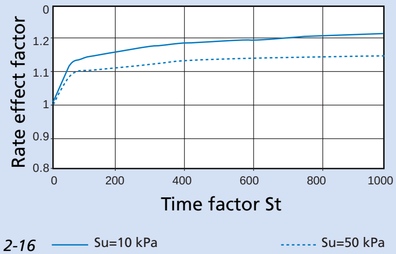


fig. 2-16

The rate effect

An increased rate of loading increases the soil resistance, consequently the anchor holding capacity increases. This must be taken into account with respect to total dynamic loads. For anchor behaviour the rate effect factor indicates how much higher the dynamic high frequency load may be without causing extra movement of the anchor once installed at the installation load. The rate of loading influences pore pressure variations, viscous intergranular forces and inertia forces. Typical rate effect factors are 1.1 to 1.3 for total dynamic loads, see Fig. 2-16 where the rate effect is presented for two different soil conditions (Su = 10 kPa and Su = 50 kPa).

Using the rate effect and set-up factors, the behaviour of the anchor after installation can be predicted more accurately.

Vertical Load Anchors

A VLA is installed just like a conventional drag embedment anchor. During installation (pull-in mode) the load arrives at an angle of approximately 45 to 50^0 to the fluke. After triggering the anchor to the normal load position, the load always arrives perpendicular to the fluke. This change in load direction generates 2.5 to 3 times more holding capacity in relation to the installation load. This means that once the required UPC of the VLA is known, the required installation load for the VLA is also known, being 33% to 40% of the required UPC.

As a VLA is deeply embedded and always loaded in a direction normal to the fluke, the load can be applied in any direction. Consequently the anchor is ideal for taut-leg mooring systems, where generally the angle between mooring line and seabed varies from 25 to 45^0.

Proof loads for high holding power anchors

The proof load according to Classification Societies' rules is applied at 1/3rd of the fluke length and is carried out immediately on fabrication of the anchor. It is obtained by placing the anchor in a test yoke in which a hydraulic cylinder applies the test loads, controlled by a calibrated manometer
(fig. 2-17). The vryhof anchor types have been approved by the following Classification Societies:

- The American Bureau of Shipping
- Bureau Veritas
- Det Norske Veritas
- Germanischer Lloyd
- Lloyd's Register of Shipping
- Registro Italiano Navale
- USSR Register of Shipping
- Nippon Kaiji Kyokai
- Norwegian Maritime Directorate

In the early days there were no specific regulations regarding the holding power and strength of mooring anchors. The rules which did exist were often followed regardless of the type of vessel.

Some anchors were approved as 'high holding power' anchors. This so-called HHP approval was obtained after carrying out field tests in various types of soil in which it had to be shown that an anchor provided a holding power of at least twice that of a standard stockless anchor. If an HHP anchor was requested by the owner, the anchor has proof tested in strict accordance with the rules, nothing more. See *table J* for some examples of HHP anchor proof loads. A more detailed overview of HHP anchor proof loads is

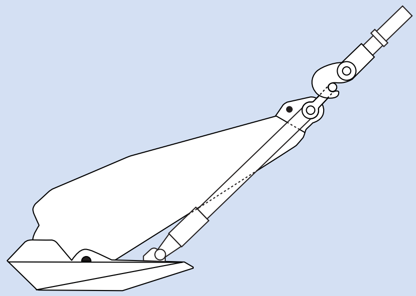


fig. 2-17

Anchor weight	Proof Load factor	Anchor weight
1 t	26 t	26 x
5 t	79 t	15 x
7 t	99 t	14 x
10 t	119 t	12 x
15 t	155 t	10 x
20 t	187 t	9 x

table J

given in the product data section.
The use of the specified proof loads for HHP anchors can lead to situations where different types of anchors with the same holding capacity are proof loaded at different loads, see *fig. 2-18*. From this figure it can be concluded that the proof load of the anchors should preferably be related to the break-load of the mooring line on the vessel.

Nowadays the rules and regulations are far more rigid, and the requirements have been substantially increased. There are now special rules for ‘mobile offshore units’ and ‘permanently moored structures’.

If anchors need mobile offshore units certification, the following properties may be required:

- Proof load of the anchors at 50% of the breaking load of the chain.
- Submission of a strength calculation of the anchor to the classification society prior to commencing anchor production: this includes determining the mechanical strength of the anchor as well as proving that the applied material can withstand the proofload.
- A statement of documented holding power from the anchor supplier.
- Submittal of a Quality Assurance/Quality Control Manual.

In *fig. 2-19*, a mooring system is shown in which all of the components are balanced. The strength of the mooring line, holding capacity of the anchor and strength of the anchor are all in the correct proportion and comply with the rules.

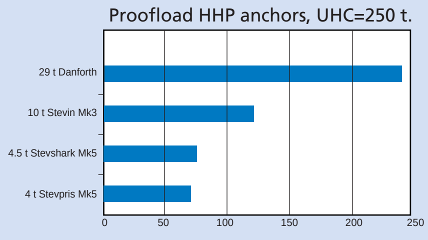


fig. 2-18

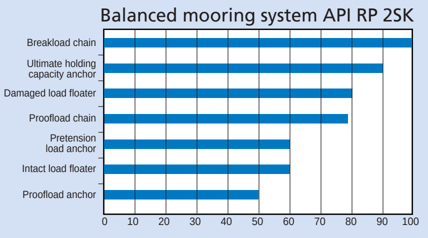


fig. 2-19

Quality control

The application of more advanced and complex technology in anchor construction has brought about requirements for a systematic approach to quality. Initiated by various authorities they are continuously refined and followed up by operating companies such as vryhof anchor. Like other companies, vryhof has become increasingly aware of the vital importance of managerial aspects and their influence on the total quality-assurance and control system.

Design and fabrication of anchors for permanent moorings are in accordance with the quality requirements of the Rules NS/ISO 9001 as described in our Quality Assurance Manual. Vryhof anchors obtained the ISO 9001 certificate No. QSC 3189 issued by Det Norske Veritas for ‘Design, Manufacture of anchors, and Sales of anchors and mooring components’.

Quality control is maintained throughout production. A compilation of certificates is presented to a client upon completion of a project.

DNV

ACCREDITED BY
THE DUTCH COUNCIL
FOR CERTIFICATION
Reg. No 24

ISO-9001CERTIFICATED FIRM
DET NORSKE VERITAS INDUSTRY B.V., THE NETHERLANDS

Introduction

In addition to practical experience of users and associates, anchor tests are one of the most reliable means of forecasting anchor performance and thus making a proper choice of anchor type and size.

Examining anchor tests that have been carried out in the past, certain conclusions can be made:

- Many tests were undertaken in which the results were recorded accurately.
- Detailed reports, however, have not been very common.
- Anchor tests of the past are not always easy to interpret or compare because of different soil and anchor types.
- Test results have not always been interpreted independently.
- The more tests results are strictly compared to practical results, the better one can forecast the holding power and general behaviour in practice.

Vryhof is in the perfect situation of having detailed test data available together with extensive practical data obtained during installation and use of anchors on projects on site.

Research into anchor behaviour and the ultimate holding capacity of anchors is often carried out by testing a model anchor, preferably followed by a full-scale test in the field. The optimal anchor test consists of model tests with 10 kg anchors, followed by full-scale tests with 1 t and 10 t anchors. The anchors should be pulled until the ultimate holding capacity is reached.

It is obvious that full-scale testing of anchors can be expensive. Large AHVs, strong winches and strong mooring lines are required, which are not always available. For example, a 5 t Stevpris Mk5 anchor, deployed in sand, is capable of stopping a modern AHV at its full bollard pull.

Testing a 10 t Stevpris Mk5 anchor to its ultimate holding capacity in sand would require a horizontal pulling capacity of approximately 600 t.

If anchor tests are to be comparable, the testing program should preferably meet, as a minimum, the following criteria:

- An accurate and sophisticated measuring system should be used.
- The anchors should be tested up to their ultimate holding capacity.
- Drag and penetration of the anchor should be recorded during testing.
- The anchor should be held under tension with a blocked winch for 15 minutes, to investigate any drop in holding capacity.

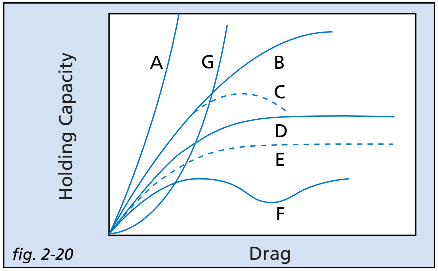


fig. 2-20

Reading test curves

The behaviour of an anchor during tensioning can be accurately interpreted from the holding capacity versus drag curve. Sample test curves are presented in *Fig. 2-20*. Properly interpreted performance curves can explain a lot about anchor behaviour.

- Curve A is very steep and represents a streamlined anchor in very stiff soil.
- Curve B is a normal curve for anchors in sand and medium clay.
- Curve C is a curve of an unstable anchor. This can be caused by a wrong fluke/shank angle setting, a short stabiliser or a fluke that is too long.
- Curve D is a normal curve for an anchor in very soft clay.
- Curve E is an anchor with a 32° fluke/shank angle in very soft clay.
- Curve F represents an anchor that is turning continuously. This can be caused by the absence of stabilisers, a too large fluke/shank angle or a low efficiency anchor at continuous drag.
- Curve G represents an anchor penetrating in a layer of stiff clay overlain by very soft clay.

Curves A, B, D, E and G show a very stable rising line, which indicates that the anchor builds up its holding capacity constantly until the ultimate holding capacity has been reached, after which the anchor shows continuous drag. The other curves are largely self-explanatory.

Test results

Vryhof’s extensive database of test results with different anchor types, sizes and soil conditions, has been frequently used in anchor design. Data has been obtained from practice, scale models and from third parties. The data has been interpreted and afterwards incorporated in the ultimate holding capacity, drag and penetration graphs of the Stevin Mk3 and Stevpris Mk5 anchor as well as in the ultimate pull-out capacity graph of the Stevmanta VLA.

Norwegian Contractors (1984)

In 1984 Norwegian Contractors carried out tests at Digernessundet, Stord, Norway. The purpose of these tests was to determine the correct anchor type and size for the mooring system of the Gullfaks A platform during the construction of the platform at Digernessundet. Although the construction would took place at one location, it was known that three different types of soil conditions would be encountered: sand, soft mud and an 8 m mud layer on rock. After the initial trials the Stevpris anchor was selected for further testing.

The 3 t Stevpris anchor that was used for the tests at a 3.3^0 pulling angle, produced a maximum holding capacity of 150 t in the sand, 102 t in the very soft clay and 150 t in the layer of mud on rock. As the mooring system required a survival load of 1500 t, a 65 t Stevpris (mud location), 40 t Stevpris (sand location) and 60 t Stevshark (mud on rock location) were selected for the final mooring. *Fig. 2-21* shows the test results of the 3 t Stevpris anchor, while *fig. 2-22* shows the result of the tensioning of the final anchors with a load of 820 t.

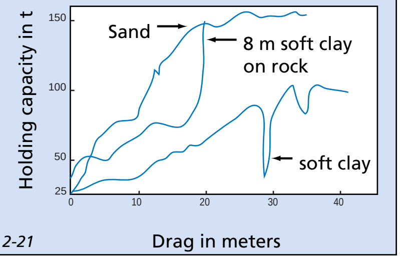
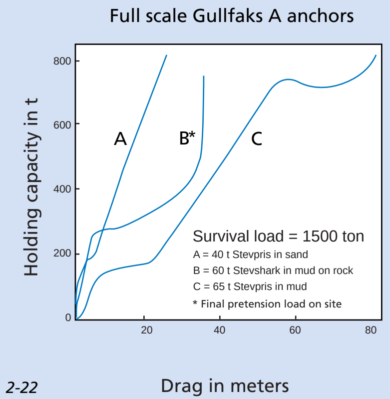


fig. 2-21



Full scale Gullfaks A anchors

fig. 2-22

Large scale anchor tests in the Gulf of Mexico

In 1990, tests were performed with 2 t and 7 t Stevpris Mk5 anchors, as part of an anchor test Joint Industry Project (JIP). The anchors were tested using a wire rope forerunner.

The 2 t Stevpris anchor was tested up to its ultimate holding capacity of 107 t (235 kips). Due to insufficient pulling capacity, the 7 t Stevpris anchor could not be pulled up to its ultimate holding capacity. Based on the results of tests, the ultimate holding capacity of the 7 t Stevpris anchor was calculated to be larger than 338 t (745 kips) (*fig. 2-23*).

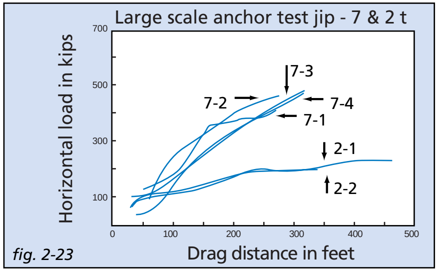


fig. 2-23

Uplift

Stevpris anchors are well capable of resisting uplift loads when they are deeply embedded. Anchors in sand and firm to hard clays do not penetrate very deeply and only take small uplift loads. Stevpris anchors installed in very soft clay and mud penetrate deeply, a typical penetration for a 15 t anchor is 15 to 25 meters. Due to the inverse catenary in the soil, the anchor line arrives at the anchor shackle at an angle of 20° to 30° with the mud line. Once the anchor is installed, a load making an angle up to 20° with the horizontal at mud line will not change the loading direction at the anchor! A Stevpris anchor has been tested in the Gulf of Mexico with gradually increasing pull angle *(fig. 2-24)*. The maximum resistance was obtained for 18° uplift at mud line.

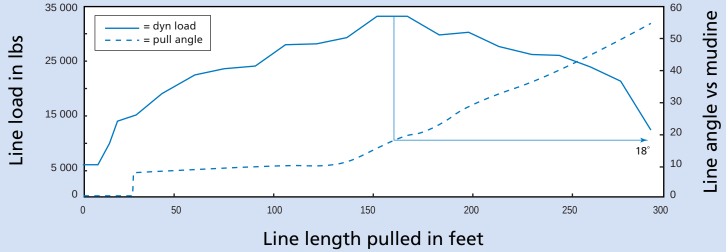


fig. 2-24

Cyclic effect factor

The loading at the anchor is cyclic. Exxon performed cyclic tests on anchors reported by Dunnavent and Kwan, 1993. Although the maximum cyclic load was less than the initial installation load, the static load applied after the cycling phase revealed 25 to 50% larger anchor resistance than the initial installation load *(fig. 2-25)*. This effect is explained by further penetration of the anchor. Applying this knowledge to the anchors, the static anchor resistance after some storm loading improves by the cyclic effect factor of 1.25 to 1.5.

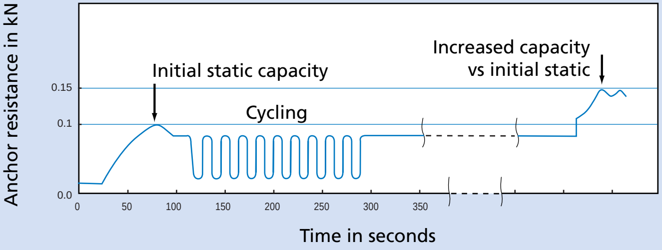
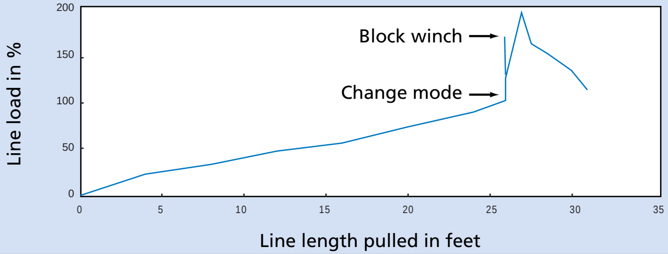


fig. 2-25

Tests with Stevmanta anchors

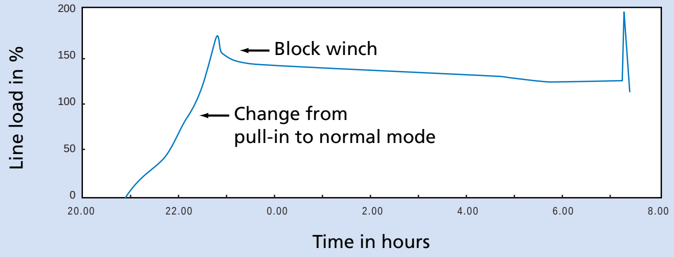
Tests have been performed in the Gulf of Mexico and offshore Brazil. The Stevmanta anchor being pulled in with a load equal to F, accepted a vertical load to the anchor of up to 2 times F! Amongst the many tests the anchor relaxation was measured. The anchor with a fluke area of 0.13 m^2 was pulled in at 0° pull angle *(fig. 2-26)*, then loaded vertically to a load equal to 1.6 times the maximum installation load. At this load the winch was blocked.



90^0 pulling angle with seabed in normal loading mode

fig. 2-26

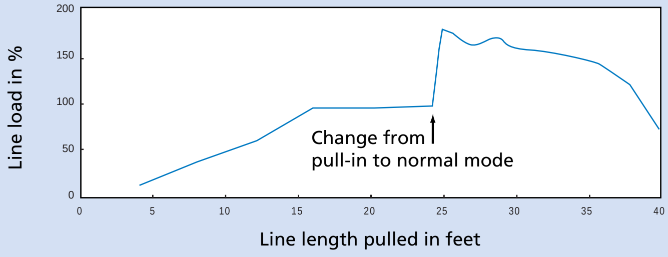
This permitted the monitoring of the load with time *(fig. 2-27)* as what would be expected in real circumstances at a constant loaded anchor line. The results show that the holding capacity of the anchor does not change significantly during continuous loading, as the observed decrease in tension was due to movement of the winch. The subsequent pulling at 7:00 AM showed that for only a small movement, the full plate capacity (2 x installation load) could be reached. Continuous pulling caused the anchor to loose resistance and break out.



90^0 pulling angle with seabed in normal loading mode

fig. 2-27

To demonstrate that the feature of these anchors is not only a vertical resistance, the anchor was installed with a horizontal pull, the mode changed to the normal (vertical) mode and the anchor subsequently pulled with an uplift angle of 30° *(fig. 2-28)*. The behaviour is similar to the earlier vertical pull test. However, for the 30° pull angle the anchor did not break out but moved slowly along the pulling direction through the soil. The graphs clearly show this effect and that the anchor can be used for substantial horizontal loads.



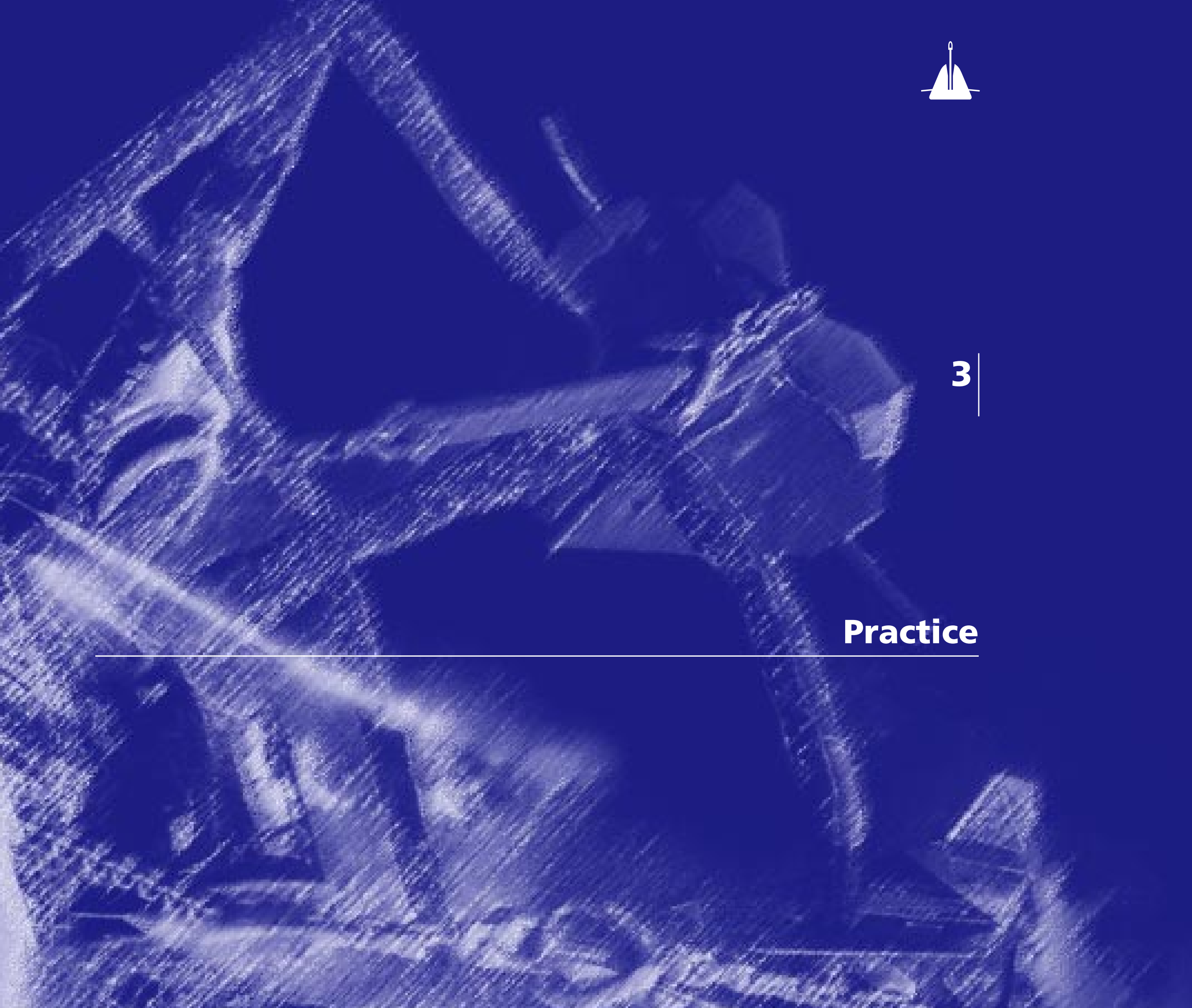
30^0 pulling angle with seabed in normal loading mode

fig. 2-28

Increasing grain size of particulate deposits ↑

	Total carbonate content %													
	90	50	10		90	50	10		90	50	10		50	
60 mm	Carbonate gravel	Mixed carbonate and non-carbonate gravel		Silica gravel	Calcirudite (carb. Conglom. Or Breccia	Conglomeratic calcirudite	Calcareous conglomerate	Conglomerate or breccia	Conglomerat limestone	Conglomerate limestone	Calcareous conglomerate	Conglomerate of Breccia	Crystalline limestone or marble	Conventional metamorphic nomenclature applies in this section
2 mm	Carbonate sand	Siliceous carbonate sand	Calcareous silica sand	Silica sand	Calcarenite (carb. Sandstone)	Siliceous calcarenite	Calcareous sandstone	Sandstone	Detrital limestone	Siliceous detrital limestone	Calcareous sandstone	Sandstone		
0.063 mm	Carbonate silt	Siliceous carbonate silt	Calcareous silica silt	Silica silt	Calcisiltite (carb. Siltstone)	Siliceous calcisiltite	Calcareous siltstone	Siltstone	Fine-grained limestone	Fine-grained siliceous limestone	Calcareous siltstone	Siltstone		
0.002 mm	Carbonate clay		Calcareous clay	Clay	Calcilutite (carb. Calystone)	Clayey calcilutute	Calcareaous claystone	Claystone		Fine-grained agrillaceous limestone	Calcareous claystone	Claystone		
Approx. Rock strength	Very weak				Weak to moderately weak				Moderately strong to strong				Strong to extemely strong	
Cementation of soil	Very weak to firmly cemented soil				Well cemented soil				(well cemented) rock					

Increasing lithification →



3

Practice

Practice

Although theoretical knowledge of anchors is essential for good anchor design and selection, the practical issues are just as important. The handling of an anchor and the selection and use of support equipment is of equal importance.

Anchor handling is a critically important and often complicated process. It is influenced by such factors as the weight and shape of the anchor, the nature of the soil, the depth of the water, the weather conditions, the available handling equipment and the type and weight of mooring line. It is for these reasons that anchor handling is a subject which requires careful consideration. Without proper anchor handling, optimal performance of an anchor is not possible.

In the process of handling anchors, various types of support equipment are necessary or beneficial. An anchor manual would be incomplete without consideration of these auxiliary items, the reasons for their use, their operation and the advantages and drawbacks involved.

This chapter gives an overview of the recommended procedures that should be followed for anchor handling and the types and use of the support equipment during the handling operations. The following handling procedures are by no means complete, but they do give some suggestions which can be applied to each anchor handling procedure and adapted for specific circumstances and locations.

Some of the topics covered in this chapter are:
requirements for a soil survey, connection of the anchor to the mooring line, chasers, handling the Stevpris anchor, handling the Stevmanta anchor, the Stevtensioner, anchor handling/supply vessels.

For the dimensioning of drag embedment anchors, the availability of site-specific soil data is important. For advice on specifying drag embedment anchor type/size and calculating expected behaviour, the site-specific soil data should be compared with soil data of previous drag embedment anchor (test) sites.

The soil survey requirement for the design of drag embedment anchors usually consists of only shallow boreholes, while in anchor pile design deep boreholes are required. For suction anchor design therefore a more extensive soil investigation is generally required when compared to drag embedment anchors. When choosing between anchor pile, suction anchor and drag embedment anchor the financial implications of the soil survey should be taken into account.

A typical soil survey for drag embedment anchor design requires a survey depth of twice the length of the fluke in sand and 8 times the fluke length in very soft clay. In most cases a depth of 8 to 10 meters is sufficient, although in very soft clay a reconnaissance depth of 20 to 30 meters should be considered. For optimal drag embedment anchor dimensioning, each anchor location should ideally be surveyed. The soil investigation can consist of boreholes, vibrocores, cone penetration tests or a combination of these. Cone penetration tests including sleeve friction are preferred, but they should be accompanied by at least one vibrocore or sample borehole per site to obtain a description of the soil. Depending upon the type of survey performed and the soil conditions encountered, the survey report should present the test results obtained on site and in the laboratory including the points as shown in *table K*.

It is possible to dimension the drag embedment anchors based on limited soil information (for instance fewer boreholes). The 'lack' of soil data can be compensated by choosing a conservative (larger) anchor size.

Typical contents survey report

- Cone penetration resistance.
- Sleeve friction.
- Pore pressure.
- SPT values.
- Granulometry and percentage fines.
- Wet and dry densities.
- Water content.
- Drained and undrained triaxal tests.
- Undrained shear strength, also remoulded.
- Unconfined compression tests.
- Plasticity limits.
- Specific gravity.
- $CaCO_3$ content.
- Shell grading.
- Angularity and porosity.
- Compressibility.
- Cementation.
- Normalised rock hardness test (point load test).
- RQD index, rock quality designation.

table K

Pile or anchor

The choice between piles and anchors is only possible for permanent systems. Piles are not a good investment when an anchored entity must be moved. But the choice is often made for piles on emotional grounds; a pile does not drag! However, anchors that are properly pre-tensioned on site will also not drag.

While it is a psychologically loaded subject, experience has shown that the choice between anchor and pile is merely a matter of economics. The required pile weight for a system is equal to the required weight of a Stevpris anchor. Piles cost about 40% of equivalent capability anchors. However, the installation costs for piles are much higher. Piles require a follower and a pile hammer. The installation spread for piles is much more significant; a crane barge with support spread versus the two anchor handling vessels. The weather downtime for a spread involving a crane vessel is much longer than when AHVs are used. To allow drag of the anchors during pretensioning, extra chain length is required. Sometimes the pretension load for piles is much less than for anchors. The survey work for anchors is generally much simpler than for piles. When abandoning a field, anchor removal is much cheaper than removal of installed piles. The choice between piles and anchors strongly depends upon the circumstances. The *table L* can help in estimating the costs for the two alternatives.

Suction piles are an alternative for drag embedment anchors and piles, also for MODU applications. The advantage is the accurate positioning of the suction piles. The disadvantage is the cost of the pile itself and the cost of the installation.

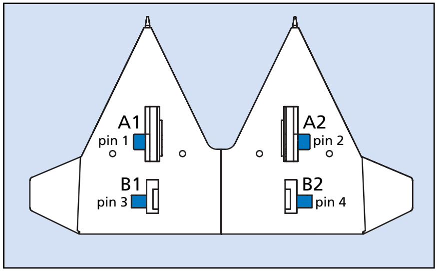
Description	**Pile**	**Suction pile**	**Anchor**
Soil survey	-	-	+
Procurement	+	-	-
Installation spread	-	-	+
Installation time	-	-	+
Pile hammer	-	+	+
Follower	-	+	+
Pump unit	+	-	+
Pretensioning	+	-	-
Extra chain	+	+	-
Rest value pile/anchor	-	+	+
Removal of anchor point	-	+	+
ROV	+	-	+

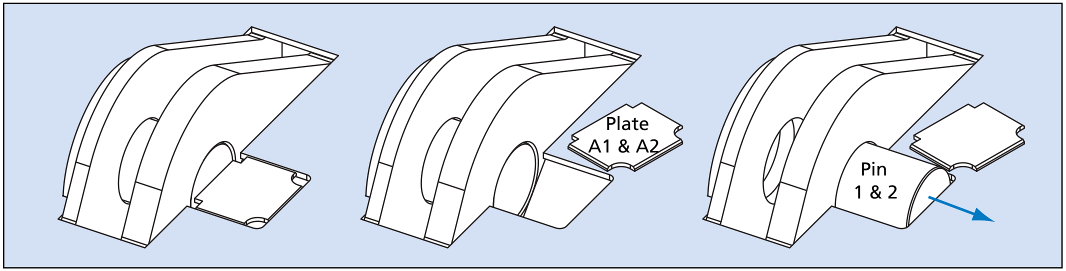
\+ less expensive - more expensive

table L

Mounting instructions

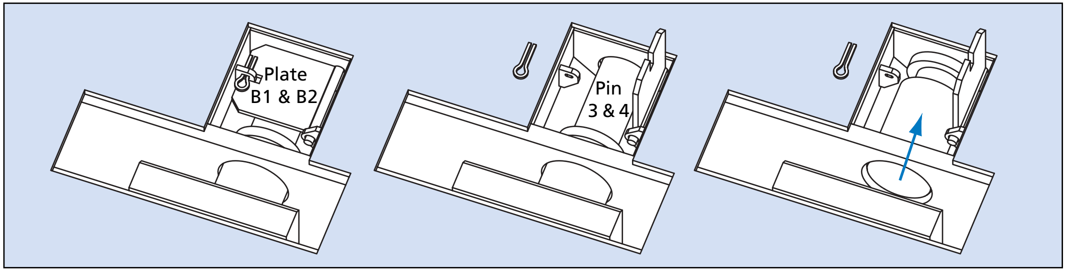
Stevpris / Stevshark Mk5





Forward fluke-shank connection

Remove the locking plates A1 and A2 which are tack-welded to the fluke



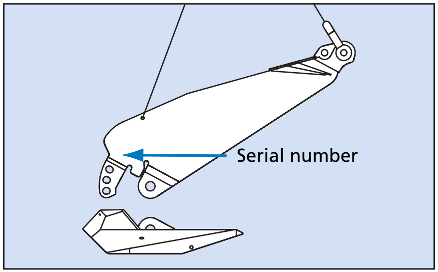
Aft fluke-shank connection

Move the pins 1 and 2 to the outer side. Remove the split pins and open the locking plates B1 and B2. Move the pins 3 and 4 to the outside.

Mounting instructions

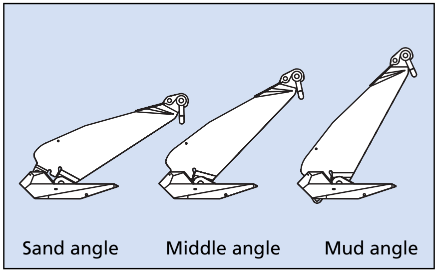
Stevpris / Stevshark Mk5

Fit the rear shank lugs into the fluke by means of a crane. Manoeuvre the rear shank lugs with the notch into the gap in the flukes, as indicated in the figures. When in position, rotate the shank forward to align the front pins with the shank.

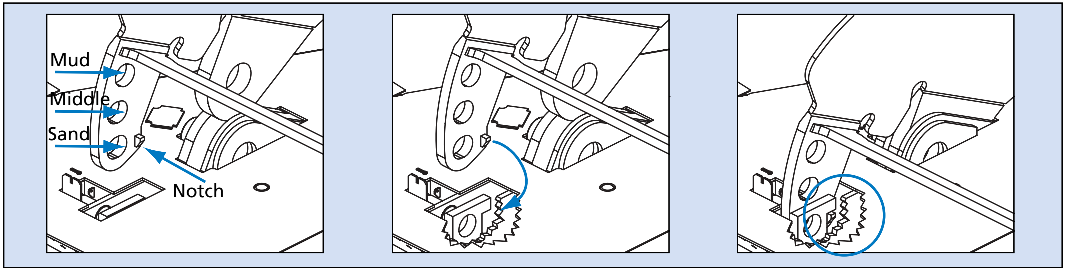


Attention

Make sure the serial number of the shank corresponds with the serial number of the fluke for reason of identification and certification.



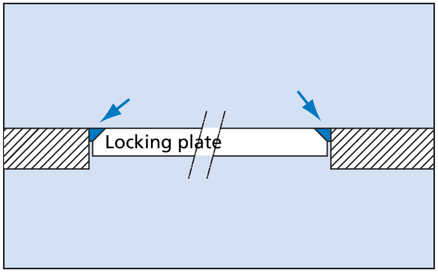
Align pins 1 and 2 with the forward shank eyes. Move pins 1 and 2 back into position. Place the shank in the sand, middle or mud position. Align pins 3 and 4 with the rear shank lugs. Move pins 3 and 4 back into position. Fit and weld the locking plates A1 and A2 on the fluke. See welding detail below. Close the locking plates B1 and B2 and secure with split pins.



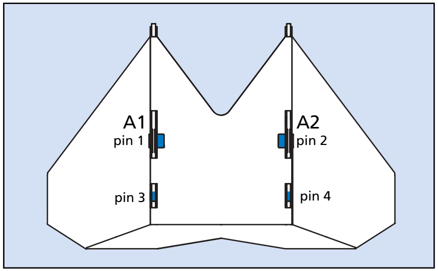
Vryhof recommended welding procedure for locking plates A1 and A2

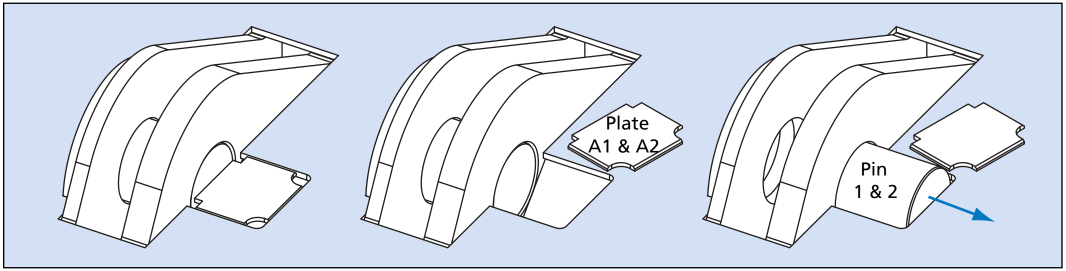
Fillet weld with electrode acc.AWS.E7018

Welding process	SMAW electrode
welding position	2F
material	S355J2G3 (St52-2N)
preheat material	50° C
interpass temp	max 250° C



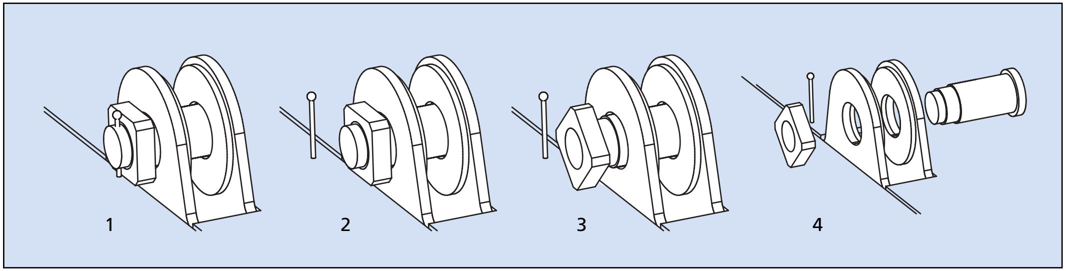
Stevpris New Generation





Forward fluke-shank connection

Remove the locking plates A1 and A2 which are tack-welded to the fluke.



Aft fluke-shank connection

Move the pins 1 and 2 to the inner side. Remove the splitpins and nuts from pins 3 and 4 and move the pins 3 and 4 to the outside.

Stevpris New Generation

Fit the rear shank lugs into the fluke by means of a crane. Manoeuvre the rear shank lugs into the gap in the flukes, as indicated in the figures. When in position, rotate the shank forward to align the front pins with the shank.

Attention

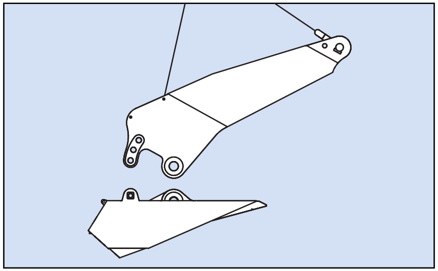
Make sure the serial number of the shank corresponds with the serial number of the fluke for reason of identification and certification.

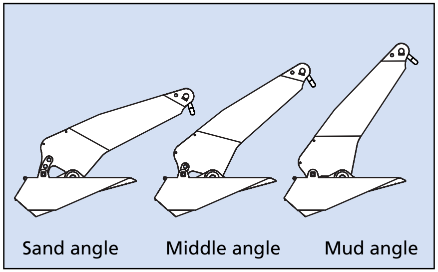
Align pins 1 and 2 with the forward shank eyes. Move pins 1 and 2 back into position. Place the shank in the sand, middle or mud position. Align pins 3 and 4 with the rear shank lugs and insert them in the lugs. Tighten the bolts and insert splitpins 3 and 4. Fit and weld the locking plates A1 and A2 on the fluke. See welding detail below.

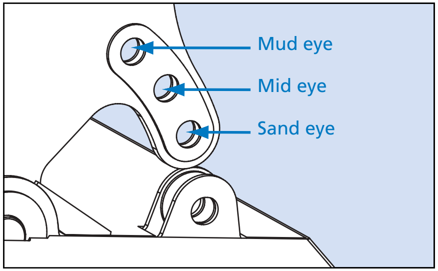
Vryhof recommended welding procedure for locking plates A1 and A2

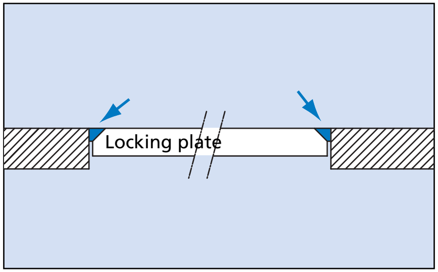
Fillet weld with electrode acc.AWS.E7018

Welding process	SMAW electrode
welding position	2F
material	S355J2G3 (St52-2N)
preheat material	50° C
interpass temp	max 250° C









Setting the fluke/shank angle

Introduction

In soil such as sand and medium to hard clay, an anchor with a fluke/shank angle of 32° will give the highest holding power. An anchor with a 50° fluke/shank angle in this soil will not penetrate but will drag along the seabed. If used in mud a 50° fluke/shank angle is appropriate. An anchor with a 32 ° fluke/shank angle will penetrate less and generate lower holding capacity in mud*(fig. 3-01).*

The Stevpris Mk5 anchor has an additional fluke/shank angle setting of 41°, which can be adopted in certain layered soil conditions *(table M)*.

Changing the fluke/shank angle on the Stevpris Mk3

This can be carried out within half an hour with the Stevpris anchor upside down on deck.

Secure the anchor on deck. Connect a tugger wire (C) to the holes (D) on the bottom side of the fluke. Change from mud to sand angle by removing the locking plates and the two rear pins in (B), decrease the fluke/shank angle by hauling the cable (C). Reinstall the pins and locking plates in (A). Seal weld the lock-ing plates, do not weld them to the pins *(fig. 3-02).*

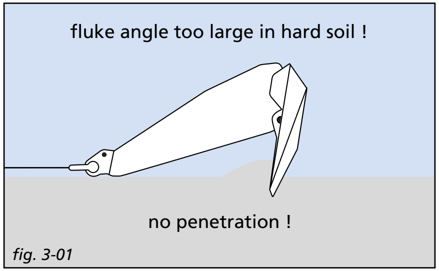


fig. 3-01

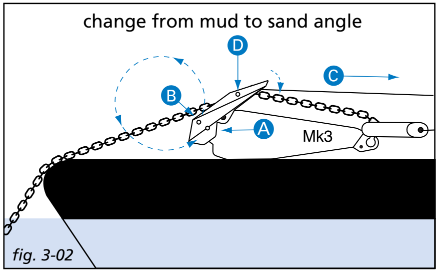


fig. 3-02

Soil type	**Optimal fluke/shank angle setting**
Very soft clay (mud)	50⁰
Certain layered soils	41⁰ *
Medium to hard clay or sand	32⁰

* Stevpris Mk5 only

table M

Change from sand to the mud position, increase angle by veering (C), change over pin and locking plates from (A) to (B). No special welding requirements *(fig. 3-03).*

Changing the fluke/shank angle on the Stevpris Mk5 Changing the fluke/shank angle on the Stevpris Mk5 anchor is even quicker. No welding required. Veering and hauling (C) to change the fluke/shank angle as above, the pin however remains in (A), the locking plate is secured by means of a cotter pin *(fig. 3-04).*

change from sand to mud angle

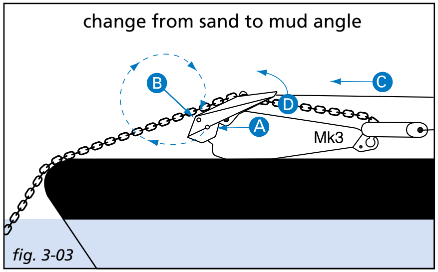


fig. 3-03

change fluke/shank angle Stevpris Mk5

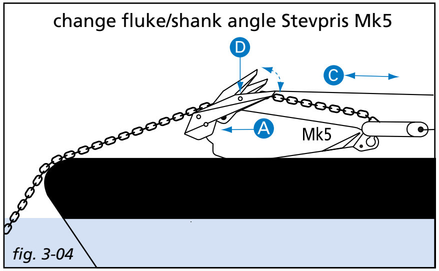


fig. 3-04

Connecting a swivel

Connecting a swivel to the Stevpris anchor

To connect a swivel to the Stevpris anchor, several different configurations are possible. These are:

Type I - The swivel is connected directly to the shank of the anchor thus omitting the anchor shackle *(fig. 3-05).*
J swivel shackle, C end link, B enlarged link, A common link

Type II - The swivel is connected to the anchor shackle *(fig. 3-06).*
J swivel shackle, C end link, B enlarged link, A common link

Type III - The swivel is connected to the anchor shackle via a special design end link
(fig. 3-07).
K special end link, J swivel, C end link, B enlarged link, A common link

Type IV - The swivel is part of a forerunner connected to the anchor shackle, for instance the forerunners VA02, VA04 and VA 06 described in the product data section *(fig. 3-08).*
PL pear link, A common link, B enlarged link, H swivel.

When a chaser is used in combination with the Stevpris and swivel, some of the configurations mentioned above are more suitable than others. In general, swivels are only designed to withstand longitudinal forces, and are usually not designed for use in combination with chasers. The design of the chaser tends to stop it at the swivel. Consequently, there will be high bending forces on the swivel, which can result in damage or even breakage.

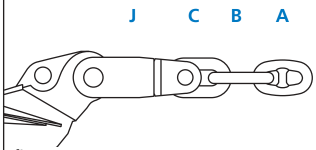


fig. 3-05

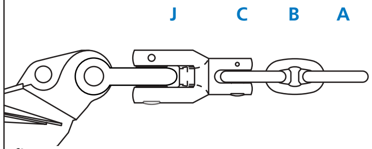


fig. 3-06

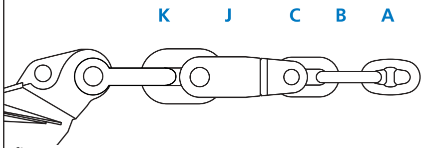


fig. 3-07

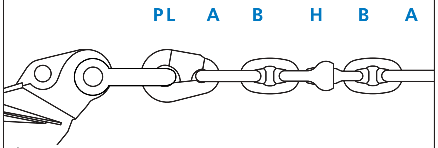


fig. 3-08

Connecting a swivel

Generally, it is best when the swivel is fitted some distance from the anchor when a chaser is used. The chaser can then pass the swivel and stop on the anchor shank. When a load is applied to the chaser, the swivel is only loaded longitudinally. This means that in combination with the use of a chaser, the configuration type III and type IV are preferred.

When the swivel (or swivel forerunner) is connected to the anchor shackle by means of an end shackle and a chaser is used, the end shackle and the anchor shackle should be connected bow through bow instead of pin through bow as is normal practice. This to minimise the chance of damage to the shackles.

The illustrations *fig. 3-09* through *fig. 3-14* show how and *how not* to connect the swivel to the Stevpris anchor when using a chaser.
(See next page for fig. 3-13 and 3-14).

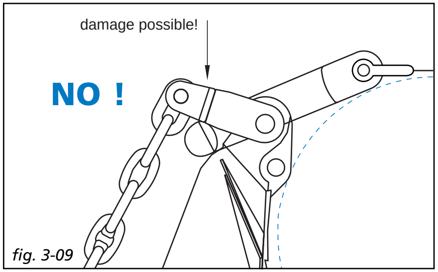


fig. 3-09

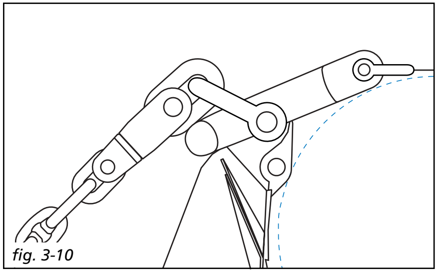


fig. 3-10

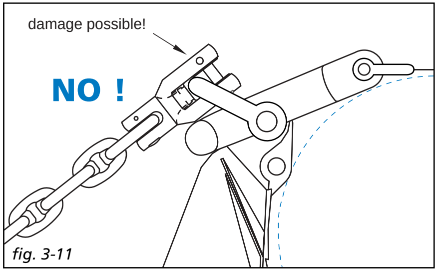


fig. 3-11

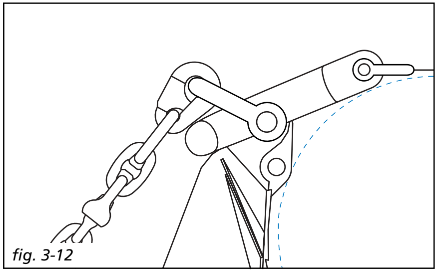


fig. 3-12

Connecting a swivel

The best method for chasing with a swivel in the system is to maintain the tension of the anchor line as much as possible during chasing. This will make the chaser pass more easily over the swivel.

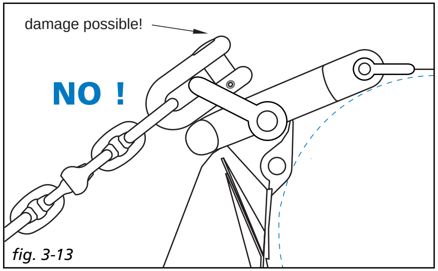


fig. 3-13

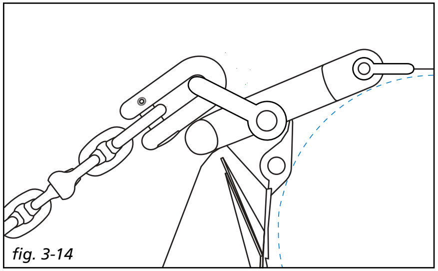


fig. 3-14

Chasers and their application

To facilitate handling, pendant wires may be applied to retrieve the anchor. These wires are connected to a pendant eye situated on the anchor and equipped with a buoy for picking up. In deeper water higher anchor break-out forces are encountered, resulting in longer, heavier pendant wires and consequently larger buoys. Due to wear caused by the continuous movement of the buoy by the waves, these pendants will break close to the buoy. The buoys would then float free and the anchors are much more difficult to recover.

To overcome this, chasers were introduced. These were rings ‘chased’ along the cable towards the anchor and back again to a rig or handling vessel. Their function was to ensure both installation and break-out of the anchor without having to use a pendant line/buoy. The chaser system thus totally eliminates buoys, partly eliminates cables and reduces wear on the system.

The cost of a chaser is small when compared to the cost of a mooring line. It is therefore extremely important from an operator’s viewpoint that chasers do not inflict damage to the mooring lines.

Chasers

Towing a chaser along mooring lines with, at times, high interface pressures, must result in wear. It is thus essential that such wear is taken by the chaser and not the mooring line. The chasers vryhof recommends are manufactured in a material that is softer than the steel used for the mooring line. Chaser wear is induced by the application of high interface pressure between the mooring line and the chaser. High interface pressure can arise from:

- Pulling the chaser along a slack mooring line.
- Maintaining high tension in the chaser workwire when chasing a tensioned mooring line.

Chasing operations are best carried out on mooring lines which are fully tensioned. There is little need for the application of high interface pressure while chasing, the permanent chaser is captive on the mooring line and, unlike the J-chaser, will not become disengaged due to a slack work wire. For optimum chasing operations, the length of the chaser pendant line should be at least 1.5 times the waterdepth.

There are many different types of chaser available on the market today. A selection of the different chaser types is described in more detail on the following pages.

Chaser types

The J-chaser

The J-chaser *(fig. 3-15)* is used on mooring lines where the anchor has to be recovered and no permanent chaser has been installed, or the normal recovery mechanism has failed. In other cases the J-chaser is used simply to keep a chain free from a pipeline during deployment of the anchors. The chaser is deployed over the stern roller of an AHV at approximately 1/3 of the water depth. The chaser is towed across the mooring catenary until it catches the chain. It is then towed into contact with the anchor shank/fluke for anchor break-out and retrieval.

The permanent chain chaser

As a practical alternative to the buoy and pendant, the permanent chain chaser *(fig. 3-16)* was introduced. Originally, simple shackles were used; these were followed by special cast oval rings which were attached to a pendant by a 'bight' of chain and shackle. Very soon afterwards the pear-shaped chaser with shackle eye was introduced. The design of these chasers offers superior sliding and penetration properties.

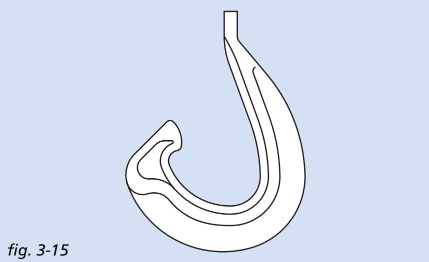


fig. 3-15

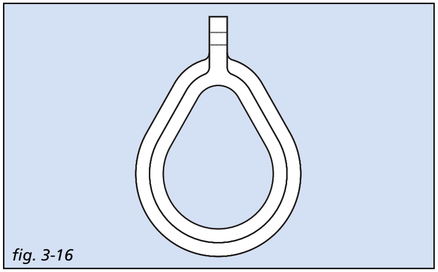


fig. 3-16

Chaser types

The detachable chain chaser

For rigs in service it is sometimes preferred to equip the mooring with a chaser which does not require the anchor chain to be broken and re-made. Detachable chain chasers *(fig. 3-17)* were introduced to satisfy this need. The withdrawal and replacement of the single bolt permits easy assembly of the chaser on the mooring cable.

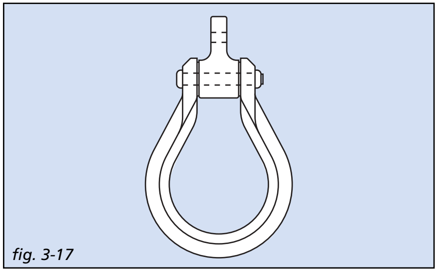


fig. 3-17

The permanent wire chaser

The permanent wire chaser *(fig. 3-18)* was introduced when rigs moved to deeper waters, and composite wire/chain mooring systems became necessary. The chaser incorporates a ‘rocker’ which is centrally mounted on a hinge bolt. The rocker has two opposing grooves, and when the chaser is engaged with the mooring line, the wire slides through one of these grooves irrespective of the angle which the chaser makes with the mooring. The large radius at the base of the groove assists in reducing wear of the rocker and avoids severe ‘opening’ of the lay of the wire if a loop of wire is pulled during the handling process. The material of the rocker is not as hard as the material of the wire. This means that wear is taken by the rocker without damage to the wire and, because the rocker is easily removable, replacement is relatively inexpensive. The permanent wire chaser is easily detachable by removal and re-assembly of the hinge bolt and rocker.

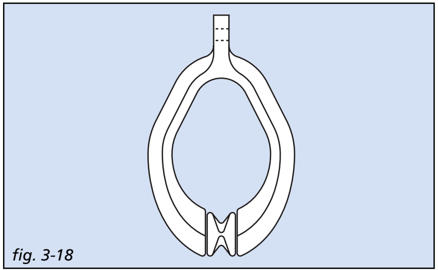


fig. 3-18

Some designs of wire chaser incorporate fully rotating rollers over which the mooring wire passes. To be effective such rollers need to be of a large diameter and require to be supported by bearings. They are consequently larger, heavier and much more costly than the permanent wire chasers discussed above, and because of their size, they require more power at the AHV to penetrate the seabed and reach the anchor.

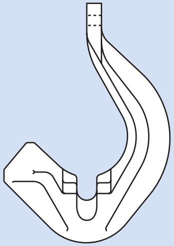


fig. 3-19

The J-lock chaser

The J-lock chaser *(fig. 3-19)* has been designed so that it can slide along the chain in one direction and when the pulling direction is reversed, the chaser locks on the chain and does not slide any further. This means that the tension in the mooring line can be wholly transferred from the rig to the chaser. The J-shape permits catching the anchor chain after the anchor has been installed. This means that this chaser can be used to assist in unforeseen circumstances. The well-balanced and 'guiding' design of the chaser enables catching the chain when the chaser approaches a mooring at a point where the catenary angle is as high as 45^0.

When a normal permanent chaser is used under unforeseen conditions, there is the chance that the AHV cannot break out the anchor by means of the chaser. The J-lock chaser can help in such an instance. It is released from a second AHV and slides along the chain towards the anchor. The design prevents the J-lock chaser from sliding back. The J-lock chaser is stopped at the permanent chaser. If the winch pull of both tugs is now increased, the J-lock chaser prevents the permanent chaser from sliding away from the anchor. Consequently, the forces required do not increase, and the anchor can easily be broken out. After this operation, the J-lock chaser can be released again.

This chaser can also be used when a very heavy chain has to be installed. It assists during installation by lifting the chain.

Stevpris deployment for MODUs

Introduction

Typical methods for deployment and retrieval of Stevpris anchors with an anchor handling vessel (AHV) are described, focusing on the use of chasers for handling the anchor *(fig. 3-20).* This is the most common practice on mobile drilling rigs (MODUs). Handling using permanent pendant lines is similar.

Deployment procedures for the Stevpris anchor will also be given for permanent moorings where chasers are normally not used.

Laying anchors

It is preferred, and by some operators required, to deck the anchor before run out to check the jewellery. Run the anchor line out the full distance with anchor on deck or on roller, with the chain between the flukes *(fig. 3-21).*

Boat increases power until anchor line tension rises on rig winch tension meter. When rig gives order to lower the anchor, veer pendant till anchor arrives at roller. Allow the anchor some speed to negotiate the bump at the change-over from the deck on to the roller *(fig. 3-22).*

If anchor is kept on roller, keep triangular plates below the main shackle on the drum for stability of the anchor. Alternatively the chaser can be kept on deck/roller. In this situation the propeller thrust passes underneath the anchor and does not influence the fluke *(fig. 3-23).*

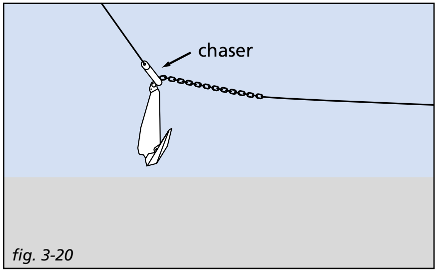


fig. 3-20

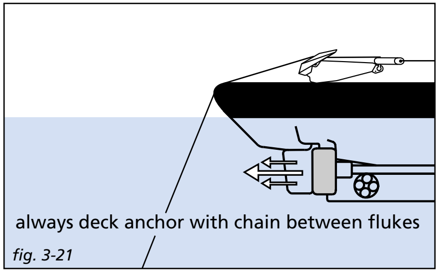


fig. 3-21

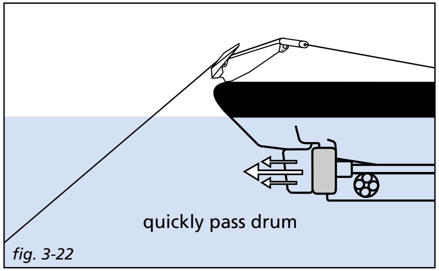


fig. 3-22

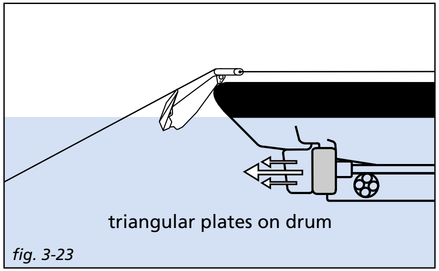


fig. 3-23

Reduce propulsion momentarily when anchor passes the propeller thrust, keep chaser on anchor head for control of anchor orientation and lower anchor *(fig. 3-24).*

Once below the propeller wash zone, reactivate and maintain propeller thrust to well above 30 tons. Keep constant tension in order to ensure anchor does not fall through chaser, i.e. anchor remains in the chaser and orientation of the anchor is correct *(fig. 3-25).*
Note: In some circumstances AHVs prefer to run the anchor hanging from the pendant line below the propeller wash approximately 60 to 80 meter above the seabed. This method requires less power on the winch during the actual laying of the anchor. If this method is employed, make sure that at all times the anchor is correctly oriented in the chaser. Keep constant tension in the pendant line to prevent the anchor from falling through the chaser and possibly turn.

Stop lowering when anchor hangs 10 to 15 meter above the bottom and advise rig. Rig now instructs AHV to pay out until pendant line is 1.4 to 1.5 times the water depth in shallow water (100m) and 1.3 to 1.4 times in deeper water. AHV increases power till tension is again seen to rise at the rig, i.e. the load in the line is larger than the chain-soil friction *(fig. 3-26).*

Rig commences to pull in slowly. AHV further increases power until tension rises further at rig winch. At this moment rig orders AHV to lay the anchor. AHV immediately stops the propulsion and is consequently pulled backwards. AHV pays out pendant and maintains paying out pendant after anchor has landed on the bottom till a wire length of 1.5 to 2 times the water depth is out. Enough slack wire must be paid out not to disturb the anchor during buoying off or waiting. Stay above or behind the anchor.

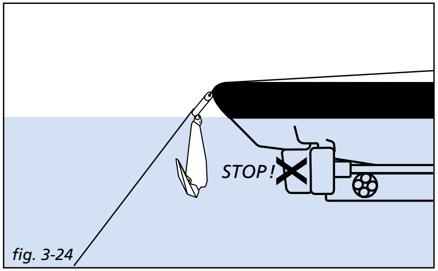


fig. 3-24

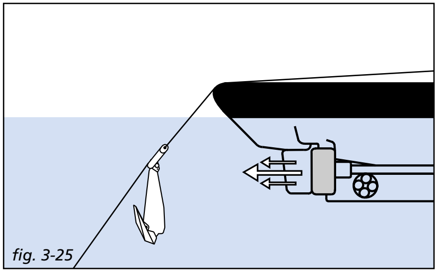


fig. 3-25

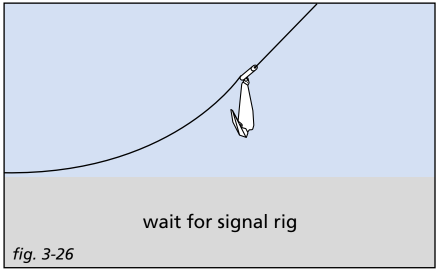


fig. 3-26

Rig continues heaving the cable to a sufficient load, equal to the total chain/soil friction plus 50 t to embed the anchor fully and create confidence in good setting.
This also gives stability to the anchor when the AHV strips the chaser back or buoys off the pendant. Now the AHV can retrieve the chaser and return to the rig. If circumstances allow, the rig can tension up to the full pretension load directly *(fig. 3-27).*

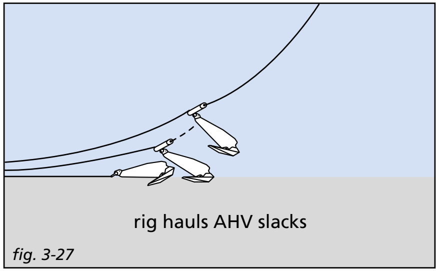


fig. 3-27

No extra pull after landing!
It is customary with older anchors such as Danforth, Moorfast, etc. to give another pull once the anchor is on bottom. Do not do this with Stevpris anchors. Once the anchor hits bottom, AHV should not pull again. Pendant line must remain slack, otherwise anchor could land upside down! *(fig. 3-28).* Suggestion: pre-load the anchors to the maximum required pretension load as soon as the chaser is 100 meter or more ahead of the anchor, i.e. do not wait. If anchor has not been laid correctly, a rerun can be made immediately.

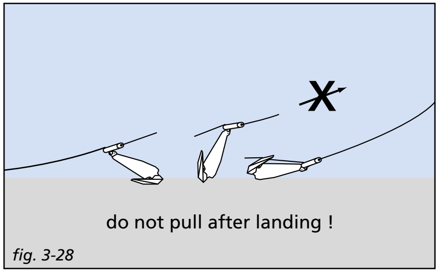


fig. 3-28

Retrieving anchors

The chaser should be brought to the anchor with a pendant of at least the length of 1.5 to 2 times the water depth, measured from the stern roller. Chaser should hang freely down from the anchor line till the bottom is reached, i.e. slack in the pendant line. A too short pendant and/or too little tension in the cable results in a situation as sketched *(fig. 3-29).*

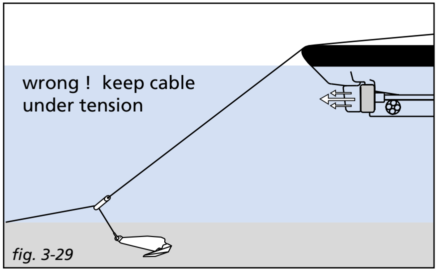


fig. 3-29

While chasing, the rig should maintain tension of 60 to 70% of the pre-load tension. No tension in pendant to ensure smooth passing over the chain. When chaser is pulled into contact with anchor shank, increase thrust and keep thrust while heaving, especially in rough water *(fig. 3-30).*

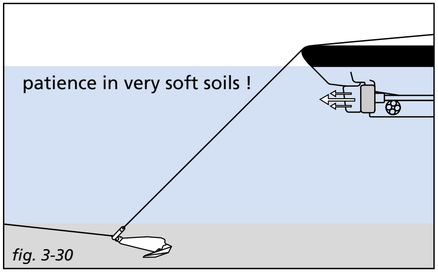


fig. 3-30

The motion of the vessel itself now helps gradually to break the anchor loose. Sequentially with the vessels motion the pendant is shortened gradually. Anchors in very soft clay can be buried very deep. Have patience, take your time and be gentle with the equipment; the anchor will come. The rig can help and speed-up the operation by hauling the anchor line at the same time! Once the anchor is off bottom, keep the chaser in contact with the bow shackle by maintaining sufficient thrust *(fig. 3-31).*

Anchor orientation

The anchor flukes are always oriented towards the rig, on deck the anchor lays on its back with shackle towards AHVs bow and cable between the upwards directed fluke points. Check jewelry *(fig. 3-32).*

It is important to control the anchor orientation at all times for easy racking, laying and decking of the anchor, i.e. keep pendant line under tension while working the anchor. If the anchor slides through the chaser, the anchor has to be pulled back to the stern roller and orientation checked *(fig. 3-33).*

Decking the Stevpris anchor

If anchor is not correctly oriented, reduce propulsion and let anchor slide down through the chaser. Rotation is easier while near the rig where all loads are lower *(fig. 3-34).*

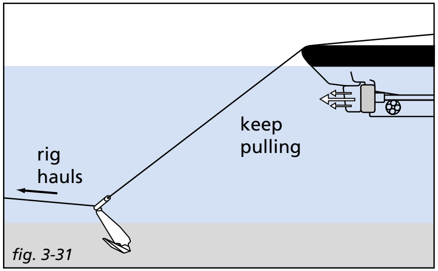


fig. 3-31

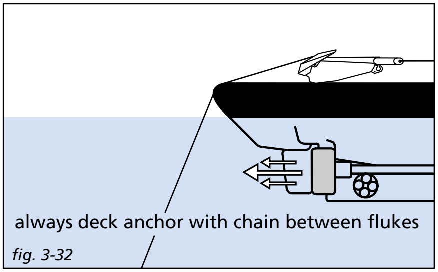


fig. 3-32

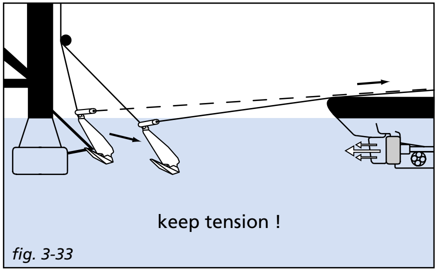


fig. 3-33

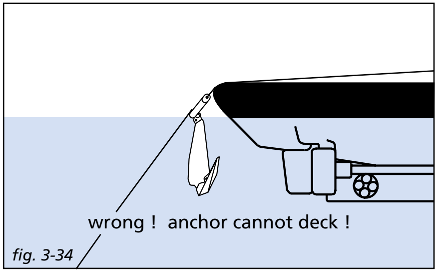


fig. 3-34

Turn the anchor with a shot of propeller wash. Then pay out pendant, make sure anchor is below the propeller wash away from the propeller influence zone *(fig. 3-35).*

Increase propulsion moving AHV forward pulling chaser in contact with the anchor. Make sure the stern roller is perpendicular to the chain, the chain directing between the fluke points *(fig. 3-36).*

With sufficient bollard pull haul pendant, stop/reduce thrust for only a few seconds when anchor passes the propeller wash onto the drum. Pull anchor on the drum, allow the anchor to turn with its back on the roller, fluke points up. Then pull further on deck *(fig. 3-37).*

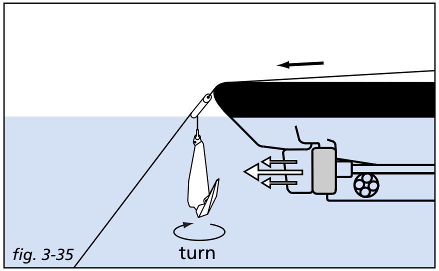


fig. 3-35

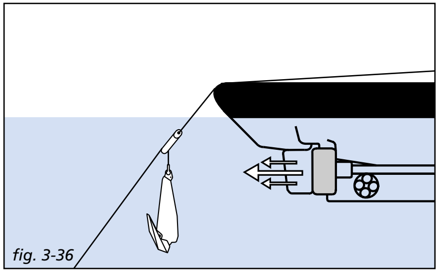


fig. 3-36

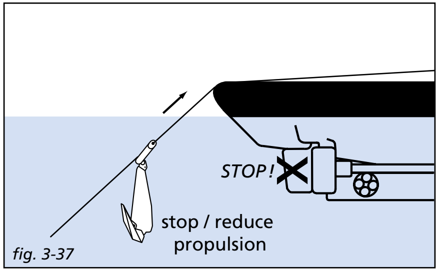


fig. 3-37

Stevpris installation

With little tension in the line, the chain hangs steep against the fluke points and anchor cannot rotate easily (A). Before rotating the anchor, pull on the cable, the anchor will be free to turn (B) and (C) *(fig. 3-38).*

With anchor on the stern roller reactivate propulsion. For inspection anchor can be pulled on deck. If required, change fluke angle to 32 degrees for hard soil or to 50 degrees for very soft soil. Mind, every anchor type will be unstable and drag in hard soil, stiff clay or sand with a fluke angle set for mud! *(fig. 3-39).*

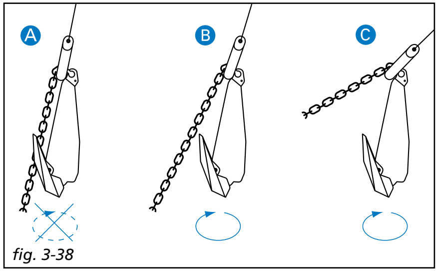


fig. 3-38

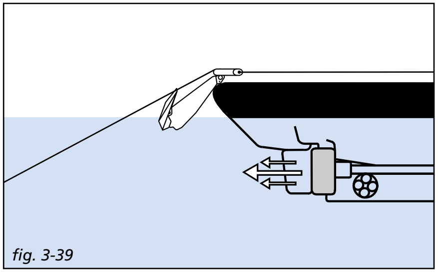


fig. 3-39

What not to do!
The anchor is approaching the drum. If the AHV maintains thrust, the water flow will push the fluke *(fig. 3-40).*

If the propeller is not stopped, the thrust risks turning the anchor around the cable then acting as a shaft *(fig. 3-41).*

The relative weight of the anchor increased by the thrust force on the fluke will cause the anchor and the cable to slide down through the chaser and control of anchor orientation is lost *(fig. 3-42).*

When the thrust is maintained while hauling in the chaser, the cable prevents the anchor to turn on its back at the stern roller. Boarding will be difficult now. The anchor could pass the stern roller on its side and get damaged!
So stop/reduce the thrust just before the anchor passes the propeller wash *(fig. 3-43).*

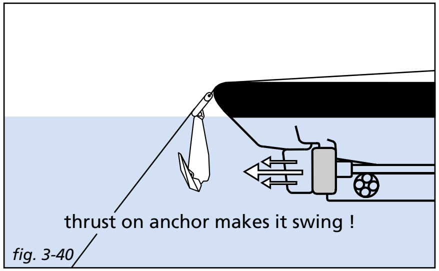


fig. 3-40

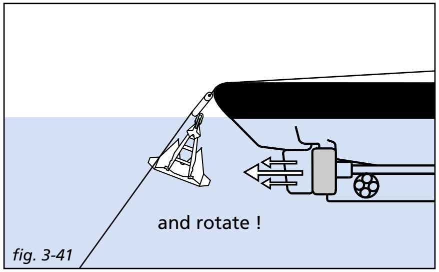


fig. 3-41

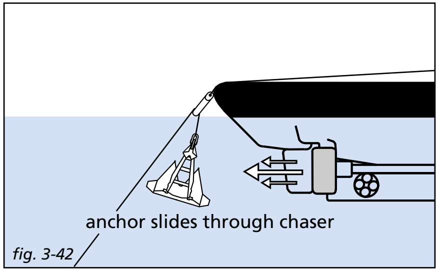


fig. 3-42

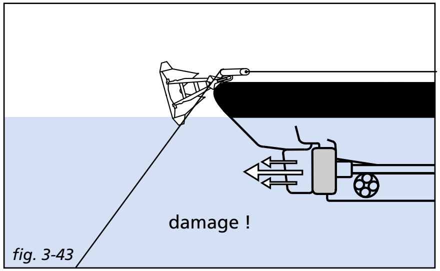


fig. 3-43

Racking the Stevpris

Rig heaves in anchor line, pulling AHV towards it. AHV keeps sufficient tension in pendant, chaser remains in tight contact with anchor, anchor remains correctly oriented *(fig. 3-44).*

At some distance from the rig, AHV pays out winch wire while keeping sufficient bollard pull (at least 1.5 times anchor weight) to keep chaser on anchor head. Anchor flukes point towards the rig. Rig hauls, AHV veers while keeping some tension in the pendant line transferring the anchor to the bolster. The direction of the anchor cable must now be perpendicular to the rack *(fig. 3-45).*

When anchor arrives at bolster, reduce tension to 15 tons. As soon as anchor is resting on bolsters, slack pendant wire completely. If tension is not sufficient, anchor falls out of control of the chaser and might rotate and make racking difficult. If this occurs, bring anchor to the stern of the AHV, rotate anchor with fluke points directing outwards and keep chaser tight on the anchor *(fig. 3-46).*

Deploying Stevpris from the anchor rack

AHV receives pendant from rig and connects to AHV winch wire. AHV moves to a position at a good distance but less than the water depth (for instance 50 meter dependent on weather) from the rig. Stop winch and keep sufficient tension, 20 to 30 tons or more as required to maintain the chaser on the head of the anchor. Only now rig pays out cable while AHV hauls in on the winch. The AHV maintains sufficient tension while pulling the anchor to the stern roller. Reduce the power of the propeller as anchor passes the wash zone and bring anchor on roller for inspection and reactivate thrust *(fig. 3-47).*

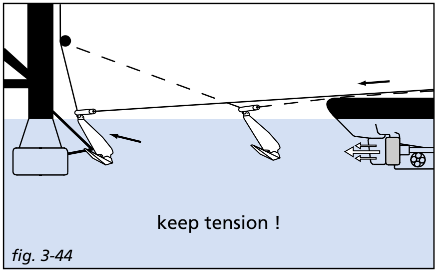


fig. 3-44

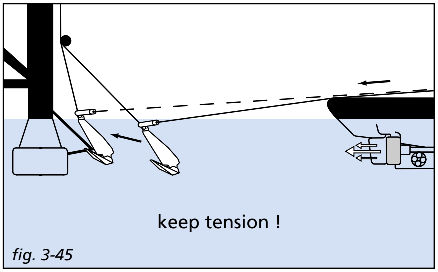


fig. 3-45

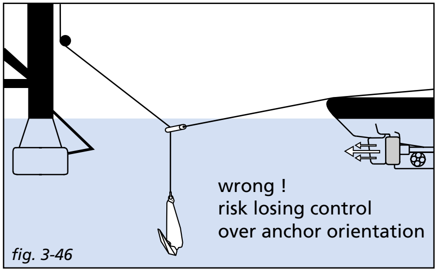


fig. 3-46

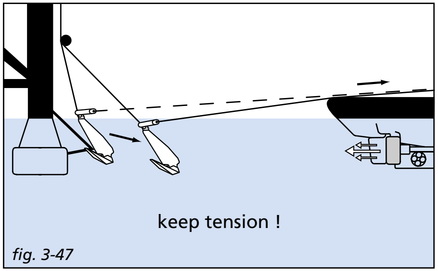


fig. 3-47

Boarding the anchor in deep water

In deep water the weight of the anchor line becomes of predominant importance. For line loads larger than 8 times the anchor weight the anchor could be pulled against the chaser as illustrated, it could even position itself upside down! In such cases boarding the anchor is difficult and damage might occur *(fig. 3-48).*

The best and preferred solution is to pull the anchor from the bottom and have the rig haul the anchor line, allowing the *boarding of the anchor near the rig* where loads are smaller.

If this is not possible or allowed for some reason, another solution is to reduce the weight that is hanging from the anchor. This can be done by lifting the anchor line using a lock chaser or grapnel handled by a second vessel *(fig. 3-49).*

It is recommended to board the anchor with the chain between the fluke. The anchor fluke is generally designed to withstand loads up to 8 times the anchor weight *(fig. 3-50).*

It happens that the anchor is accidentally pulled over the roller on its side. Due to the large forces damage to shank and fluke might occur when the chain is hanging over the anchor *(fig. 3-51).*

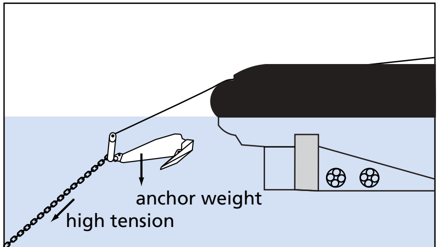


fig. 3-48

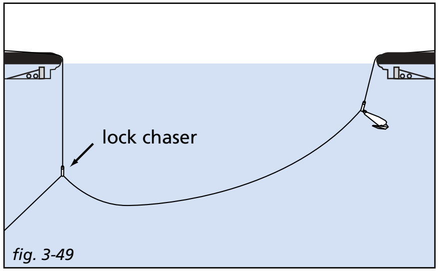


fig. 3-49

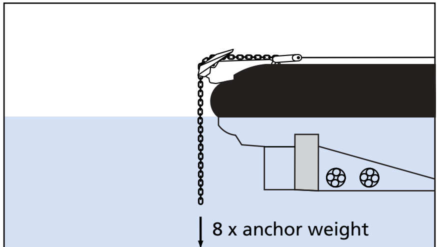


fig. 3-50

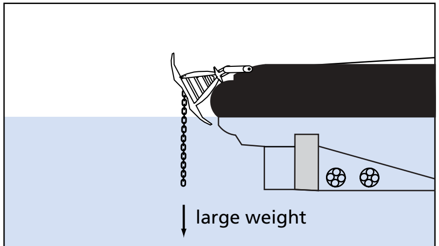


fig. 3-51

Stevpris installation

If boarding the anchor on its side is inevitable, make sure that before boarding, the vessel is turned to free the anchor line from the anchor and haul gently. The chain will pass the stern roller next to the anchor. However, this situation should be avoided as damage may occur *(fig. 3-52).*

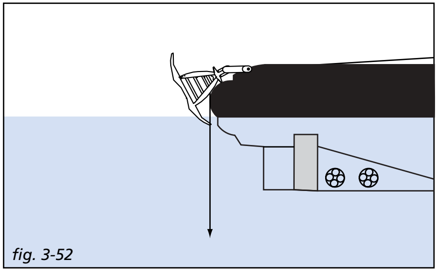


fig. 3-52

Ballast in fluke

Using a wire rope forerunner and ballast material placed inside the hollow fluke, the anchor may not topple over with the fluke points directed downwards. A wire anchor line might be too light to position the anchor correctly and the anchor may not topple over, the anchor could skid over the seabed and prevent penetration.

When the fluke is ballasted, the weight of a chain forerunner will cause the shackle to nose down and bring the fluke in penetration position *(fig. 3-53).*

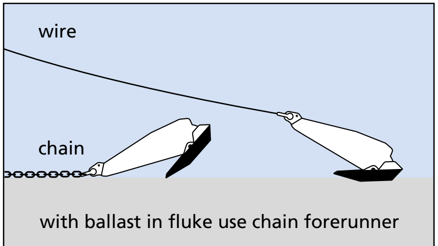


fig. 3-53

Chaser equilibrium

To control the anchor, the chaser collar must always be on the anchor head. The tension in the anchor cable must be equal or larger than 1.5 times the weight of the anchor. If not, the anchor slides through the chaser and the orientation is not controlled *(fig. 3-54).*

Equilibrium forces determine if chaser is in contact with the anchor. Near bottom, the vertical load at the chaser from the anchor line Flv is small. The chaser remains only in contact with the anchor if the bollard pull Fp_h is larger than the horizontal line load Fl_h which in turn must be larger than the anchor weight W (if not the anchor will slide down). The angle of the pendant line must be larger than 45° *(fig. 3-55).*

Recommendation: Bollard pull must always be equal or larger than the line tension, i.e. use a minimum bollard pull of 20 to 30 tons for a 12 to 15 ton anchor. Use a minimum pendant line length of 1.4 to 1.5 times the water depth in shallow water (100m) and 1.3 to 1.4 times the depth in deeper water *(fig. 3-56).*

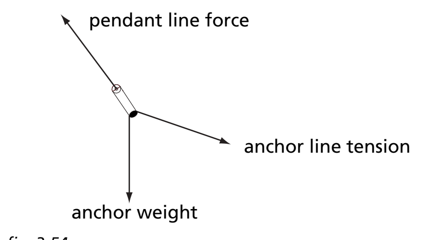


fig. 3-54

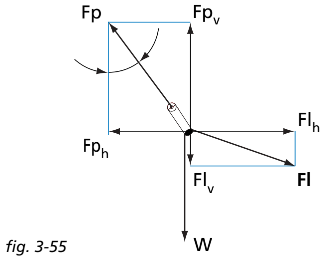


fig. 3-55

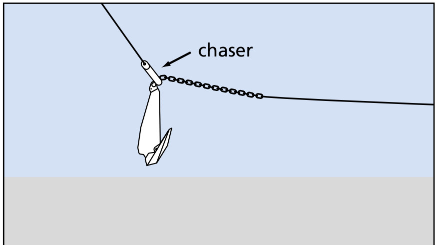


fig. 3-56

Deployment for permanent moorings

The simplest deployment procedure for the Stevpris anchor is to lower the anchor to the seabed using the mooring line. When the anchor is nearly on the seabed, the AHV should start moving slowly forward to ensure that the anchor lands correctly on the seabed *(fig. 3-57).*

Another option for the deployment of the Stevpris anchor is to connect a temporary installation bridle (wire rope) to the anchor. The bridle is connected to the padeyes situated at the back of the shank of the anchor. The AHV then lowers the anchor overboard while paying out the mooring line and the bridle simultaneously *(fig. 3-58).*

To recover a Stevpris anchor after it has been installed, the AHV should take the mooring line and pull it in the opposite direction that the anchor was installed in, generally away from the centre of the mooring. The AHV should recover the mooring line till a length of approximately 1.5 times the water depth is still overboard.
When only 1.5 times the water depth of mooring line is left overboard, the AHV should block the winch and keep a constant tension on the mooring line equal to the pre-load tension. Once the anchor starts to move in the soil, a lower tension in the mooring line can be used *(fig. 3-59).*

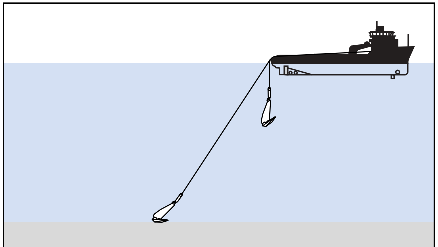


fig. 3-57

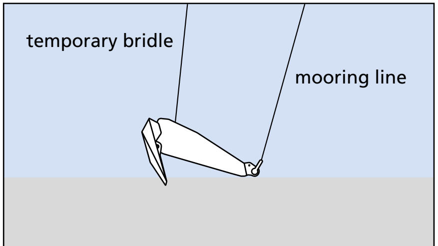


fig. 3-58

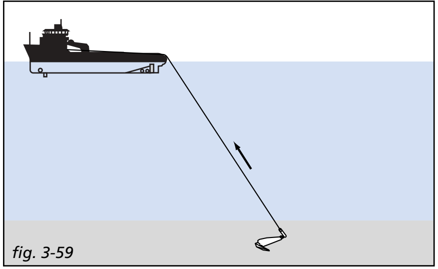


fig. 3-59

Piggy-backing

Introduction

Piggy-back is the practice of using two or more anchors in order to obtain holding power greater than can be achieved with one only. Piggy-backing is used when anchors are employed with insufficient holding capacity. This can be caused by improper design for the particular environment or insufficient anchor size.

In some soil conditions, the use of two smaller anchors in piggy-back can offer an advantage over the use of one larger anchor. This can be the case when the anchor has to hold in a certain layer and holding capacity in the underlying layer is uncertain.

Considerations to remember on piggy-backing:

- Installing a piggy-back system is more costly than the installation of a single anchor.
- If the mooring line of the second anchor is connected to the rear of the first anchor, the stability, penetration and holding capacity of the first anchor may be less than is the case for a single anchor. The force from the second anchor may tend to pull the fluke of the first anchor closed (hinging type anchors).
- If the piggy-back anchor is connected to the first anchor by means of a chaser, the chaser may obstruct penetration of the first anchor.
- Both anchors must be exactly in line with the mooring line load. The lead anchor may become unstable if a lateral load is applied.
- Two hinging anchors in piggy-back do not provide 2 times but only 1 to 1.6 times the individual holding capacity of the two anchors, for reasons described in second point above.

- If the first anchor is not influenced by the pull from the second anchor, and the second anchor (fixed fluke/shank type anchors) is connected at 3 to 4 shank lengths distance from the first anchor, the holding capacity of the 2 anchors may be up to 2.5 times the holding capacity of the individual anchors, due to the extra penetration of the second anchor.

Piggy-backing involving hinging anchors

Since there is little difference between handling one hinging anchor or two, the first method is described with a Stevin anchor (hinging) in combination with a Stevpris anchor (non-hinging). Here, the Stevpris is main anchor and the Stevin is back-up. This is the best solution when using a fixed shank anchor as the fluke of the Stevpris anchor can not be pulled closed. The pendant line is connected to the padeye near the anchor shackle so performance is not reduced. Note: if the piggy-back anchor can not be laid in line with the mooring load, the piggy-back anchor makes the main anchor unstable. In such a case the Stevpris can better be placed as the second anchor.

For optimal performance of the combination, the pendant line between the two anchors should be wire rope, to promote penetration and obtain better holding capacity *(fig. 3-60)*.

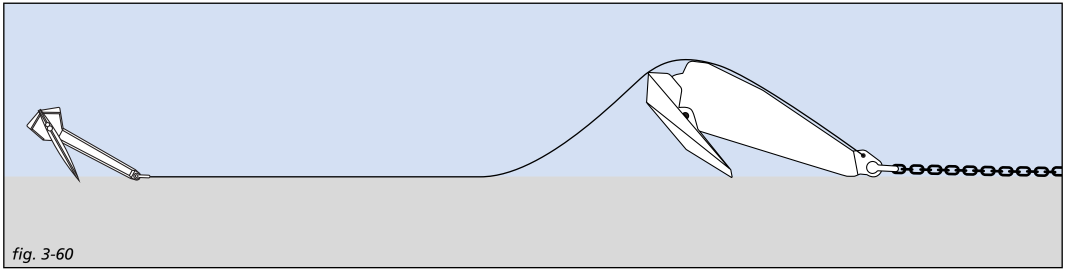


fig. 3-60

The installation procedure is described as follows:

- Pay out the main anchor as usual.
- Tension the mooring line until the anchor slips.
- Connect the second anchor to the pendant line.
- Bring the anchor to its location.
- Lower the piggy-back anchor and tension the mooring line again.
- Provide the pendant of the second anchor with a buoy for easy retrieval.

Piggy-backing with two Stevpris anchors

When two Stevpris anchors are used in piggy-back, the holding capacity of the combination may be equal or higher than the sum of the individual holding capacities of the anchors. The installation procedure of two Stevpris anchors in piggy-back is as follows:

- Pay out the main Stevpris anchor, with the mooring line connected to the anchor shackle and the pendant line (wire rope for optimal performance and approximately three times the shank length of the first Stevpris anchor) connected to the padeye behind the anchor shackle.
- Connect the other end of the pendant line to the anchor shackle of the second Stevpris anchor *(fig. 3-62).*
- To lower the second Stevpris anchor to the seabed, a second pendant line is connected to the padeye behind the anchor shackle.
- Using the second pendant line, the Stevpris anchors are lowered to the seabed and positioned and buoyed off.
- The Stevpris anchors are then tensioned by pulling on the mooring line *(fig. 3-61).*

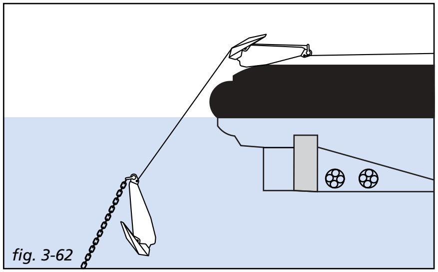


fig. 3-62

Piggy-backing by using a chaser

Sometimes chasers are used to connect the piggy-back anchor to the first anchor *(fig. 3-63)*, although a pendant line connected directly to the padeye behind the main anchor shackle of the first anchor is prefered.

The installation procedure described for two Stevpris anchors is also applicable when a chaser is used for the connection.

During the deployment of the piggy-back combination, care must be taken that anchors are installed in line with the load.

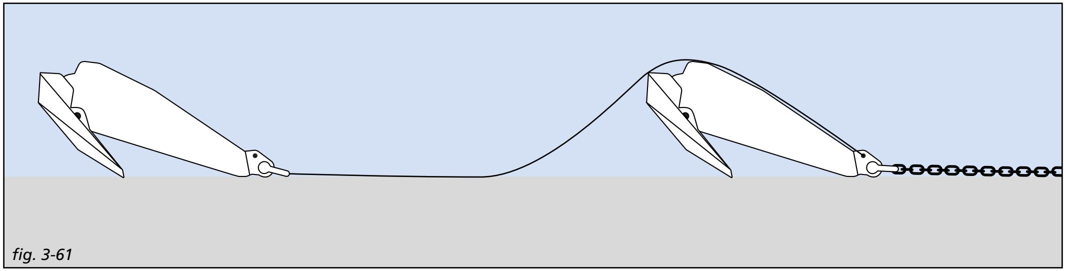


fig. 3-61

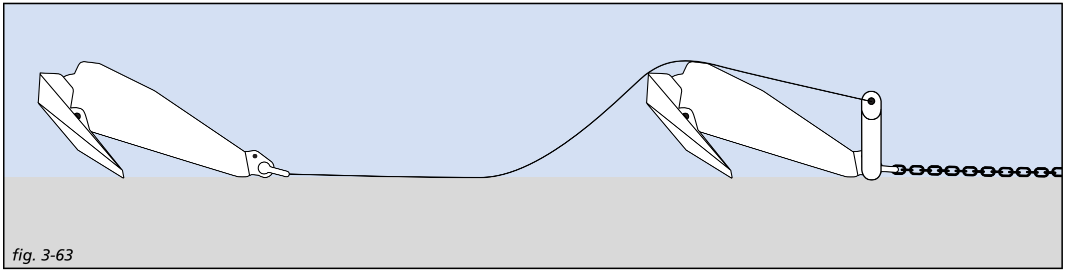


fig. 3-63

Stevmanta VLA installation

Introduction

The Stevmanta VLA consists of an anchor fluke which is connected with wires to the angle adjuster. The angle adjuster is responsible for changing the anchor from the installation mode to the vertical (or normal) loading mode.

There are many options to install VLA anchors. The most efficient methods are based on two different principles:

- Double line installation method using the fixed angle adjuster.
- Single line installation method using the shear pin angle adjuster.

The double line installation method is typically used when it is preferable to install the anchor with a steel wire rope installation line instead of using the actual mooring line (for example polyester).

The following three typical methods for installing the Stevmanta VLA are discussed:

- Single line installation method.
- Double line installation method.
- Double line installation method using the Stevtensioner.

It is also possible to use the Stevtensioner with the single line installation method, however because this is very similar to the double line installation method with Stevtensioner, it is not presented here.

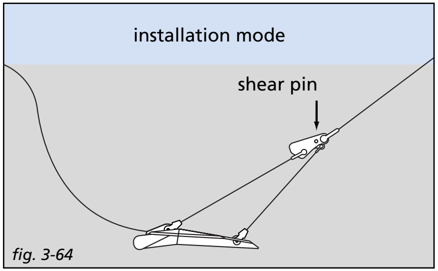


fig. 3-64

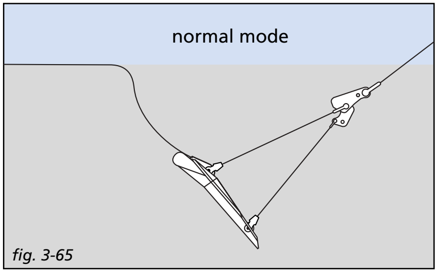


fig. 3-65

Single line installation procedure

This procedure requires only one AHV for installation of the Stevmanta. The Stevmanta is deployed with the shearpin angle adjuster. The mode of the anchor changes when the shearpin breaks at a load equal to the required installation load. When the shear pin breaks, the Stevmanta changes from the installation mode to the normal (vertical) loading mode *(fig. 3-64 and fig. 3-65).*

Installation procedure

In the installation procedure an optional tail has been included on the Stevmanta. The tail assists in orientation of the Stevmanta on the seabed. Connect the installation/mooring line to the angle adjuster on the Stevmanta on the AHV. Lower the Stevmanta overboard. The Stevmanta will decend tail first, i.e. the tail will be the first part to reach the seabed *(fig. 3-66)*.

When the Stevmanta is on the seabed, an ROV can optionally inspect the anchor (position and orientation). The AHV starts paying out the installation/ mooring line while slowly sailing away from the Stevmanta *(fig. 3-67).*

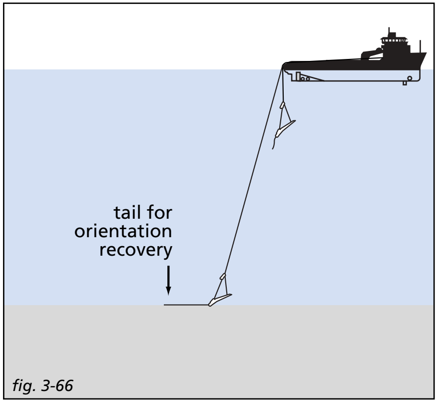


fig. 3-66

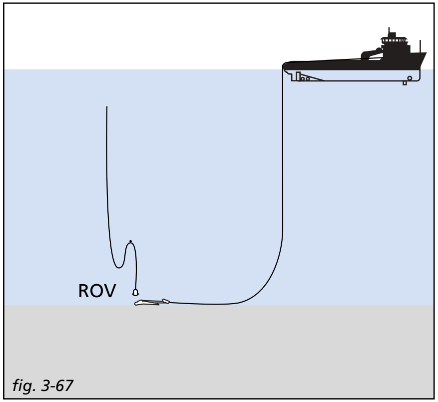


fig. 3-67

Show movie in browser

Stevmanta VLA installation

When enough of the installation/mooring line has been paid out, the AHV starts increasing the tension in the installation line. The Stevmanta will start to embed into the seabed *(fig. 3-68).*

When the predetermined installation load has been reached with the AHVs bollard pull, the shearpin in the angle adjuster fails, triggering the Stevmanta into the normal (vertical) loading mode. This can be clearly noticed on board the AHV, as the AHV will stop moving forward due to the sudden increase in holding capacity. Now that the Stevmanta is in the normal (vertical) loading mode, the AHV can continue to increase the tension in the (taut-leg) installation/mooring line up to the required proof tension load *(fig. 3-69).*

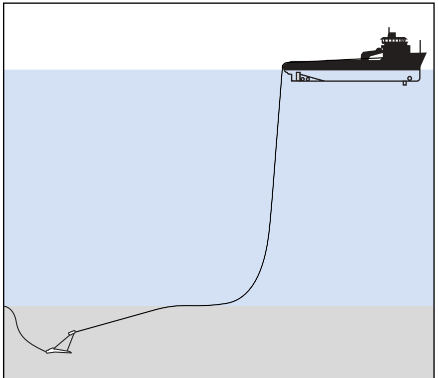


fig. 3-68

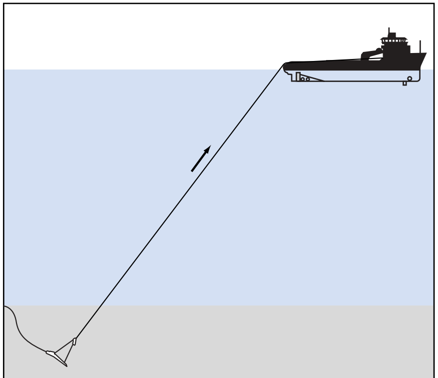


fig. 3-69

After the Stevmanta has been proof tensioned to the required load, the installation/mooring line can be attached to the floater.

In case of a pre-laid mooring, the mooring line can be buoyed off, for easy connection later on *(fig. 3-70).*

Stevmanta retrieval

The Stevmanta is easily retrieved by pulling on the ‘tail’. Connection to the tail can be achieved either with a grapnel or by using an ROV *(fig. 3-71).*

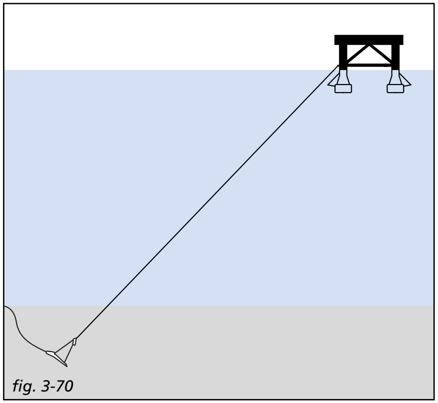


fig. 3-70

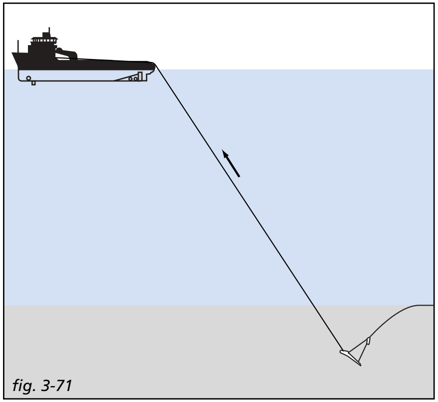


fig. 3-71

Stevmanta VLA installation

Alternatively the Stevmanta can be equipped with an optional recovery system. The recovery system consists of two special sockets which connect the front wires to the fluke.
To recover the anchor, the mooring line is pulled backwards, i.e. away from the centre of the mooring. Once the mooring line has been pulled back, the front sockets will disconnect from the fluke *(fig. 3-72).*

The Stevmanta VLA is now pulled out of the soil using just the rear wires. This reduces the resistance of the anchor, so that it can be retrieved with a load equal to about half the installation load *(fig. 3-73).*

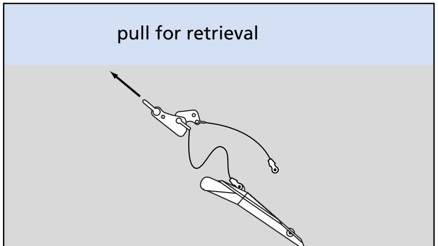


fig. 3-72

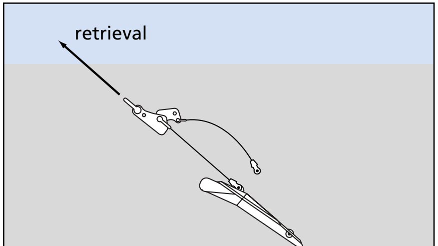


fig. 3-73

Double line installation procedure

This procedure requires two AHVs. The Stevmanta is deployed with the fixed angle adjuster. The mode of the anchor (installation mode or normal (vertical) loading mode) is chosen by pulling on either the installation line or the mooring line.

The Stevmanta is in the installation mode when the installation line is tensioned, i.e. the line on the front of the angle adjuster *(fig. 3-74).*

The Stevmanta is in the normal (vertical) loading mode when the *mooring line* is tensioned, i.e. the line on the rear of the angle adjuster *(fig. 3-75).*

During the installation AHV1 handles the steel installation line and AHV2 handles the *mooring line*, for instance polyester *(fig. 3-76).*

In the installation procedure an optional subsea recovery buoy can be included in the installation line. The recovery buoy is connected to the installation line via a delta plate at approximately 90 m from the Stevmanta *(fig. 3-77).*

Show movie in browser

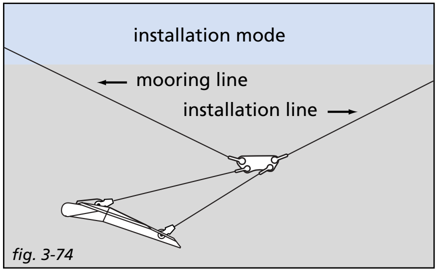


fig. 3-74

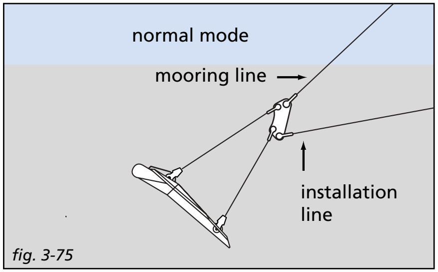


fig. 3-75

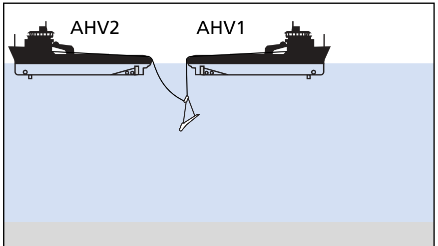


fig. 3-76

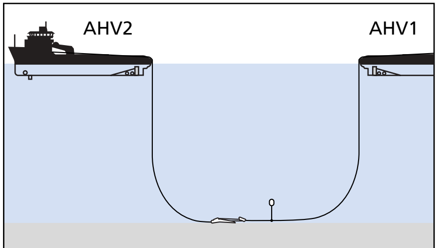


fig. 3-77

Connect the installation line to the angle adjuster on the Stevmanta on board AHV1.
Pass the *mooring line* from AHV2 to AHV 1 and connect it to the angle adjuster.
Lower the Stevmanta VLA overboard by keeping tension on both the installation line (AHV1) and the *mooring line* (AHV2).
When the Stevmanta is on the seabed, an ROV can inspect the anchor's position and orientation. AHV2 slackens the tension in the *mooring line* and AHV1 starts paying out the installation line while slowly sailing away from the Stevmanta *(fig. 3-78).*

When enough of the installation line has been paid out, AHV1 starts increasing the tension. The Stevmanta will start to embed into the seabed. AHV2 keeps the *mooring line* slack by keeping the same distance from AHV1. If more bollard pull is required than one AHV can deliver, AHV2 can buoy off the *mooring line* and pull with AHV1 in tandem.

When the predetermined installation load has been reached, the breaking device in the installation line fails (break shackle connecting the installation line to the delta plate), freeing the installation line from the Stevmanta *(fig. 3-79).*

If the optional recovery buoy is used, the breaking device is placed on the delta plate connecting it to the installation line and AHV1. AHV1 is now no longer connected to the Stevmanta and the installation line can be recovered on deck *(fig. 3-80).*

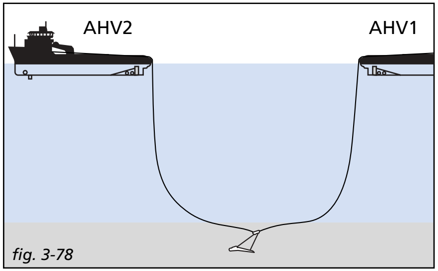


fig. 3-78

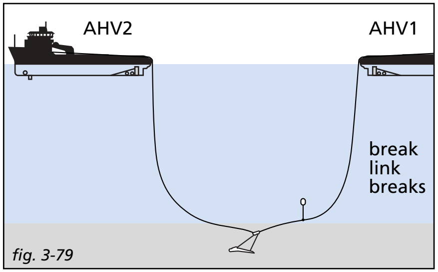


fig. 3-79

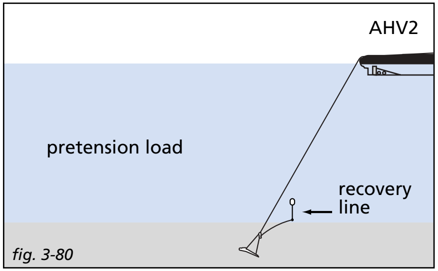


fig. 3-80

AHV2 can now start increasing the tension in the *mooring line*. If AHV2 can not generate enough bollard pull to reach the required proof tension load, AHV1 can be connected in tandem to AHV2 to generate additional bollard pull.

After the Stevmanta has been proof tensioned to the required load, the *mooring line* can be attached to the floater.
In case of a pre-laid mooring, the *mooring line* can be buoyed off, for easy connection later on *(fig. 3-81).*

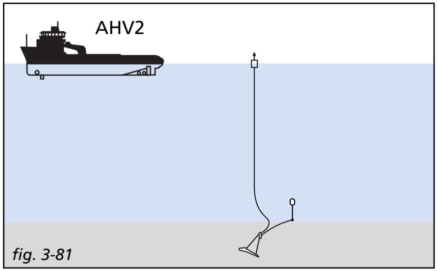


fig. 3-81

Stevmanta retrieval

The Stevmanta is recovered from the seabed by returning to 'installation mode' instead of the normal (vertical) loading mode. The AHV picks up the recovery buoy from the seabed and by pulling on the installation load at an angle of approximately 45^0 with the seabed, the anchor is easily retrieved *(fig. 3-82)*.

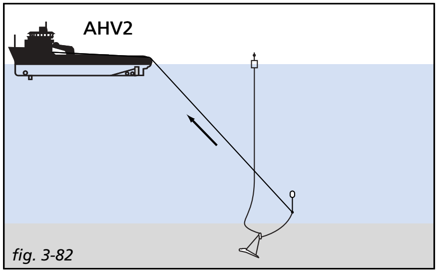


fig. 3-82

Single line installation with Stevtensioner

The Stevmanta VLA is deployed with the shearpin angle adjuster. The mode of the anchor changes when the shearpin breaks at a load equal to the required installation load. When the shear pin breaks, the Stevmanta VLA changes from installation mode to the normal (vertical) loading mode.

In the installation procedure a tail (approximately 30 m length, consisting of a length of wire with approximately 5 m of chain on the end) has been included on the Stevmanta VLA. The tail assures correct orientation of the Stevmanta VLA on the seabed.

Connect the tail to the rear of the fluke of the Stevmanta VLA #1. Connect the forerunner to the angle adjuster of the Stevmanta VLA on the AHV.

Lower Stevmanta VLA #1 overboard *(fig. 3-83)*. The Stevmanta VLA will be going downwards tail first, i.e. the tail will be the first part that reaches the seabed.

Connect the tensioning chain to the forerunner on Stevmanta VLA #1 using the subsea connector and pass the other end through the Stevtensioner. This end of the chain is terminated with a male part of the subsea connector.

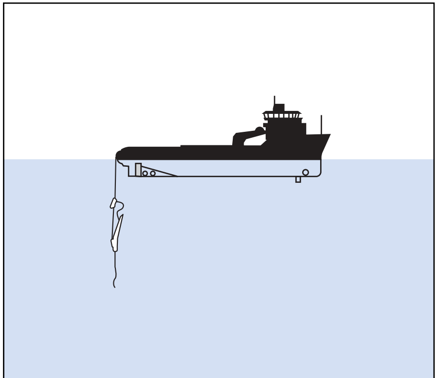


fig. 3-83

Connect the forerunner of Stevmanta VLA #2 to the passive side of the Stevtensioner. As part of the forerunner a tri-plate is included with a breaklink between the Stevtensioner and the tri-plate. The male part of a subsea connector is connected to the third hole of the tri-plate. Connect the AHV work-wire to the tail of Stevmanta VLA #2 using a subsea connector.

Deploy the Stevtensioner and Stevmanta VLA #2 overboard by slacking the AHV workwire *(fig. 3-84 and fig. 3-85).*

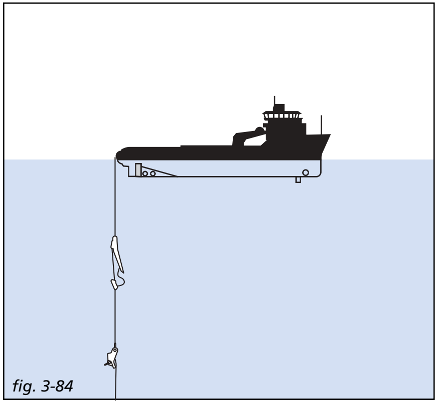


fig. 3-84

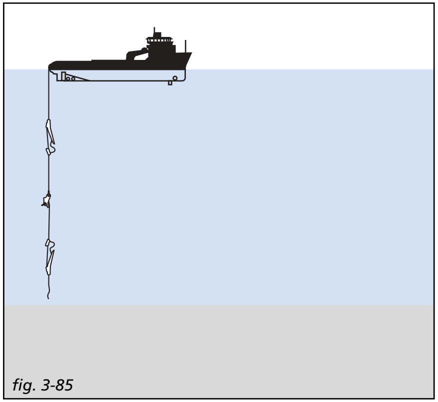


fig. 3-85

Stevmanta VLA installation

When the tail of Stevmanta VLA #1 touches the seabed, the resistance of the tail will orient the Stevmanta in the heading of the AHV which is moving forward slowly. The AHV places the Stevmanta on the seabed and continues with the deployment of the rest of the system (Stevtensioner and Stevmanta VLA #2) *(fig. 3-86)*.

When Stevmanta VLA #2 is near the seabed, the AHV stops the winch and increases the tension in the mooring system *(fig. 3-87)*. This will start to embed Stevmanta VLA #1. When a tension of approximately 1000 kN has been reached, the AHV can lay down Stevmanta VLA #2 on the seabed. The purpose of the applied tension is to ensure that Stevmanta VLA #1 is embedding properly and to take the slack out of the system.

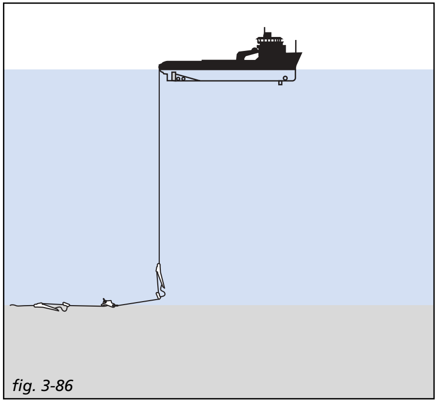


fig. 3-86

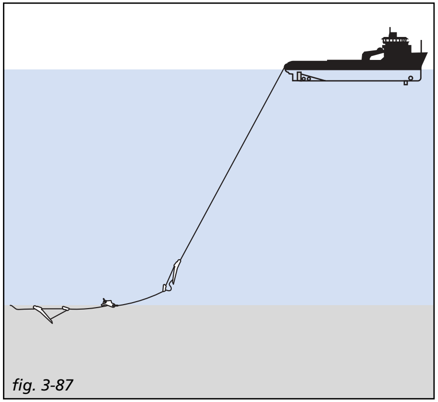


fig. 3-87

When Stevmanta VLA #2 has been placed on the seabed, the AHV continues to deploy the work wire until the tail and the subsea connector are on the seabed. When this has been accomplished, the AHV stops paying out the work wire and the ROV is sent down to disconnect the subsea connector from the tail on Stevmanta VLA #2. The female part of the subsea connector (connected to the work wire) is then moved to the male part of the subsea connector connected to the tensioning chain above the Stevtensioner *(fig. 3-88)*.

With the work wire now connected to the tensioning chain, the AHV can start the tensioning operation. This will generally consist of 4 to 7 yo-yo procedures to reach the required tension at the anchors. *(fig. 3-89 and fig. 3-90).*

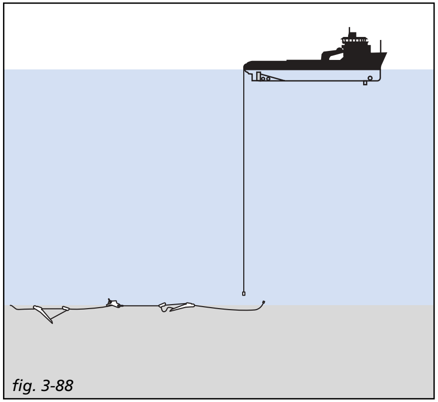


fig. 3-88

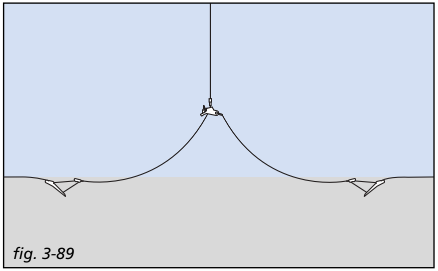


fig. 3-89

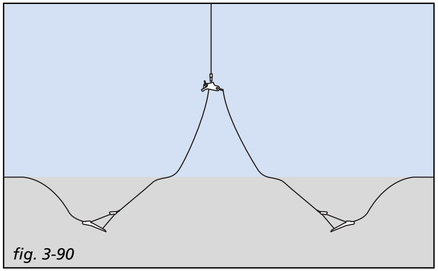


fig. 3-90

Stevmanta VLA installation

When the tension in the system reaches the break load of the shear pins in the angle adjuster of the Stevmanta VLAs, these will break and trigger the Stevmanta VLAs to their normal loading mode *(fig. 3-91)*. When the AHV continues to increase the tension in the system, the anchors will be proof loaded in their normal loading mode. After the proof loading of the anchors, the AHV increases the tension in the system up to the point were the breaklink connecting the passive line to the Stevtensioner fails. The tensioning of the anchors is now complete.

With the tensioning of the anchors completed, the ROV disconnects the subsea connector between Stevmanta VLA #1 and the Stevtensioner *(fig. 3-92)*. The anchor forerunners are now no longer connected to the Stevtensioner. The AHV can start recovering the Stevtensioner with the tensioning chain by winching in the work wire *(fig. 3-93)*. The ROV can be used to connect the mooring lines (with separate female connectors) to the male connectors on the anchor forerunners.

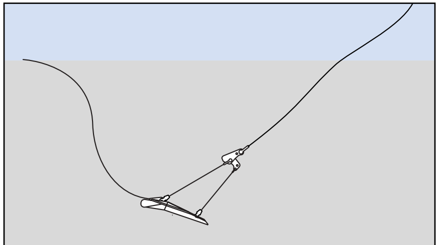


fig. 3-91

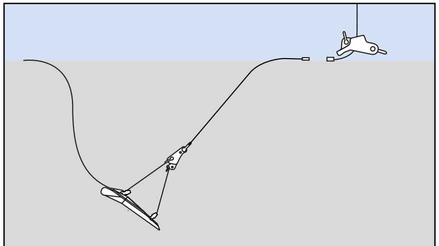


fig. 3-92

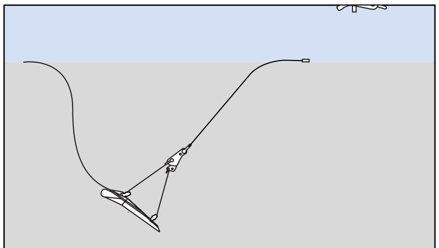


fig. 3-93

Double line installation with Stevtensioner

The Stevmanta is deployed with the fixed angle adjuster. The mode of the anchor (installation mode or normal (vertical) loading mode) is chosen by pulling on either the installation line or the *mooring line*. The Stevmanta is in the installation mode when the installation line is tensioned, i.e. the line on the front of the angle adjuster *(fig. 3-94).*

The Stevmanta is in the normal (vertical) loading mode when the mooring line is tensioned, i.e. the line at the rear of the angle adjuster. During the installation AHV1 handles the installation line (preferably chain and steel wire) and AHV2 handles the *mooring line*, for instance polyester *(fig. 3-95)*.

The installation procedure with the Stevtensioner requires a reaction anchor (the typical use of the Stevtensioner is presented in the next chapter). In this case the reaction anchor can be either a Stevpris or Stevmanta. For now a Stevpris is shown as reaction anchor and is to be on the active side of the Stevtensioner.

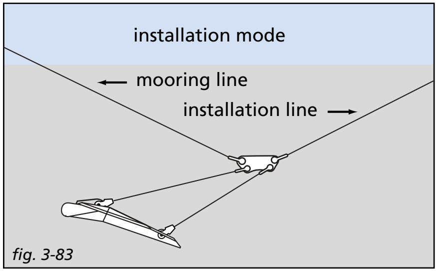


fig. 3-83

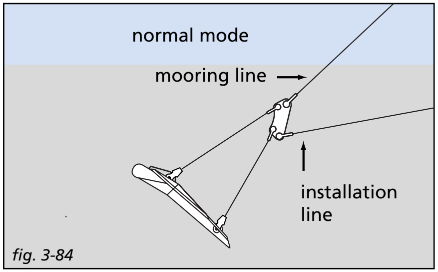


fig. 3-84

Show movie in browser

Connect the installation line to the angle adjuster on the Stevmanta on AHV1. Pass the *mooring line* from AHV2 to AHV1 and connect it to the angle adjuster.

Lower the Stevmanta to the seabed by keeping tension on both the installation line and *mooring line*.

Connect the installation line to the passive side of the Stevtensioner. A break link can be installed between the Stevtensioner and the installation line on the passive side *(fig. 3-96)*.

Connect the installation line to the reaction anchor. Pass the installation line through the Stevtensioner *(fig. 3-97)*.

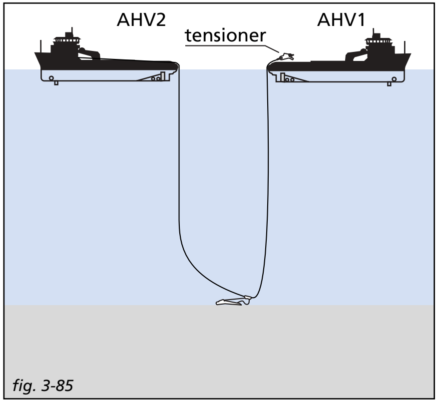


fig. 3-85

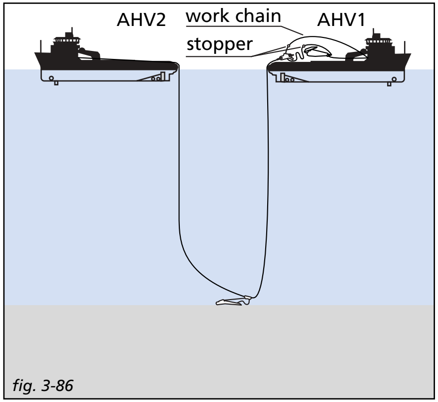


fig. 3-86

Sail to set-down position of the reaction anchor (AHV1 only). AHV2 stays above the Stevmanta. During the movement of AHV1, the installation line of the Stevmanta has to be paid out *(fig. 3-98)*.

Lower the Stevtensioner and reaction anchor to the seabed *(fig. 3-99)*.

Buoy off the retrieval line (or mooring line) of the reaction anchor. AHV1 sails to tensioning point and starts taking in the slack of the tensioning line *(fig. 3-100)*.

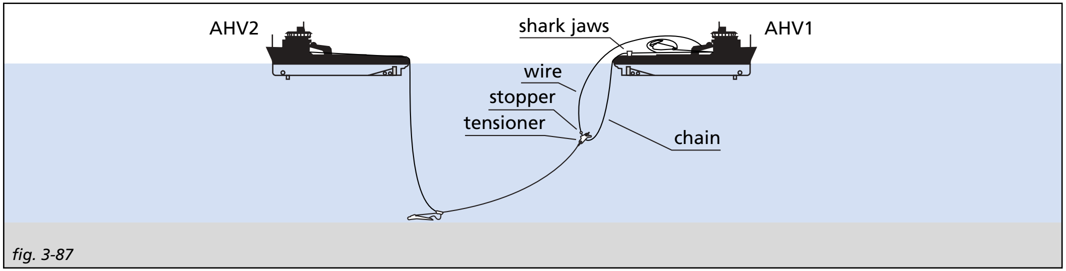


fig. 3-87

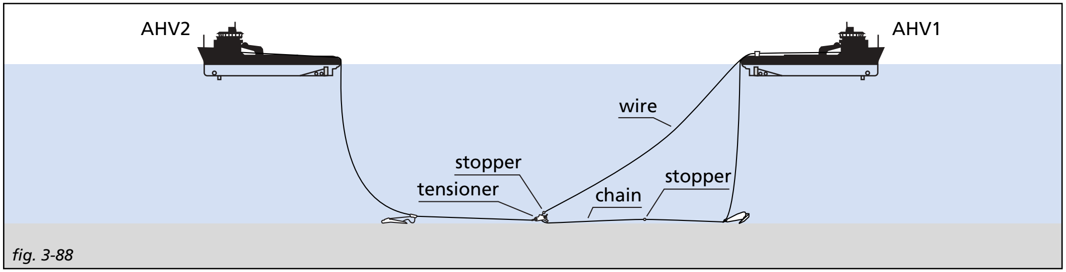


fig. 3-88

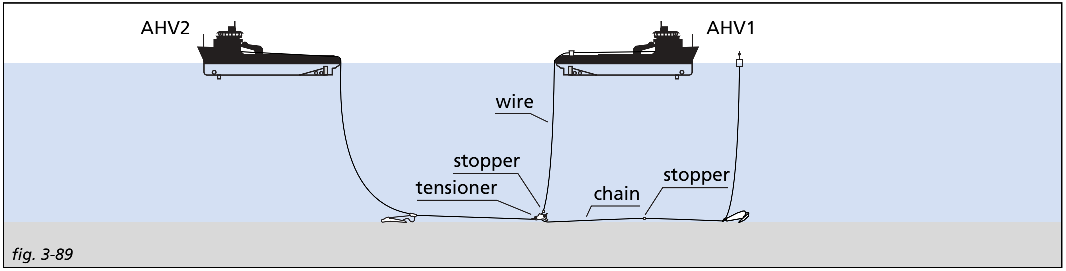


fig. 3-89

Start the tensioning procedure (yo-yoing) *(fig. 3-101)*.

The break link will break on the Stevmanta when the required installation load has been reached *(fig. 3-102)*.

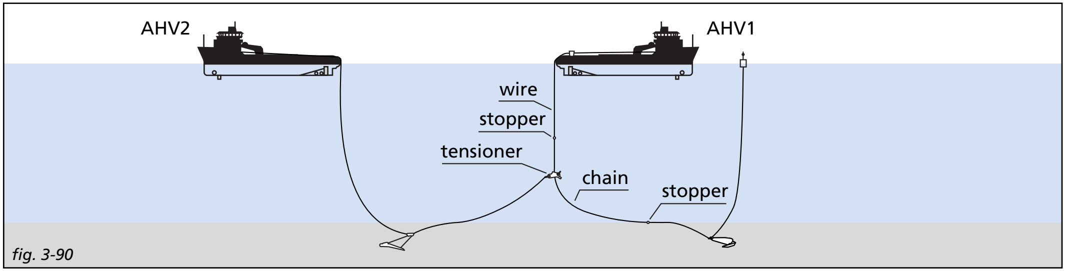


fig. 3-90

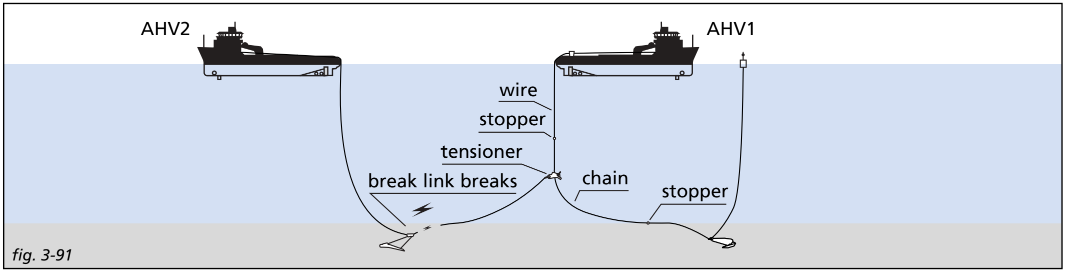


fig. 3-91

Stevmanta VLA installation

Recover the Stevtensioner, the installation line and the reaction anchor to AHV1.

AHV2 can now proof tension the Stevmanta and then buoy off the mooring line. Installation of the Stevmanta is now complete *(fig. 3-103)*.

Instead of using a reaction anchor, two Stevmantas can also be installed at the same time. After completion of the tensioning (yo-yoing), AHV2 proof tensions one Stevmanta while AHV1 recovers the Stevtensioner and disconnects it from the installation line of the other Stevmanta. This Stevmanta can then also be proof tensioned *(fig. 3-104)*.

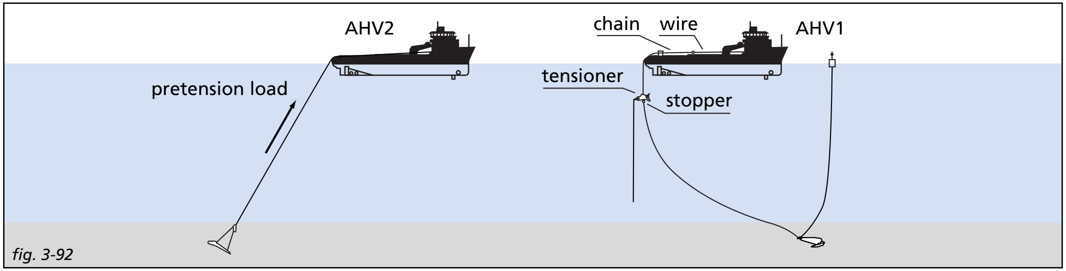


fig. 3-92

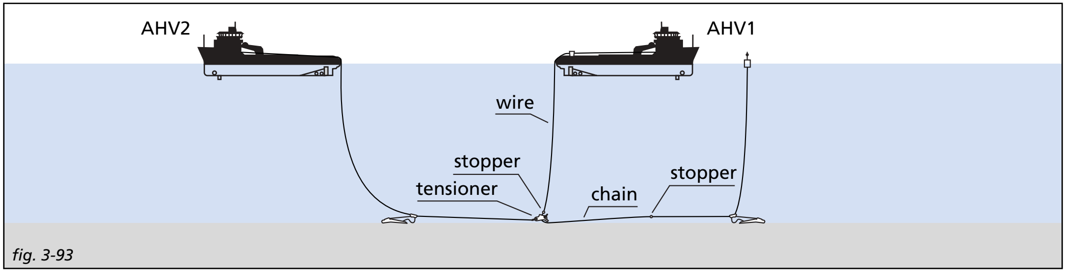


fig. 3-93

Introduction

The Stevtensioner is used for cross tensioning of diametrically opposed anchor legs moored by drag anchors or anchor piles. The Stevtensioner is generally used for the installation of (semi) permanent floating structures such as the SPM buoy, STL, TLP, FPS, FPSO, etc. After the tensioning operations the Stevtensioner is demobilised and ready for the next project. The Stevtensioner can however also be used for permanent tensioning purposes, becoming a part of the mooring system. The Stevtensioner can be deployed from a crane barge, AHV or any vessel having enough crane/winch capacity to pull the required vertical force. The existing models VA220 and VA500 were designed for handling a single size of chain. The new Stevtensioner models VA600, VA1000 and VA1250 can handle chain diameter ranging from 76 mm up to 152 mm. Because of this variety in chain sizes additional work chain may not be required *(fig. 3-105)*.

he working principle of the tensioner

The Stevtensioner is based on the principle that a vertical load to a horizontal string causes high horizontal loads. To achieve the required horizontal pretension load at the anchor points, the vertical pulling force only needs to be 40% of this pretension. The anchor line tension is measured by a measuring pin located inside the Stevtensioner and as such well protected against damage caused by handling and lifting operations *(fig. 3-106)*.

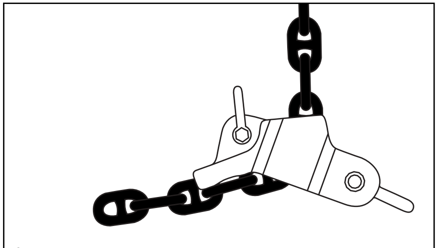


fig. 3-94

The new Stevtensioner models offer the following features:

- Smaller dimensions, reduced weight and improved handling, but heavy enough to easilty slide down the mooring line.
- Designed to smoothly guide at least 5 links and therefore prevent chain getting stuck inside.
- Due to economical volume/weight ratio, the new Stevtensioner models allow for containerised freight by either sea or, for rush deliveries, by air.
- The integrated shape allows for smooth passage over stern roller.
- Load measuring pin is equipped with two independent sets of strain gauges. The umbilical cable connections are protected against handling and lifting operations. These connections may be used for acoustic transfer of the signals.

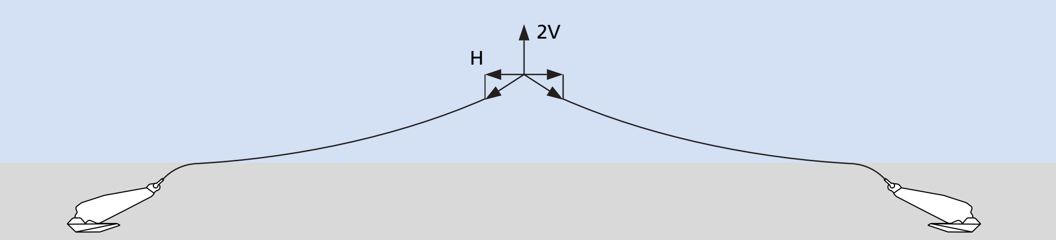


fig. 3-95

One anchor line (passive line) is attached to the tension measuring pin at the Stevtensioner. The oppos-ite anchor line (active line) passes through the Stevtensioner. Tensioning starts by applying the yo-yo movement to the active line *(fig. 3-107)*.

When the Stevtensioner is lifted by the active chain, it blocks the chain. When the Stevtensioner is lifted from the seabed, the passive and active mooring lines are also lifted. Consequently the anchors or piles are loaded and cause an inverse catenary of the mooring line in the soil, as well as causing the anchor to drag and embed. In other words: chain length is gained. Lowering the Stevtensioner slackens the anchor lines and allows it to slide down over the active chain. By repeating this several times (called the yo-yo movement), the horizontal load on the anchor points increases. Generally the required horizontal load is achieved after 5 to 7 steps. Once tensioning is completed, the Stevtensioner is recovered by pulling the lifting/pennant wire making it disengage. This allows the Stevtensioner to slide up along the active chain to the surface *(fig. 3-108)*.

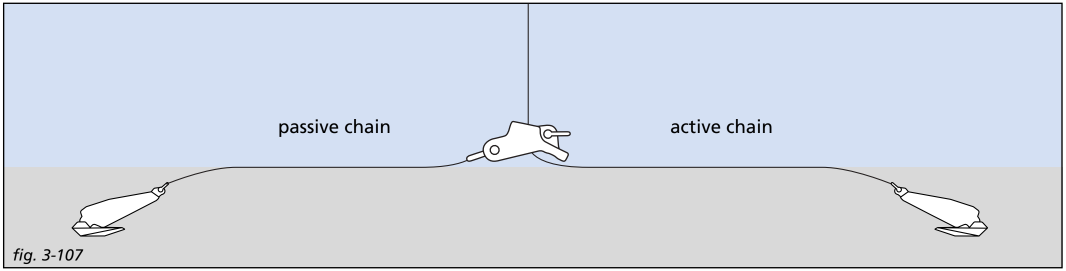


fig. 3-107

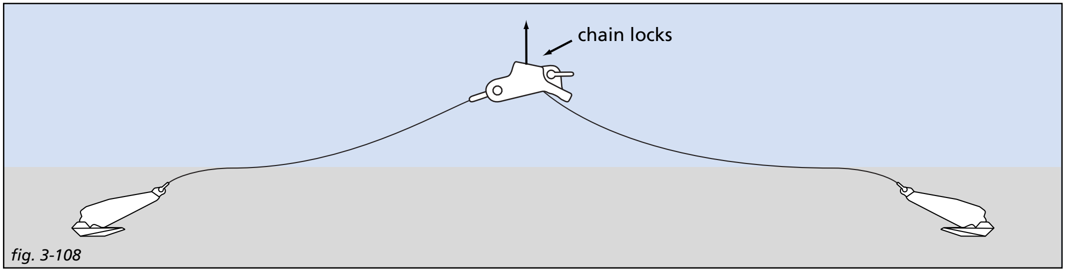


fig. 3-108

Measurement of the tensions applied

Fig. 3-109 shows the curve recorded during tensioning of chains connected to piles for the Coveñas Pipeline Project in Colombia. The graph shows a total of 5 heaves (yo-yo's), each resulting in a higher tension.

When the Stevtensioner is lifted from the seabed, the passive and active mooring lines are also lifted from the seabed. Consequently the anchors or piles are loaded. The loading causes an inverse catenary of the mooring line in the soil, and also causes the anchor to drag and embed; in other words: chain length is gained. When lowering to seabed the gain in chain length (slack) is won by the Stevtensioner sliding down the chain (approximately 5 to 8 links). The next heave (yo-yo) will therefore create a higher tension in the system. In practise a total of 5 to 7 yo-yos are required to reach the required proof tension load.

Different methods can be applied to verify the tension in the chain. These are discussed below.

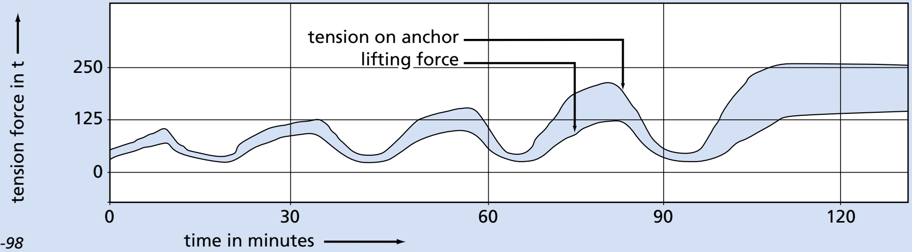


fig. 3-98

Computer calculations

The tension in the chain can be calculated by means of computer catenary calculations. Besides known parameters such as submerged chain weight, and the length of the mooring line, other parameters measured during tensioning need to be incorporated in the calculation:

- Height Stevtensioner above seabed.
- Vertical pulling load.

By using this method the tension in the chain can be calculated at any height of the Stevtensioner above seabed. This method is independent of the waterdepth.

Umbilical cable and measuring pin

The chain tension can be measured with a measuring pin. The pin is part of the Stevtensioner housing and is equipped with strain gauges. The pin is connected to a tension read-out unit on the installation vessel by using an umbilical cable. The pin is connected to the passive chain. All tensioning data are measured on deck and presented during tensioning on a chart recorder. A hand winch with sliding contacts is used to veer and haul the umbilical without disconnecting the umbilical from the registration equipment. The measurement is insensitive for variations in cable length. The use of an umbilical is an effective method in waterdepths down to approximately 200 meters. Beyond this depth it becomes more efficient to use either an acoustic system or computer calculations.

Break-link

The passive chain can be attached to the Stevtensioner by a break-link. When, during the tensioning operation, a predetermined load has been reached, the link breaks. Consequently the passive chain falls to the bottom, and the Stevtensioner can be retrieved.

Duration of pretensioning anchors and piles

Once the required tension has been achieved, the tension has to be maintained for a certain duration. This period is described in the table below for various Certification Authorities.

Certification Authority	Required duration of maintaining tension
Lloyds Register of Shipping	20 minutes
American Bureau of Shipping	30 minutes
Det Norske Veritas (NMD)	15 minutes

Handling the Stevtensioner

Handling operations can generally be described as follows:

- Positioning the anchors and paying out the chain
- Hook-up all necessary hardware for tensioning operations on deck of barge or AHV
- Deployment Stevtensioner to the seabed and positioning of the installation vessel
- First lift (yo-yo)
- Series of yo-yo's
- Maintain required tension for a specified period of time
- Retrieve the Stevtensioner and disconnect
- Prepare for next tensioning

A Stevtensioner can be deployed from a crane barge, Anchor Handling Vessel or any vessel having enough crane/winch capacity to lift the required vertical force.

General tensioning procedures

General tensioning procedures using crane barge or AHV for Stevtensioner models VA1000 and VA1250 are presented in *fig. 3-110 and 3-111*.

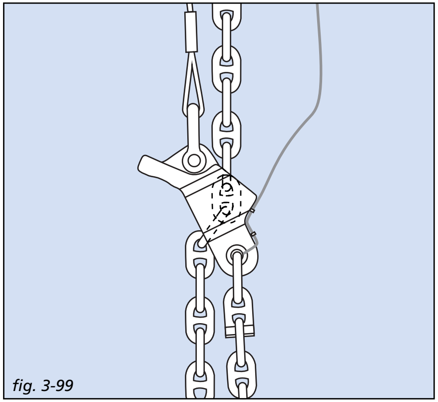


fig. 3-99

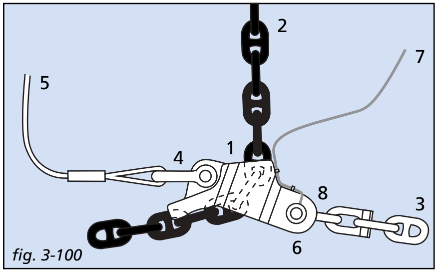


fig. 3-100

Hook-up

Pass the active chain (2) through the tensioner (1) on deck. Connect passive chain (3) to measuring pin shackle (8). Connect dislock wire (5) to shackle (4). Connect umbilical cable (7) to read-out system on deck and to the measuring pin (6).

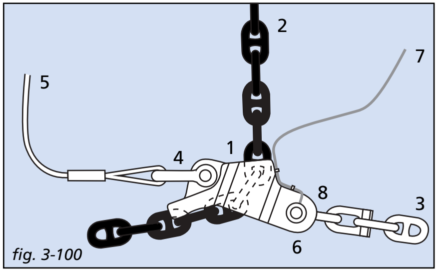


fig. 3-100

Lowering

Fix active chain (2) to winch or crane hook. Slack dislock wire (5) and lower Stevtensioner to seabed. Stevtensioner will pass over active chain (2).

Tensioning mode

When Stevtensioner is on seabed, slack dislock wire (5) before the first yo-yo, and keep slack during all yo-yos!

Tensioning is achieved by pulling on active chain (2). The mooring lines will be lifted from the seabed causing the anchors or piles to be loaded. After each yo-yo active chain is gained. The active chain can only pass through the Stevtensioner in one direction. Approximately 4 to 7 yo-yos are required to obtain the required pretension load *(fig. 3-111)*.

Retrieving

When tensioning is completed be sure to lower the Stevtensioner to seabed and slack off active chain (2) before retrieving Stevtensioner with dislock wire (5). Pull on dislock wire (5). Stevtensioner will pass over chain (2). Disconnect Stevtensioner on deck of the barge or AHV.

Stevtensioner Product Range

The following Stevtensioners are available from vryhof anchors.

Stevtensioner model	Maximum horizontal load [t]	Suitable* for chain size with Kenter shackle [mm]	Suitable* for chain size without Kenter shackle [mm]	Size Stevtensioner lxhxw [m]	Weight Stevtensioner [t]
VA 220	220	50	60	2.6 x 1.2 x 1.0	5
VA 500	500	102	112	5.4 x 2.6 x 2.4	20
VA 600	600	76 - 84	76 - 87	2.2 x 0.9 x 0.6	2.5
VA1000	1000	102 - 117	102 - 135	3.1 x 1.2 x 0.8	6
VA1250	1250	114 - 132	114 - 152	3.5 x 1.4 x 0.9	9

** The suitability only refers to the section of chain passing through the Stevtensioner. Chain or wire not passing through the Stevtensioner may have any dimension.*

Supply/anchor handling vessels

Drilling rigs are generally moored with 8 to 12 anchors. These are laid in a mooring pattern. Originally normal tugs were used for these operations, but very soon, there was a call for specialised vessels.

For anchor handling vessels, it is very important to be able to work quickly and effectively. Much depends on the expertise of the captain and crew. The equipment and its design are also extremely important. Engine power has to be sufficient to handle chain and/or wire and anchors at the water depth concerned. The newest generation of AHVs has bollard pulls far in excess of 200 t.

Care should be given to the rated maximum bollard pull which in reality might be less, depending on the use of other power consuming equipment such as bow (and sometimes) stern thrusters, winches, etc.
The winch often causes confusion. An AHV owner demonstrates maximum pulling capacity at the bare drum during the maiden trip, but a contractor requires high winch output when the drum is 70 to 100% wound with wire under working conditions. It is also possible that an owner limits the pressure of the hydraulic system below factory limits, to reduce winch wear and repair costs.

The dynamic capacity of the winch brake is particul-arly important when a long heavy chain must be deployed. Hydraulically and electrically braked drums are more efficient than band brakes.

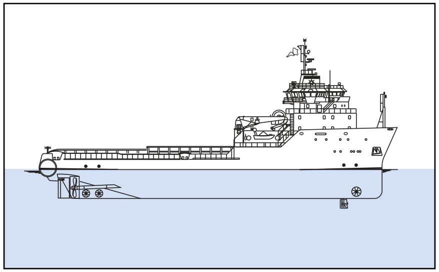
For handling chain, many supply vessels have chain lockers below decks and a wildcat above the chain locker.

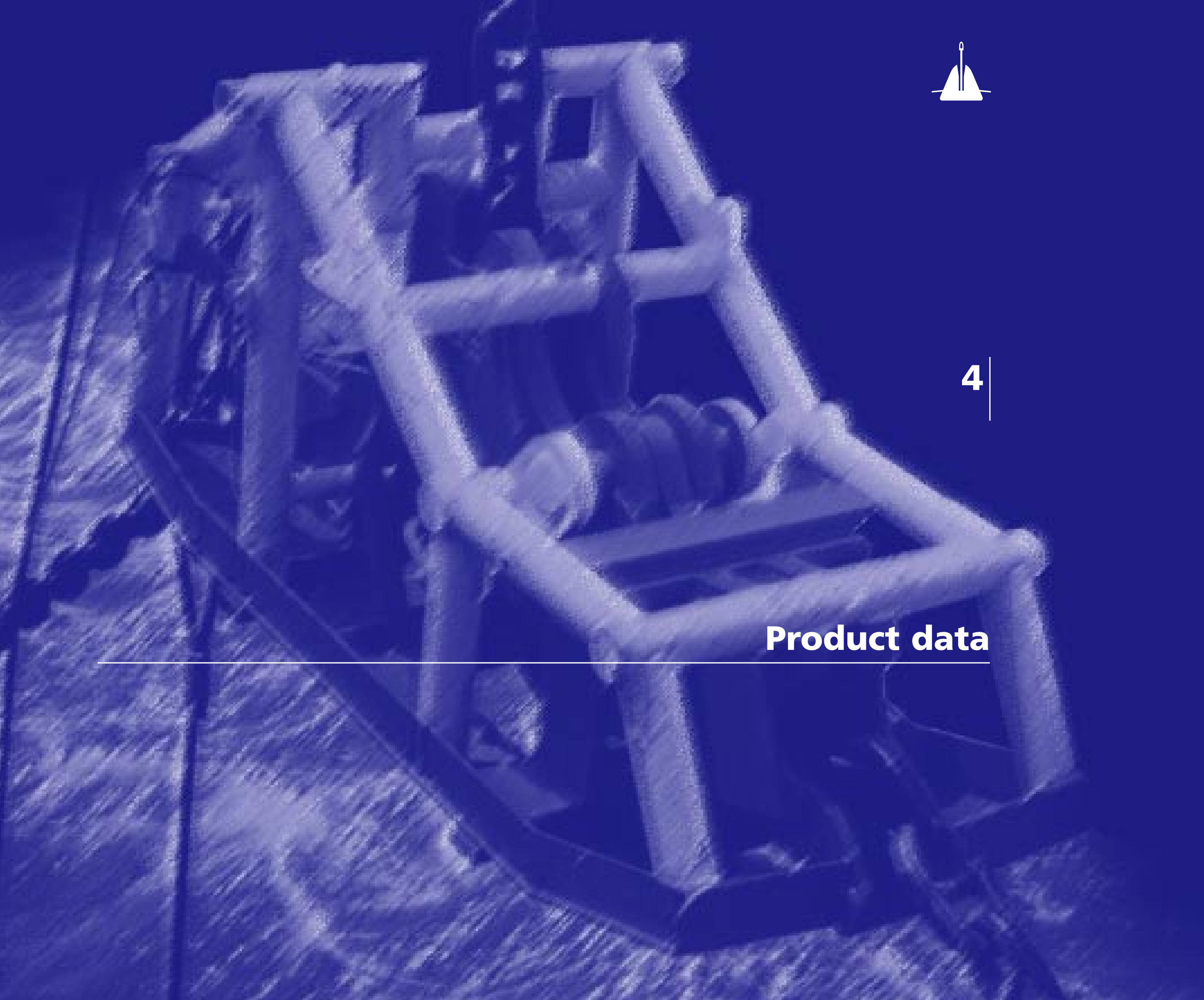
To ensure easy handling of chain and wire, simple, well-constructed tools are necessary. An experienced crew will also make the handling easier.

These specialised anchor handling vessels (AHVs) now have:

- A large deck space.
- Powerful winches, with auxiliary winches to reel extra wires.
- Large chain lockers, for storage of the chain.
- Large wire storage capacity.
- An adapted seaworthy design and very manoeuvrable with bow and stern thrusters. Some even with a dynamic positioning system.
- Space for drilling mud and fuel tanks for supply to drilling rigs.
- Small auxiliary cranes.
- One or two sets of towing pins and shark jaws.
- A stern roller that sometimes consists of two individually rotating drums.

table P





4

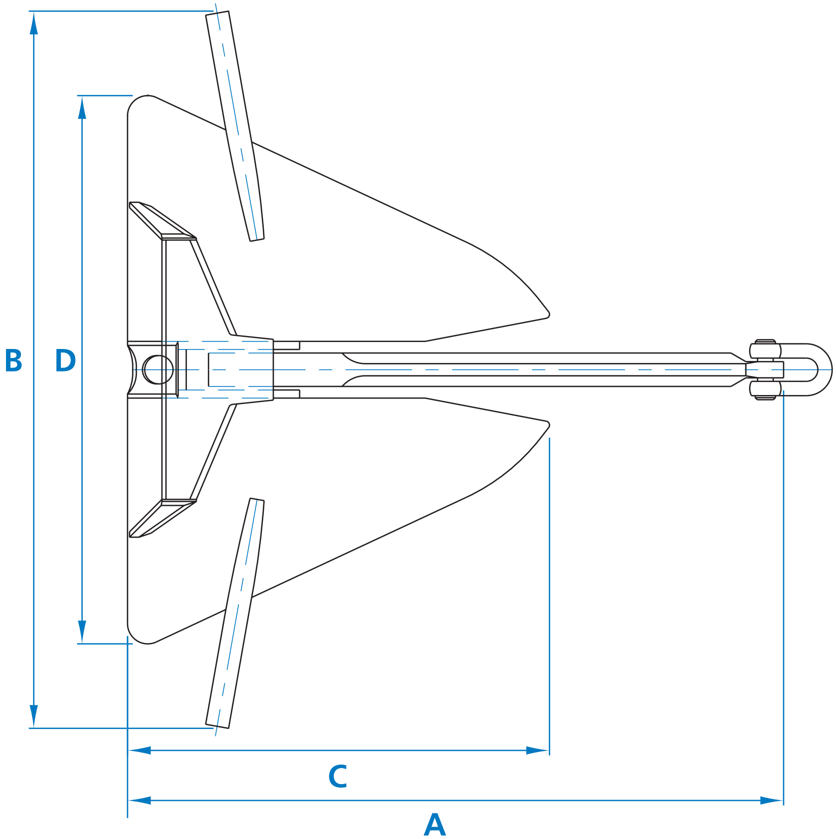
Product data

Product Data

In this editon of the vryhof anchor manual, we have given the reader as much information and data as we imagined would normally be needed. Undoubtedly some is missing. This can be vryhof-specific or general information. Vryhof-specific, information can be related to brochures, detailed handling recommendations and product data. This can be obtained on request, while general information will also be provided if available.

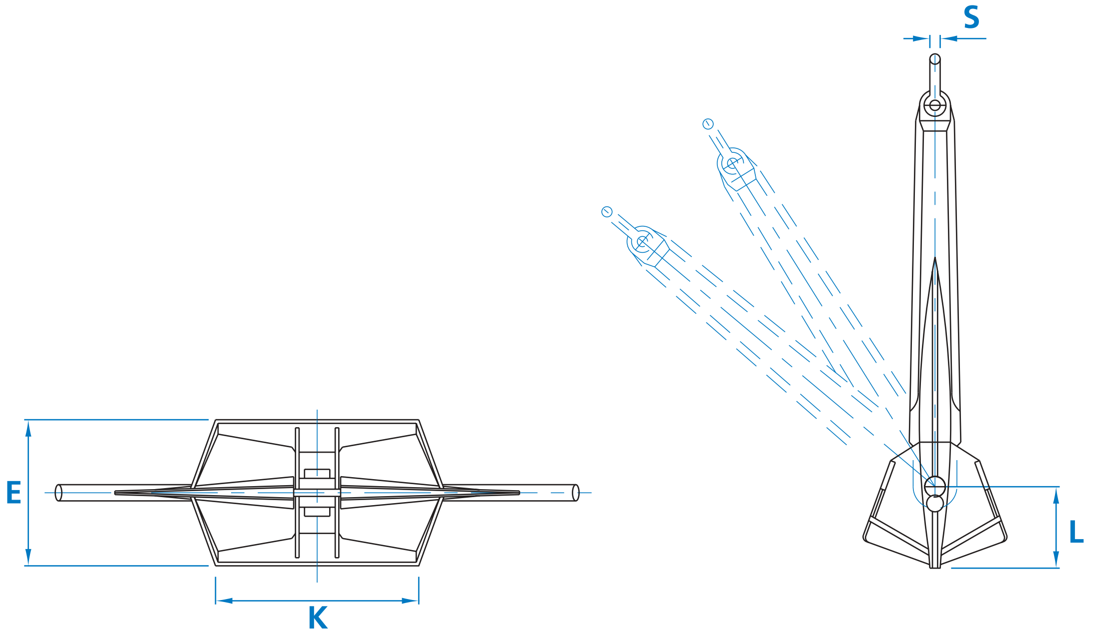
To make the next edition of the anchor manual suit the requirements of the reader even better than this one, your suggestions of comments are much appreciated.

Dimensions of vryhof anchor types



Stevin Mk3

Dimensions of vryhof anchor types



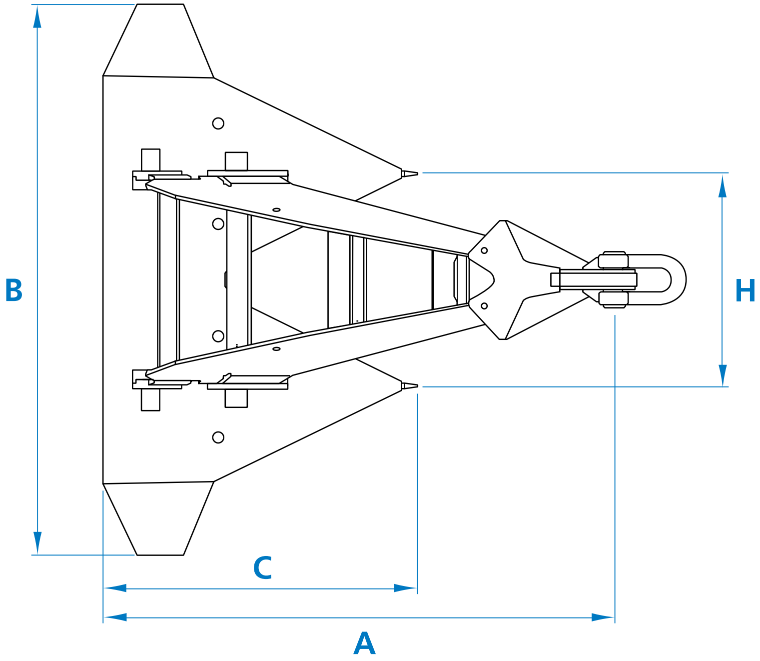
Stevin Mk3

Main dimensions Stevin Mk3 dimensions in mm anchor weight in kg

weight	1000	1500	3000	5000	7000	9000	12000	15000	20000	30000
A	2429	2774	3493	4120	4602	5012	5516	5942	6372	7289
B	2654	3038	3828	4538	5077	5521	6076	6545	6986	7997
C	1559	1785	2249	2667	2983	3244	3570	3846	4100	4694
D	2023	2316	2918	3460	3871	4209	4632	4990	5324	6094
E	737	843	1063	1260	1409	1533	1687	1817	2048	2345
K	1010	1156	1456	1727	1932	2100	2312	2490	2674	3061
L	412	471	594	704	788	857	943	1016	1083	1240
S	60	65	80	80	90	100	110	120	160	180

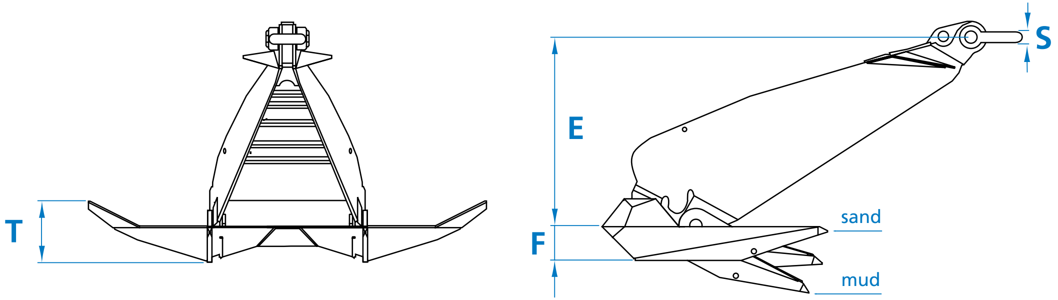
Note: The dimensions of the Stevin Mk3 anchor may be changed for specific applications

Main dimensions of vryhof anchor types



Stevpris Mk5

Main dimensions of vryhof anchor types



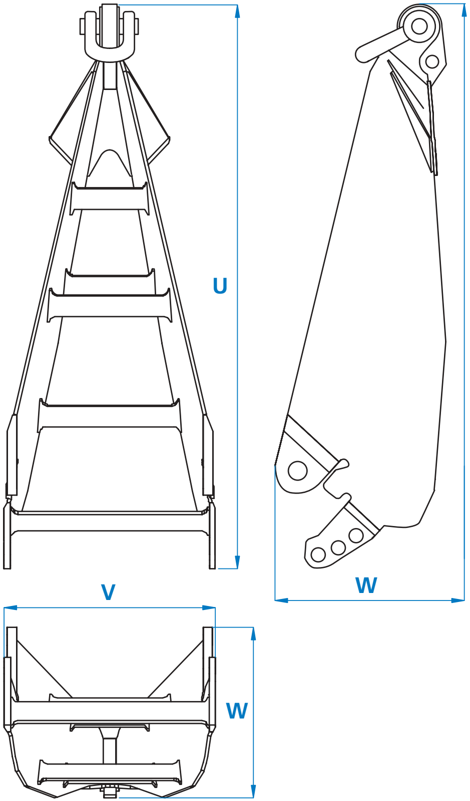
Stevpris Mk5

Main dimensions Stevpris Mk5 dimensions in mm anchor weight in kg

weight	1500	3000	5000	8000	10000	12000	15000	18000	20000	22000	25000	30000	65000
A	2954	3721	4412	5161	5559	5908	6364	6763	7004	7230	7545	8018	10375
B	3184	4011	4756	5563	5992	6368	6860	7290	7550	7794	8133	8643	11184
C	1812	2283	2707	3166	3410	3624	3904	4149	4297	4436	4629	4919	6365
E	1505	1896	2248	2629	2832	3010	3242	3446	3569	3684	3844	4085	5286
F	271	342	406	474	511	543	585	622	644	665	694	737	954
H	1230	1550	1837	2149	2315	2460	2650	2816	2917	3011	3142	3339	4321
T	493	622	738	862	929	988	1064	1131	1171	1209	1262	1341	1736
S	80	90	110	130	140	150	170	180	190	200	200	220	300

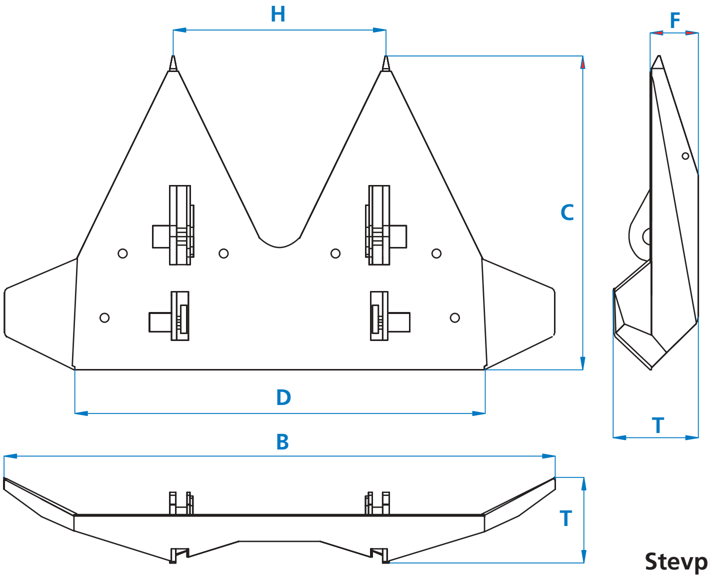
Note: The dimensions of the Stevpris Mk5 anchor may be changed for specific applications

Transport dimensions of vryhof anchor types



Stevpris Mk5

Transport dimensions of vryhof anchor types

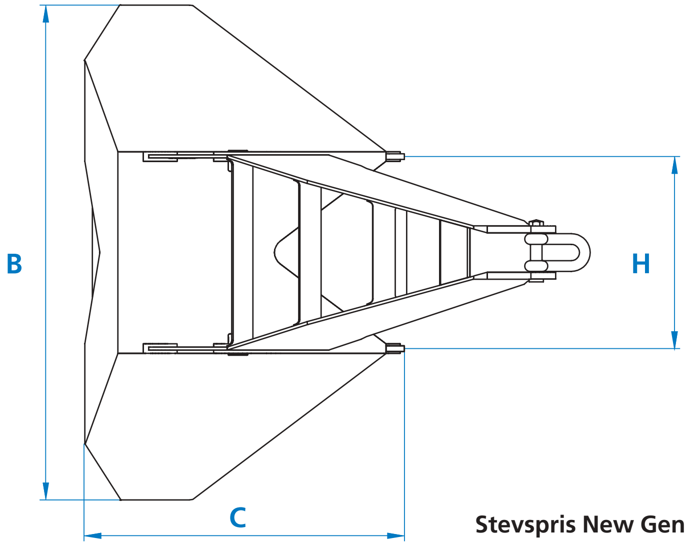


Stevpris Mk5

Transport dimensions Stevpris Mk5 dimensions in mm weight in kg													
weight													
anchor	1500	3000	5000	8000	10000	12000	15000	18000	20000	22000	25000	30000	65000
fluke	600	1300	2100	3400	4300	5200	6400	7700	8600	9400	10700	12900	27900
shank	900	1700	2900	4600	5700	6800	8600	10300	11400	12600	14300 1	7100	37100
B	3184	3999	4750	5550	5980	6348	6848	7278	7547	7799	8123	8650	11193
C	1812	2283	2707	3166	3411	3625	3904	4149	4297	4436	4629	4919	6365
D	2367	2969	3529	4122	4442	4714	5087	5407	5609	5799	6035	6431	8322
H	1232	1538	1831	2140	2301	2443	2642	2808	2920	3016	3135	3345	4328
T	494	623	739	864	930	989	1065	1132	1172	1210	1263	1342	1737
U	3294	4141	4913	5747	6190	6578	7090	7533	7806	8060	8406	8936	11563
V	1221	1526	1817	2120	2285	2422	2618	2783	2891	2994	3108	3321	4297
W	984	1240	1470	1719	1852	1968	2120	2253	2334	2409	2514	2671	3456

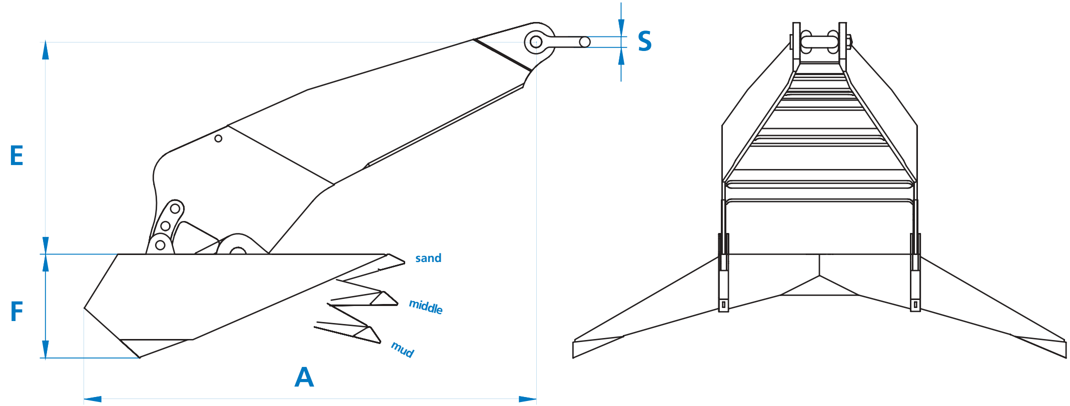
Note: The dimensions of the Stevshark Mk5 anchor may be changed for specific applications

Main dimensions of vryhof anchor types



Stevspris New Generation

Main dimensions of vryhof anchor types



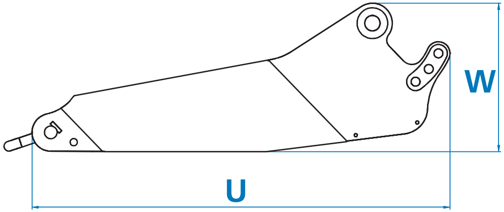
Stevspris New Generation

Main dimensions Stevpris New Generation dimensions in mm anchor weight in kg

weight	1500	3000	5000	8000	10000	12000	15000	18000	20000	22000	25000	30000
A	2797	3523	4178	4886	5263	5593	6025	6402	6631	6845	7143	7591
B	3059	3870	4602	5390	5807	6171	6679	7101	7368	7625	7962	8451
C	1981	2495	2958	3460	3728	3961	4267	4534	4696	4848	5059	5376
E	1321	1664	1973	2308	2486	2642	2846	3024	3132	3234	3374	3586
F	641	808	958	1120	1206	1282	1381	1468	1520	1569	1637	1740
H	1170	1490	1781	2090	2253	2394	2610	2777	2890	3002	3138	3324
S	65	80	100	120	130	140	160	170	180	190	200	210

Note: The dimensions of the Stevpris New Generation anchor may be changed for specific applications

Transport dimensions of vryhof anchor types



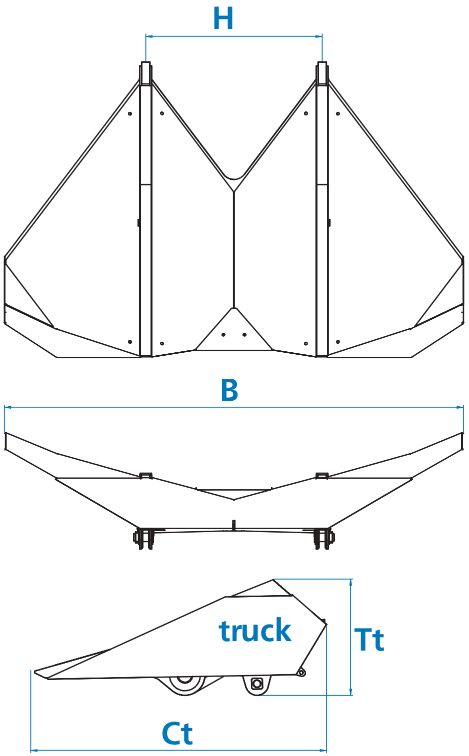
Stevspris New Generation

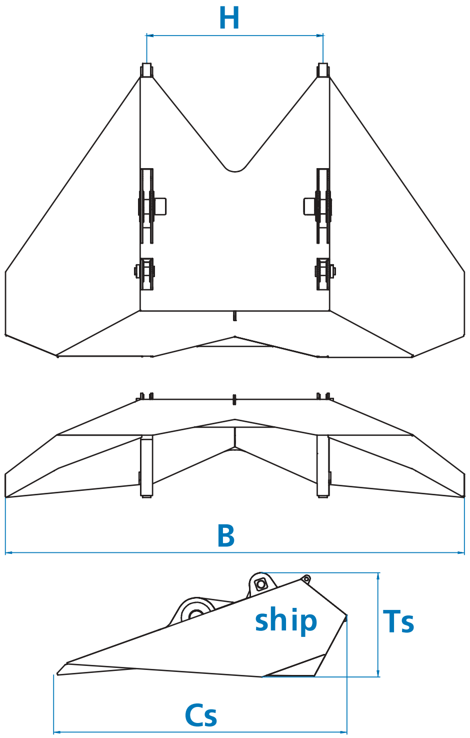
Transport dimensions Stevspris New Generation dimensions in m anchor weight in kg

weight	1500	3000	5000	8000	10000	12000	15000	18000	20000	22000	25000	30000
B	3.06	3.87	4.60	5.39	5.81	6.17	6.68	7.10	7.37	7.63	7.96	8.45
Ct	1.98	2.49	2.95	3.45	3.72	3.95	4.26	4.52	4.69	4.84	5.05	5.36
Cs	1.96	2.47	2.93	3.43	3.69	3.92	4.23	4.49	4.65	4.80	5.01	5.32
H	1.17	1.49	1.78	2.09	2.25	2.39	2.61	2.78	2.89	3.00	3.14	3.32
Tt	0.78	0.98	1.16	1.36	1.46	1.55	1.68	1.78	1.84	1.90	1.99	2.11
Ts	0.70	0.88	1.04	1.22	1.31	1.39	1.50	1.59	1.65	1.70	1.78	1.89
U	2.79	3.52	4.17	4.88	5.26	5.59	6.02	6.40	6.62	6.84	7.14	7.58
V	1.21	1.54	1.83	2.15	2.32	2.46	2.69	2.86	2.97	3.09	3.23	3.42
W	0.99	1.25	1.48	1.73	1.86	1.98	2.13	2.27	2.35	2.42	2.53	2.69

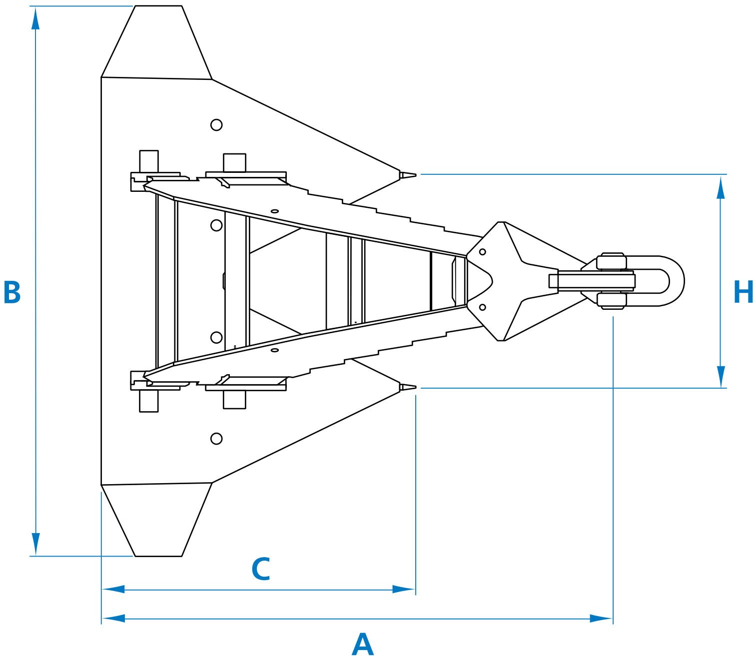
Note: The dimensions of the Stevspris New Generation anchor may be changed for specific applications

Transport dimensions of vryhof anchor types

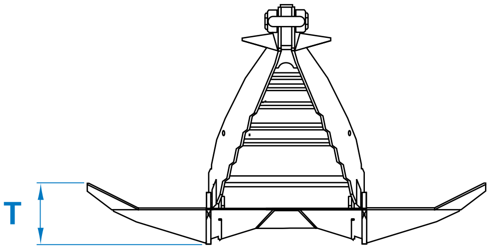


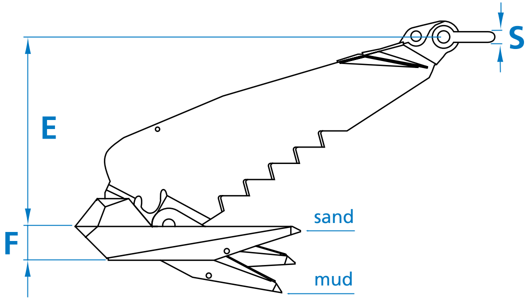


Stevspris New Generation



Stevshark Mk5



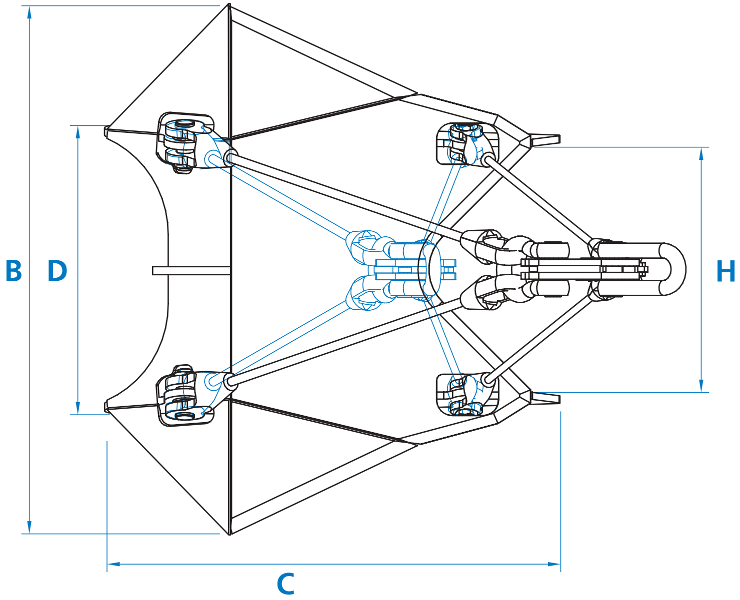


Main dimensions Stevshark Mk5 dimensions in mm anchor weight in kg

weight	1500	3000	5000	8000	10000	12000	15000	18000	20000	22000	25000	30000	65000
A	2862	3605	4275	4999	5385	5723	6165	6551	6785	7004	7309	7767	10051
B	3085	3886	4608	5389	5805	6169	6645	7062	7314	7550	7879	8373	10834
C	1755	2212	2622	3067	3304	3511	3782	4019	4163	4297	4484	4765	6166
E	1458	1837	2178	2547	2743	2915	3140	3337	3457	3568	3723	3957	5120
F	263	332	393	460	495	526	567	602	624	644	672	714	924
H	1192	1502	1780	2082	2243	2383	2567	2728	2826	2917	3044	3235	4186
T	478	603	715	836	900	957	1031	1095	1135	1171	1222	1299	1681
S	80	90	110	130	140	150	160	170	180	190	200	210	300

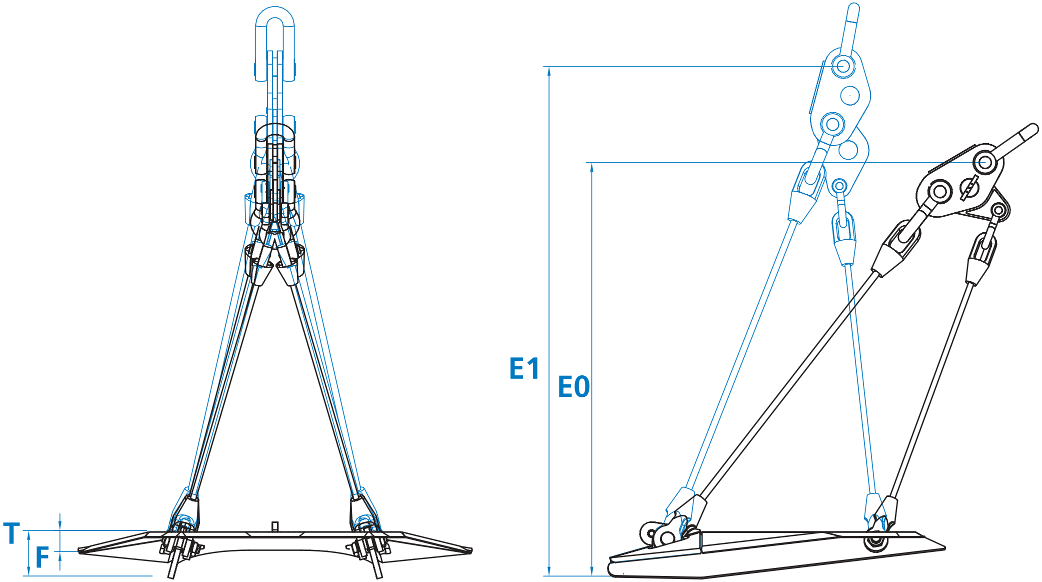
Note: The dimensions of the Stevshark Mk5 anchor may be changed for specific applications

Dimensions of vryhof anchor types



Stevmanta VLA - permanent

Dimensions of vryhof anchor types

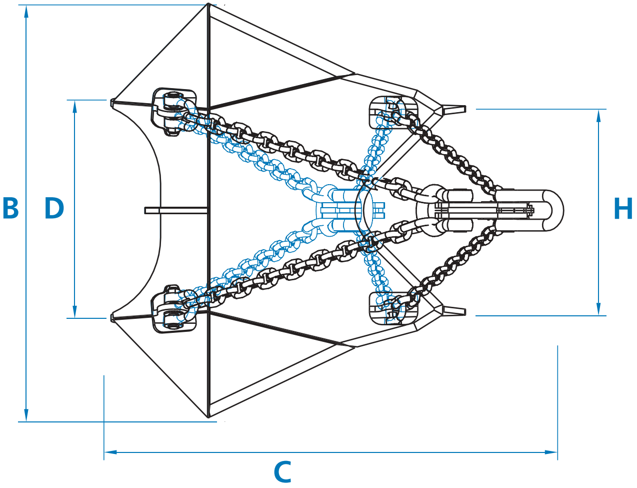


Stevmanta VLA - permanent

Main dimensions Stevmanta VLA dimensions in mm area in m²							
area	5	8	10	12	15	17	20
B	3143	3975	4445	4869	5443	5795	6286
C	2976	3765	4209	4611	5155	5488	5953
D	1945	2460	2750	3013	3368	3586	3890
E0	3075	3890	4349	4764	5326	5670	6150
E1	3371	4264	4767	5222	5839	6216	6742
F	172	217	243	266	298	317	344
H	1459	1845	2063	2260	2527	2690	2918
T	639	809	904	991	1107	1179	1279

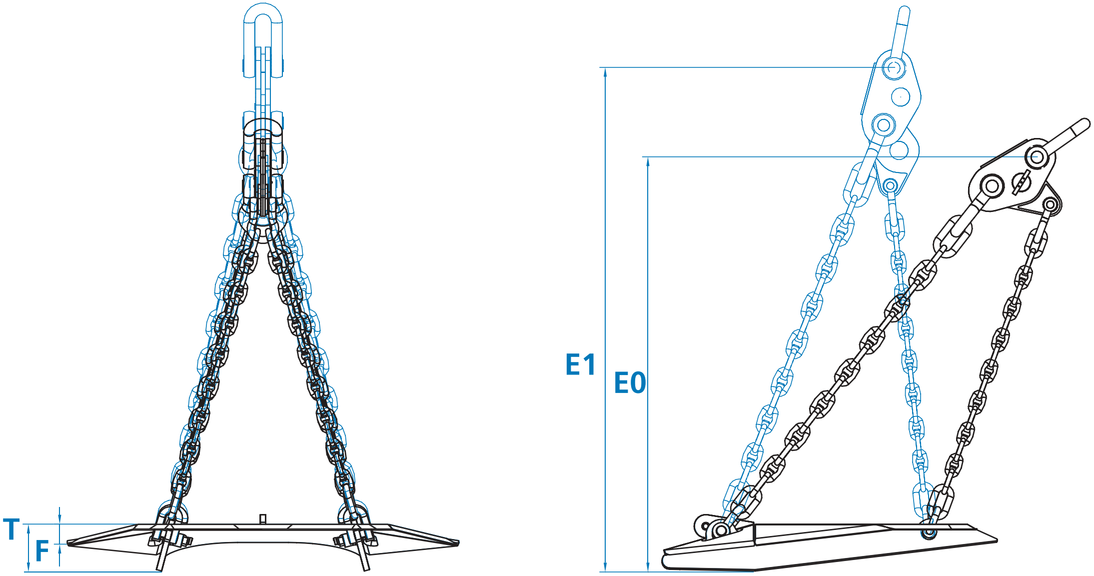
Note: The dimensions of the Stevmanta VLA anchor may be changed for specific applications

Dimensions of vryhof anchor types



Stevmanta VLA - MODU

Dimensions of vryhof anchor types



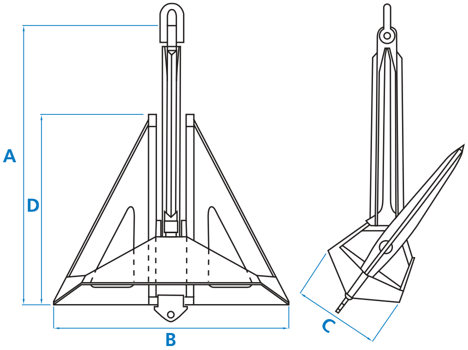
Stevmanta VLA - MODU

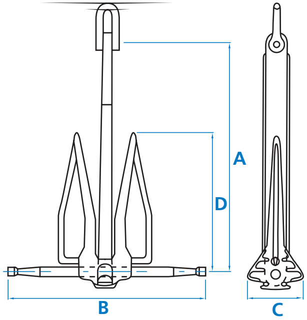
Main dimensions Stevmanta VLA dimensions in mm area in m²

area	5	8	10	12	15	17	20
B	3143	3975	4445	4869	5443	5795	6286
C	2976	3765	4209	4611	5155	5488	5953
D	1945	2460	2750	3013	3368	3586	3890
E0	3075	3890	4349	4764	5326	5670	6150
E1	3371	4264	4767	5222	5839	6216	6742
F	172	217	243	266	298	317	344
H	1459	1845	2063	2260	2527	2690	2918
T	639	809	904	991	1107	1179	1279

Note: The dimensions of the Stevmanta VLA anchor may be changed for specific applications

Dimensions other anchor types





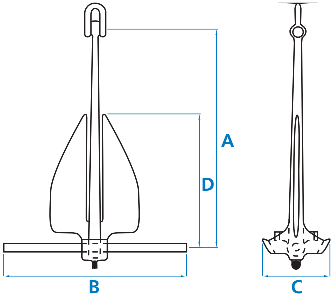
Flipper Delta

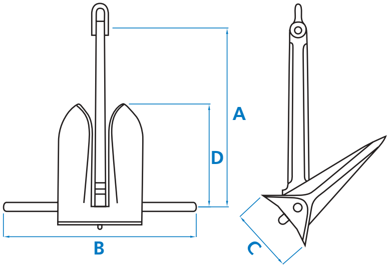
weight		A	B	C	D
lb.	kg	mm	mm	mm	mm
2205	1000	2605	1960	740	1560
5512	2500	3150	2660	1005	2130
11023	5000	3945	3300	1260	2660
16535	7500	4565	3850	1435	3080
22046	10000	5040	4270	1600	3400
26455	12000	5335	4530	1705	3600
33069	15000	5735	4845	1830	3875
44092	20000	6405	5410	2010	4320
71650	32500	7320	6200	2310	4930
88185	40000	7850	6650	2480	5290

Danforth

weight		A	B	C	D
lb.	kg	mm	mm	mm	mm
1000	454	1830	1580	410	1100
2500	1134	2260	2140	560	1350
5000	2268	2780	2700	710	1650
10000	4536	3510	3330	890	2100
12000	5443	3730	3540	945	2240
14000	6350	3920	3720	995	2360
16000	7257	4100	4000	1040	2470
20000	9072	4370	4150	1110	2620
25000	11340	4710	4470	1195	2820
30000	13608	5000	4750	1270	3000

Dimensions other anchor types



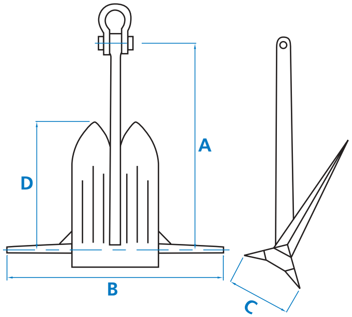


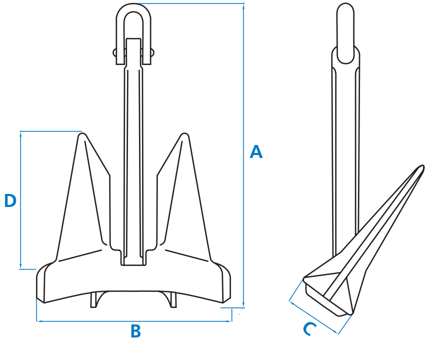
LWT

weight		A	B	C	D
lb.	kg	mm	mm	mm	mm
1000	454	1905	1803	622	1168
5000	2268	2997	2845	984	1829
10000	4536	3658	3480	1245	2235
15000	6804	3988	3791	1362	2438
20000	9072	4394	4166	1499	2692
25000	11340	4851	4521	1708	2946
30000	13608	5029	4801	1715	3073
35000	15876	5283	5055	1803	3226
40000	18144	5537	6096	1905	3327
60000	27216	6350	7061	2184	3810

Moorfast

weight		A	B	C	D
lb.	kg	mm	mm	mm	mm
1000	454	1549	1905	483	940
6000	2722	2565	3632	787	1549
10000	4536	3327	3988	1041	2032
12000	5443	3531	4242	1092	2159
16000	7257	3886	4750	1219	2388
20000	9072	4166	4978	1295	2591
30000	13608	4801	5512	1499	2997
40000	18144	5436	6299	1600	3226
50000	22680	5639	6528	1676	3353
60000	27216	5893	6883	1778	3556



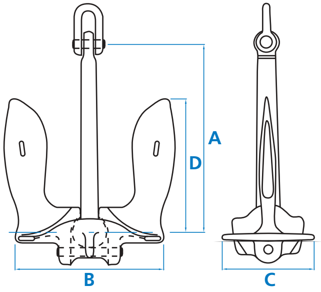


Stato

weight		A	B	C	D
lb.	kg	mm	mm	mm	mm
3000	1361	3277	2769	860	1829
6000	2722	3658	3632	960	2337
9000	4082	4064	4318	1090	2540
15000	6804	5182	5690	1370	3200
20000	9072	5334	5842	1420	3277
25000	11340	5740	6248	1540	3480
30000	13608	5969	6528	1570	3683
35000	15876	6299	6883	1670	3886
40000	18144	6553	7188	1750	4064
60000	27216	7540	8120	2000	4570

AC14

weight		A	B	C	D
lb.	kg.	mm	mm	mm	mm
2844	1290	2025	1568	470	1067
4630	2100	2382	1844	553	1255
6746	3060	2700	2091	627	1423
12368	5610	3305	2559	768	1741
18298	8300	3793	2916	875	1984
23149	10500	4073	3154	946	2146
29762	13500	4429	3249	1029	2333
41447	18800	4946	3829	1149	2606
44092	20000	5049	3909	1173	2660
50706	23000	5290	4095	1229	2787



US Navy Stockless

weight		A	B	C	D
lb.	kg	mm	mm	mm	mm
1000	454	1072	841	521	772
5000	2268	1854	1437	889	1319
10000	4536	2337	1810	1121	1661
15000	6804	2680	2089	1295	1861
20000	9072	2946	2280	1413	2094
25000	11340	3175	2456	1522	2256
30000	13608	3372	2608	1616	2394
35000	15876	3550	2743	1703	2523
40000	18144	3708	2872	1778	2619
60000	27216	4775	3194	2218	3375

Proof load test for HHP anchors (US units)

anchor weight lbs	proof load kips
100	6.2
125	7.3
150	8.2
175	9.1
200	9.9
250	11.5
300	12.9
350	14.2
400	15.5
450	16.7
500	18.1
550	19.2
600	20.5
650	21.7
700	23
750	24.3
800	25.5
850	26.6
900	27.8
950	28.9
1000	29.8
1100	32.1
1200	34.5
1300	36.8
1400	39.1
1500	41.3
1600	43.5
1700	45.8
1800	48.2
1900	50.3
2000	52.3
2100	54.5
4100	92.5
4200	94.2
4300	95.9
4400	97.5
4500	99.1
4600	100.7
4700	102.3
4800	103.9
4900	105.5
5000	107
5100	108.5
5200	110
5300	111.4
5400	112.9
5500	114.4
5600	115.9
5700	117.4
5800	118.7
5900	120
6000	121.4
6100	122.7
6200	124.1
6300	125.4
6400	126.8
6500	128.2
6600	129.5
6700	130.8
6800	132
6900	133.2
7000	134.4
7100	135.7
7200	136.9
10000	165.8
11000	174.5
12000	184.8
13000	194.7
14000	205.2
15000	214.3
16000	222.9
17000	230.9
18000	239
19000	245
20000	250.4
21000	256.7
22000	263.5
23000	270.9
24000	277.2
25000	282.8
26000	289.2
27000	296.7
28000	304.9
29000	312.3
30000	318.9
31000	326.9
32000	333.7
33000	341.2
34000	348
35000	354.8
36000	361.6
37000	368.4
38000	375.2
39000	382
40000	388.8
42000	400.6

Proof load test for HHP anchors (US units)

anchor weight lbs	proof load kips
2200	56.6
2300	58.6
2400	60.8
2500	62.8
2600	64.8
2700	66.8
2800	68.8
2900	70.7
3000	72.6
3100	74.5
3200	76.4
3300	78.3
3400	80.1
3500	81.9
3600	83.7
3700	85.5
3800	87.2
3900	89
4000	90.7
7300	138.1
7400	139.3
7500	140.6
7600	141.6
7700	142.7
7800	143.7
7900	144.7
8000	145.7
8100	146.8
8200	147.9
8300	149
8400	150
8500	151.1
8600	152.2
8700	153.2
8800	154.3
8900	155.2
9000	156.2
9500	161.1
44000	411.5
46000	425.1
48000	437
50000	449.1
52000	460.4
54000	472
56000	484.3
58000	496.5
60000	508.4
62000	519.3
64000	530.2
66000	541
68000	551.9
70000	562.8
75000	590
80000	617
82500	630

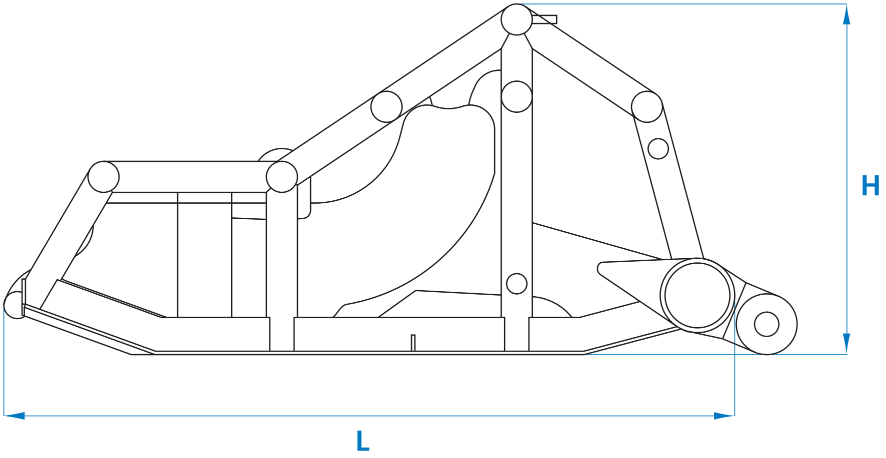
Proof load test for HHP anchors (SI units)

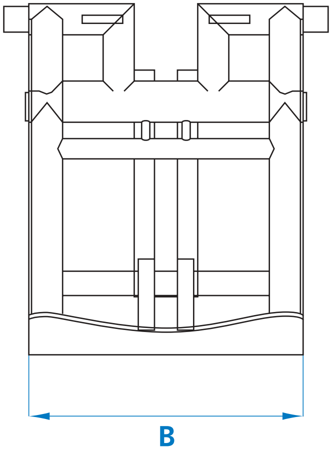
anchor weight kg	proof load kN
50	29.7
55	31.7
60	34
65	35.3
70	37
75	39
80	40.7
90	44
100	47.3
120	53
140	58.3
160	63.7
180	68.4
200	73.3
225	80
250	85.7
275	91.7
300	98
325	104.3
350	110.3
375	116
400	122
425	127.3
450	132
475	137.3
500	143
550	155
600	166
650	177.3
700	188
750	199
800	210.7
2000	434.3
2100	450
2200	466
2300	480.7
2400	495
2500	509.7
2600	524.3
2700	537
2800	550.3
2900	563.7
3000	577
3100	589
3200	601
3300	613
3400	625
3500	635.7
3600	645
3700	655.7
3800	666.3
3900	677
4000	687
4100	696.3
4200	706
4300	715.7
4400	725.7
4500	735
4600	742.3
4700	751.7
4800	760
4900	769
5000	777
5100	786
7000	970.3
7200	987
7400	1002
7600	1018
7800	1034
8000	1050
8200	1066
8400	1078
8600	1088.7
8800	1099.3
9000	1110
9200	1120.7
9400	1132
9600	1148
9800	1162.7
10000	1173.3
10500	1210
11000	1240
11500	1266.7
12000	1300
12500	1340
13000	1380
13500	1410
14000	1450
14500	1483.3
15000	1520
15500	1553.3
16000	1586.7
16500	1620
17000	1653.3
17500	1686.7
18000	1720

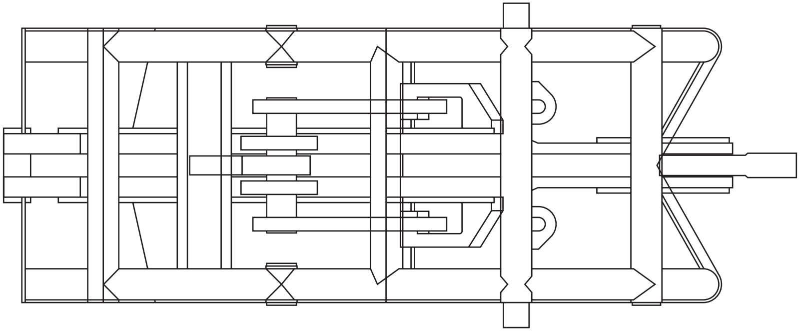
Proof load test for HHP anchors (SI units)

anchor weight kg	**proof** load kN
850	221.3
900	231
950	241.7
1000	252.3
1050	262
1100	272.7
1150	282.7
1200	292
1250	302
1300	311.7
1350	321
1400	330.3
1450	339.7
1500	349
1600	366.7
1700	384
1800	401
1900	418.3
5200	797.3
5300	808.7
5400	818
5500	827.3
5600	836.3
5700	845
5800	855.7
5900	866.3
6000	877
6100	887
6200	897.3
6300	908
6400	917.3
6500	926.7
6600	936
6700	944.7
6800	953
6900	961
18500	1753.3
19000	1780
19500	1800
20000	1833.3
21000	1900
22000	1956.7
23000	2016.7
24000	2070
25000	2130
26000	2190
27000	2250
28000	2303.3
29000	2356.7
30000	2410
31000	2463.3
32000	2516.7
34000	2623.3
36000	2730

Dimensions vryhof tensioners

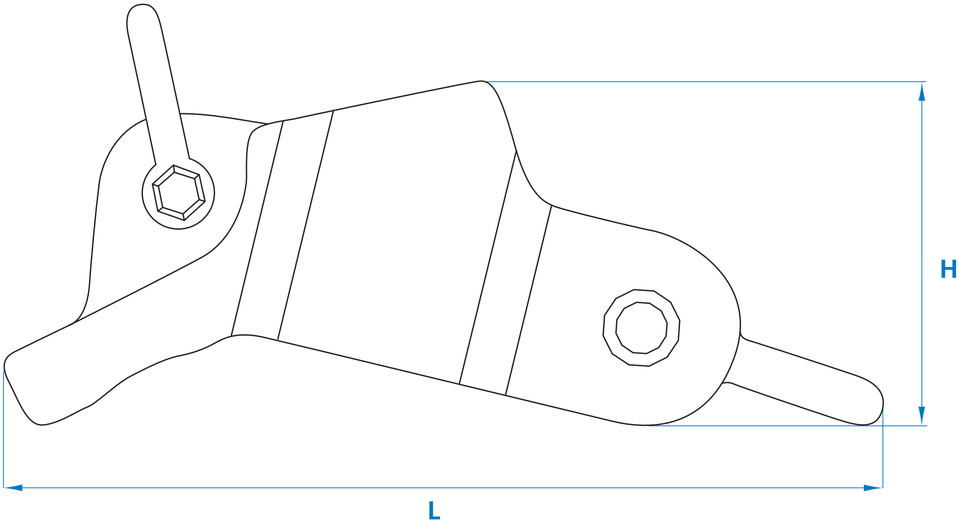


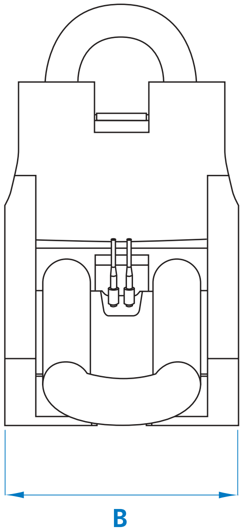


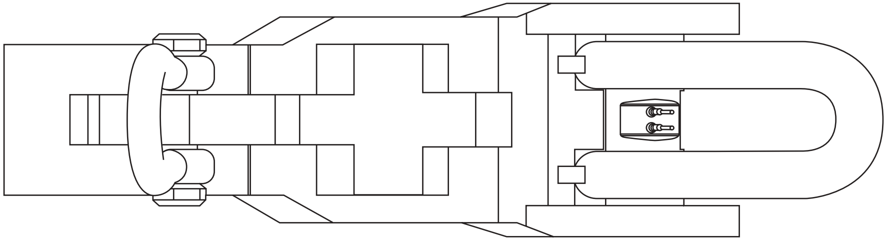


Main dimensions Stevtensioner dimensions in m. weight in t				
Stevtensioner model	L	B	H	weight
VA220	2.6	1.0	1.2	5
VA500	5.4	2.4	2.6	20

Dimensions vryhof tensioners







Main dimensions Stevtensioner dimensions in m. weight in t

Stevtensioner model	L	B	H	weight
VA600	2.2	0.6	0.9	2.5
VA1000	3.1	0.8	1.2	6
VA1250	3.5	0.9	1.4	9

Proof load/break load of chains (in US units)

diameter	Proof load						Break load				Weight	
	R4-RQ4		R3S		R3	RQ3-API	R4-RQ4	R3S	R3	RQ3-API		
	stud	studless	stud	studless	stud studless	stud studless	stud and studlless				stud	studless
inches	*kips*	*kips*	*kips*	*kips*	*kips*	*kips*	*kips*	*kips*	*kips*	*kips*	*lbs/ft*	*lbs/ft*
3/4	75	66	62	60	54	49	95	86	77	73	5	5
13/16	88	77	73	71	63	57	111	101	90	86	6	6
1	131	116	110	106	95	85	167	152	136	128	10	9
1 1/8	165	146	138	133	119	107	210	191	171	162	12	11
1 1/4	203	179	169	163	147	132	257	234	210	198	15	14
1 3/8	244	216	203	197	176	158	310	281	252	238	18	16
1 1/2	289	255	241	233	208	187	366	333	298	282	21	20
1 5/8	337	298	281	271	243	218	427	388	348	329	25	23
1 3/4	388	343	323	313	280	252	492	447	401	379	29	27
1 7/8	443	391	369	357	320	287	562	510	457	432	33	31
2	500	443	417	403	361	324	635	577	517	489	38	35
2 1/16	531	469	442	427	383	344	673	612	548	518	40	37
2 1/8	561	496	468	452	405	364	712	647	580	548	43	39
2 3/16	593	524	494	478	428	384	752	684	612	579	45	42
2 1/4	625	553	521	504	452	405	793	721	646	611	48	44
2 5/16	658	582	549	530	476	427	835	759	680	643	51	46
2 3/8	692	612	577	558	500	449	878	798	715	676	54	49
2 1/2	762	674	635	614	550	494	967	878	787	744	59	54
2 5/8	835	738	696	672	603	541	1059	962	862	815	65	60
2 11/16	872	771	727	702	630	565	1106	1005	900	852	69	63
2 3/4	910	805	758	733	657	590	1154	1049	940	889	72	66
2 7/8	988	874	823	796	714	640	1253	1139	1020	965	79	72
3	1069	945	891	861	772	693	1356	1232	1103	1044	86	78
3 1/16	1110	982	925	894	802	719	1408	1280	1146	1084	89	81
3 1/8	1152	1019	960	928	832	747	1461	1328	1189	1125	93	85
3 3/16	1194	1056	995	962	863	774	1515	1377	1233	1167	97	88
3 1/4	1237	1094	1031	997	894	802	1570	1427	1278	1209	100	92
3 5/16	1281	1133	1068	1032	925	830	1625	1477	1323	1251	104	95
3 3/8	1325	1172	1105	1068	957	859	1681	1528	1368	1295	108	99
3 1/2	1416	1252	1180	1140	1022	918	1796	1632	1462	1383	116	106
3 9/16	1462	1292	1218	1177	1056	947	1854	1685	1509	1428	121	110
3 5/8	1508	1334	1257	1215	1089	977	1913	1739	1557	1473	125	114
3 3/4	1603	1417	1336	1291	1158	1039	2033	1848	1655	1566	134	122
3 13/16	1651	1460	1376	1330	1192	1070	2094	1903	1704	1613	138	126
3 7/8	1699	1503	1416	1369	1227	1101	2156	1959	1754	1660	143	130
3 15/16	1749	1546	1457	1409	1263	1133	2218	2016	1805	1708	147	135
4	1798	1590	1498	1448	1299	1165	2281	2073	1856	1756	152	139
4 1/8	1899	1679	1582	1529	1371	1231	2409	2189	1960	1855	162	148
4 1/4	2001	1770	1668	1612	1445	1297	2538	2307	2066	1955	172	157

Proof load/break load of chains (in US units)

diameter	Proof load						Break load				Weight	
	R4-RQ4		R3S		R3	RQ3-API	R4-RQ4	R3S	R3	RQ3-API		
	stud	studless	stud	studless	stud studless	stud studless	stud and studlless				stud	studless
inches	*kips*	*kips*	*kips*	*kips*	*kips*	*kips*	*kips*	*kips*	*kips*	*kips*	*lbs/ft*	*lbs/ft*
4 3/8	2105	1862	1754	1696	1521	1365	2671	2427	2174	2057	182	166
4 1/2	2211	1955	1843	1781	1597	1433	2805	2549	2283	2160	192	176
4 5/8	2319	2050	1932	1868	1675	1503	2941	2673	2394	2265	203	186
4 3/4	2428	2147	2023	1956	1753	1574	3080	2799	2507	2372	214	196
4 7/8	2538	2245	2115	2045	1833	1645	3220	2926	2621	2480	226	206
5	2650	2344	2209	2135	1914	1718	3362	3055	2736	2589	238	217
5 1/8	2764	2444	2303	2226	1996	1791	3506	3186	2853	2700	250	228
5 1/4	2878	2545	2398	2319	2079	1865	3651	3318	2971	2812	262	239
5 3/8	2994	2647	2495	2412	2162	1940	3798	3451	3091	2925	274	251
5 1/2	3111	2751	2592	2506	2247	2016	3946	3586	3211	3039	287	262
5 5/8	3228	2855	2690	2601	2332	2093	4095	3722	3333	3154	301	275
5 3/4	3347	2960	2789	2696	2417	2170	4246	3859	3456	3270	314	287
5 7/8	3467	3066	2889	2793	2504	2247	4398	3997	3579	3387	328	299
6	3587	3172	2989	2890	2591	2325	4551	4135	3704	3504	342	312
6 1/8	3709	3279	3090	2987	2678	2404	4704	4275	3829	3623	356	325
6 1/4	3830	3387	3192	3086	2766	2483	4859	4416	3954	3742	371	339
6 3/8	3953	3495	3294	3184	2855	2562	5014	4557	4081	3861	386	353
6 1/2	4076	3604	3396	3283	2944	2642	5170	4698	4208	3981	401	367
6 5/8	4199	3713	3499	3383	3033	2722	5327	4841	4335	4102	417	381
6 3/4	4323	3822	3602	3482	3122	2802	5483	4983	4463	4223	433	395
6 7/8	4447	3932	3706	3582	3211	2882	5641	5126	4591	4344	449	410
7	4571	4042	3809	3682	3301	2963	5798	5269	4719	4465	466	425
7 1/8	4695	4152	3913	3782	3391	3043	5956	5412	4847	4586	482	440
7 1/4	4820	4262	4016	3882	3481	3124	6114	5556	4976	4708	500	456

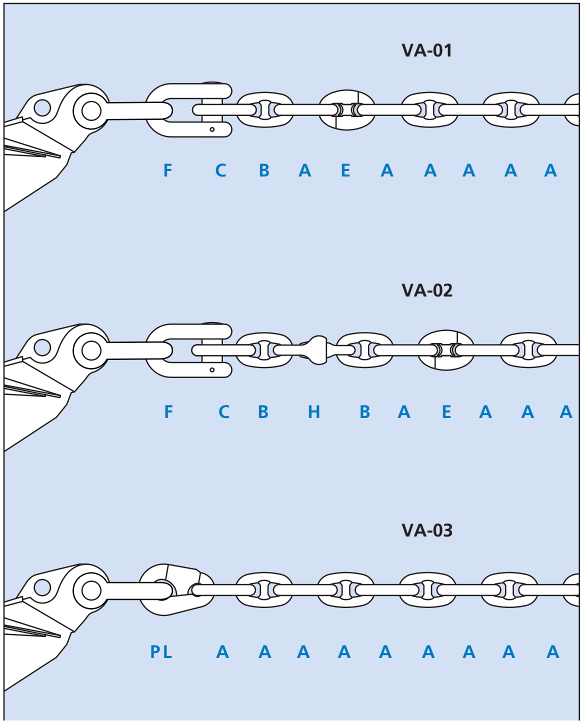
Proof load/break load of chains (in SI units)

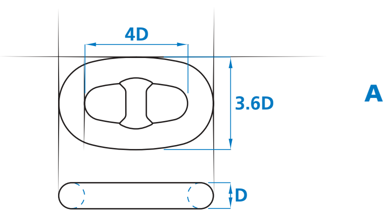
diameter	Proof load						Break load				Weight	
	R4-RQ4		R3S		R3	RQ3-API	R4-RQ4	R3S	R3	RQ3-API		
	stud	studless	stud	studless	stud-studless	stud-studless	stud and studlless				stud	studless
mm	kN	kN	kN	kN	kN	kN	kN	kN	kN	kN	kg/m	kg/m
19	331	293	276	267	239	215	420	382	342	324	8	7
20.5	385	340	320	310	278	249	488	443	397	376	9	8
22	442	390	368	356	319	286	560	509	456	431	11	10
24	524	463	436	422	378	339	664	604	541	511	13	12
26	612	541	510	493	442	397	776	706	632	598	15	14
28	707	625	589	570	511	458	897	815	730	691	17	16
30	809	715	674	651	584	524	1026	932	835	790	20	18
32	917	811	764	738	662	594	1163	1057	946	895	22	20
34	1031	911	859	830	744	668	1308	1188	1064	1007	25	23
36	1151	1018	959	927	831	746	1460	1327	1188	1124	28	26
38	1278	1130	1065	1029	923	828	1621	1473	1319	1248	32	29
40	1410	1247	1175	1136	1018	914	1789	1625	1456	1377	35	32
42	1548	1369	1290	1247	1118	1004	1964	1785	1599	1513	39	35
44	1693	1497	1411	1364	1223	1097	2147	1951	1748	1654	42	39
46	1843	1630	1536	1485	1331	1194	2338	2124	1903	1800	46	42
48	1999	1767	1666	1610	1443	1295	2535	2304	2063	1952	50	46
50	2160	1910	1800	1740	1560	1400	2740	2490	2230	2110	55	50
52	2327	2058	1939	1874	1681	1508	2952	2682	2402	2273	59	54
54	2499	2210	2083	2013	1805	1620	3170	2881	2580	2441	64	58
56	2677	2367	2231	2156	1933	1735	3396	3086	2764	2615	69	63
58	2860	2529	2383	2304	2066	1854	3628	3297	2953	2794	74	67
60	3048	2695	2540	2455	2201	1976	3867	3514	3147	2978	79	72
62	3242	2866	2701	2611	2341	2101	4112	3737	3347	3166	84	77
64	3440	3042	2867	2771	2484	2230	4364	3965	3551	3360	90	82
66	3643	3221	3036	2935	2631	2361	4621	4200	3761	3559	95	87
68	3851	3406	3209	3102	2782	2496	4885	4440	3976	3762	101	92
70	4064	3594	3387	3274	2935	2634	5156	4685	4196	3970	107	98
73	4392	3884	3660	3538	3172	2847	5572	5064	4535	4291	117	107
76	4731	4183	3942	3811	3417	3066	6001	5454	4884	4621	126	116
78	4962	4388	4135	3997	3584	3216	6295	5720	5123	4847	133	122
81	5317	4702	4431	4283	3840	3446	6745	6130	5490	5194	144	131
84	5682	5024	4735	4577	4104	3683	7208	6550	5866	5550	155	141
87	6056	5355	5046	4878	4374	3925	7682	6981	6252	5916	166	151
90	6439	5693	5365	5187	4650	4173	8167	7422	6647	6289	177	162
92	6699	5923	5582	5396	4838	4342	8497	7722	6916	6544	185	169
95	7096	6275	5913	5716	5125	4599	9001	8180	7326	6932	198	181
97	7365	6513	6138	5933	5319	4774	9343	8490	7604	7195	206	188
100	7776	6876	6480	6264	5616	5040	9864	8964	8028	7596	219	200
102	8054	7122	6712	6488	5817	5220	10217	9285	8315	7868	228	208

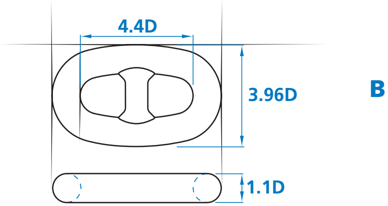
Proof load/break load of chains (in SI units)

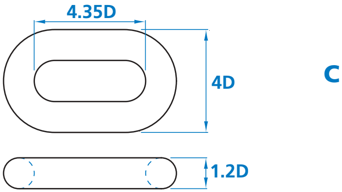
diameter	**Proof load**						**Break load**				**Weight**	
	R4-RQ4		R3S		R3	RQ3-API	R4-RQ4	R3S	R3	RQ3-API		
	stud	studless	stud	studless	stud-studless	stud-studless	stud and studlless				stud	studless
mm	kN	kN	kN	kN	kN	kN	kN	kN	kN	kN	kg/m	kg/m
105	8478	7497	7065	6829	6123	5495	10754	9773	8753	8282	241	221
107	8764	7750	7304	7060	6330	5681	11118	10103	9048	8561	251	229
111	9347	8265	7789	7529	6750	6058	11856	10775	9650	9130	270	246
114	9791	8658	8159	7887	7071	6346	12420	11287	10109	9565	285	260
117	10242	9057	8535	8251	7397	6639	12993	11807	10574	10005	300	274
120	10700	9461	8916	8619	7728	6935	13573	12334	11047	10452	315	288
122	11008	9734	9173	8868	7950	7135	13964	12690	11365	10753	326	298
124	11319	10009	9432	9118	8175	7336	14358	13048	11686	11057	337	308
127	11789	10425	9824	9497	8515	7641	14955	13591	12171	11516	353	323
130	12265	10846	10221	9880	8858	7950	15559	14139	12663	11981	370	338
132	12585	11129	10488	10138	9089	8157	15965	14508	12993	12294	382	348
137	13395	11844	11162	10790	9674	8682	16992	15441	13829	13085	411	375
142	14216	12571	11847	11452	10267	9214	18033	16388	14677	13887	442	403
147	15048	13306	12540	12122	10868	9753	19089	17347	15536	14700	473	432
152	15890	14051	13241	12800	11476	10299	20156	18317	16405	15522	506	462
157	16739	14802	13949	13484	12089	10850	21234	19297	17282	16352	540	493
162	17596	15559	14663	14174	12708	11405	22320	20284	18166	17188	575	525
165	18112	16016	15094	14590	13081	11739	22976	20879	18699	17693	596	545
168	18631	16474	15525	15008	13455	12075	23633	21477	19234	18199	618	564
171	19150	16934	15959	15427	13831	12412	24292	22076	19771	18707	640	585
175	19845	17548	16538	15986	14333	12863	25174	22877	20488	19386	671	613
178	20367	18010	16972	16407	14709	13201	25836	23479	21027	19896	694	634
180	20715	18318	17263	16687	14961	13427	26278	23880	21387	20236	710	648
185	21586	19088	17989	17389	15590	13991	27383	24884	22286	21087	750	685

Chain components and forerunners

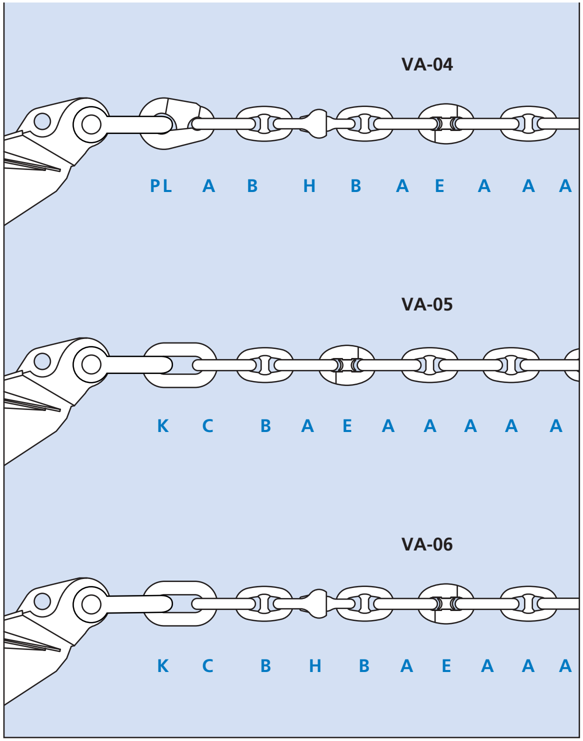


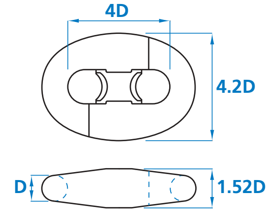




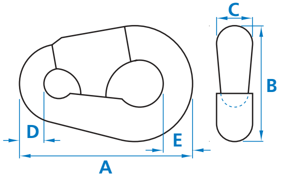


Chain components and forerunners

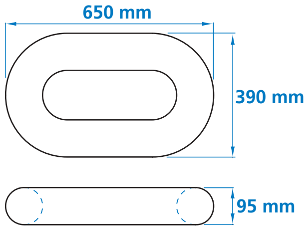




E

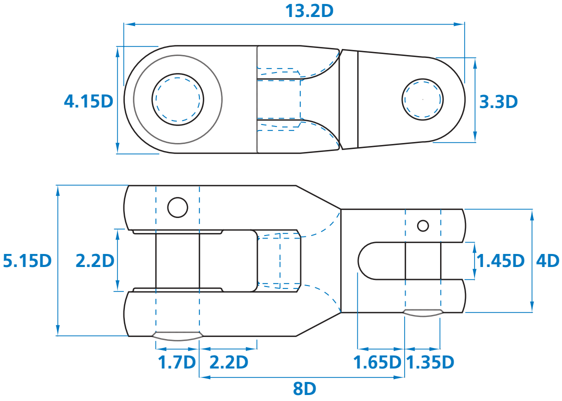


PL



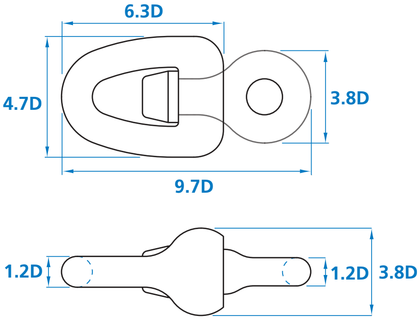
K

Chain components and forerunners

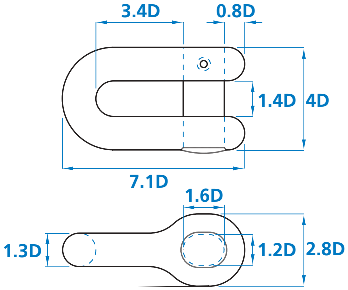


I

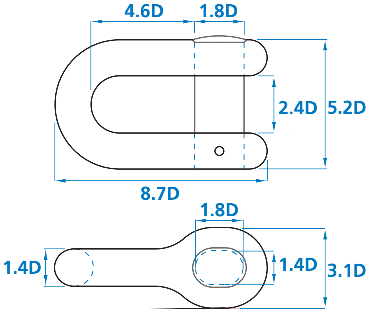
A = common link
B = enlarged link
C = end link
E = joining shackle kenter type
F = anchor shackle D type
G = joining shackle D type
PL = pear link
H = swivel
I = swivel shackle
K = special end link



H

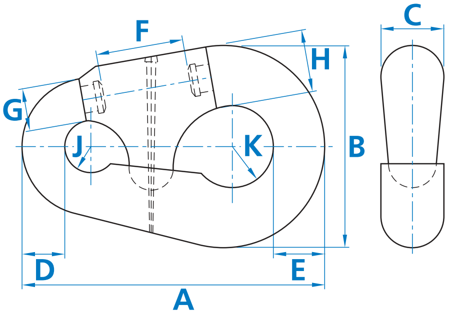


G



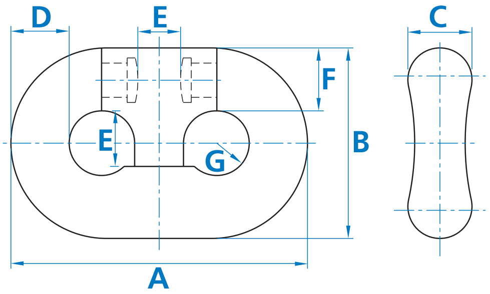
F

Connecting links



Pear shaped anchor connecting link (pearlink) dimensions in mm

NO	chain size	A	B	C	D	E	F	G	H	J	K	kg
4	32 - 40	298	206	59	40	48	83	44x44	56	26	43	13
5	42 - 51	378	260	76	51	64	100	51x60	74	32	52	27
6	52 - 60	454	313	92	60	76	121	62x73	88	37	64	49
7	62 - 79	562	376	117	79	95	149	85x79	111	48	76	94
8	81 - 92	654	419	133	92	124	149	111x102	130x133	54	79	149
9	94 - 95	692	435	146	98	130	159	124x137	141	57	83	236
10	97 - 102	889	571	190	121	165	190	130	181	73	108	386
11	103 - 108	940	610	203	127	175	203	156	200	76	111	418



Detachable chain connecting link (C-connector) dimensions in mm

chain size	A	B	C	D	E	F	G	weight kg
30 - 32	190.5	127	44	32	35	39	21	4.5
33 - 35	210	140	49	35	39	42	23	6.0
36 - 38	229	152	53	38	43	46	25	7.8
40 - 42	248	165	57	41	50	50	27	10.0
43 - 44	267	190	62	44	51	56	30	12.5
46 - 48	286	184	64	48	55	60	31	14.5
50 - 51	305	197	64	51	59	64	33	16.5
52 - 54	324	210	67	54	64	67	36	20.0
56 - 58	343	221	71	57	67	71	38	23.5
59 - 60	362	234	78	60	70	75	40	27.5
62 - 64	381	246	79	64	73	78	42	32.0
66 - 67	400	246	83	67	78	79	44	37.0
68 - 70	419	275	92	73	83	90	46	45.5
71 - 73	438	283	94	73	85	93	48	48.5
74 - 76	457	295	95	76	90	94	50	54.5
78 - 79	476	308	102	79	92	96	52	62.5
81 - 83	495	320	103	83	92	103	55	73.0
84 - 86	514	332	107	86	100	107	57	80.5
87 - 89	537	350	116	92	105	114	59	93.5
90 - 92	552	356	119	92	106	116	61	97.5
94 - 95	571	368	122	95	114	119	62	116.0
97 - 98	590	381	127	98	117	121	67	123.0
100 - 102	607	394	132	102	119	122	68	130.0

Conversion table

	to convert from		multiply by	to obtain	
length	millimetres	mm	0.03937	inches	in
	metres	m	3.28084	feet	ft
	kilometres	km	0.62137	miles	mi
	kilometres	km	0.53996	nautical miles	nmile
	inches	in	25.4	millimetres	mm
	feet	ft	0.30480	metres	m
	miles	mi	1.60934	kilometres	km
	nautical miles	nmile	1.852	kilometres	km
area	square millimetres	mm^2	0.00155	square inches	in^2
	square metres	m^2	10.76391	square feet	ft^2
	square kilometres	km^2	0.38610	square miles	mi^2
	square inches	in^2	645.16	square millimetres	mm^2
	square feet	ft^2	0.09290	square metres	m^2
	square miles	mi^2	2.58999	square kilometres	km^2
volume	millilitres	ml	0.06102	cubic inches	in^3
	litres	l	0.26417	gallons (US)	gal
	cubic metres	m^3	35.31467	cubic feet	ft^3
	cubic inches	in^3	16.38706	millilitres	ml
	gallons (US)	gal	3.78541	litres	l
	cubic feet	ft^3	0.02832	cubic metres	m^3
mass	kilograms	kg	2.20462	pounds	lb
	metric tons	t	1.10231	short tons	US ton
	pounds	lb	0.45359	kilograms	kg
	short tons	US ton	0.90718	metric tons	t
density	kilograms per cubic metre	kg/m^3	0.06243	pounds per cubic foot	lb/ft^3
	pounds per cubic foot	lb/ft^3	16.01846	kilograms per cubic metre	kg/m^3

Conversion table

	to convert from		multiply by	to obtain	
force or weight	kilonewtons	kN	0.22481	kips	kip
	kilonewtons	kN	0.10197	metric tons	t
	metric tons	t	2.20462	kips	kip
	kips	kip	4.44822	kilonewtons	kN
	metric tons	t	9.80665	kilonewtons	kN
	kips	kip	0.45359	metric tons	t
pressure or stress	kilopascals	kPa	20.88555	pounds per square foot	psf
	megapascals	MPa	0.14504	kips per square inch	ksi
	pounds per square foot	psf	0.04788	kilopascals	kPa
	kips per square inch	ksi	6.89472	megapascals	MPa
velocity	metres per second	m/s	1.94384	knots	kn
	metres per second	m/s	2.23694	miles per hour	mph
	knots	kn	0.51444	metres per second	m/s
	miles per hour	mph	0.44704	metres per second	m/s
temperature	degrees celsius	°C	multiply by 1.8 then add 32	degrees fahrenheit	°F
	degrees fahrenheit	°F	subtract 32 then multiply by 0.555	degrees celsius	°C

Mooring line catenary

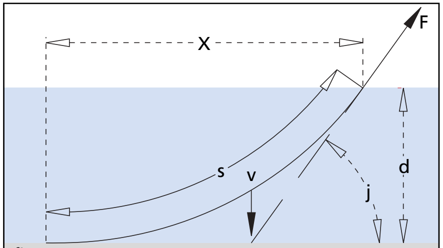


fig. 4-01

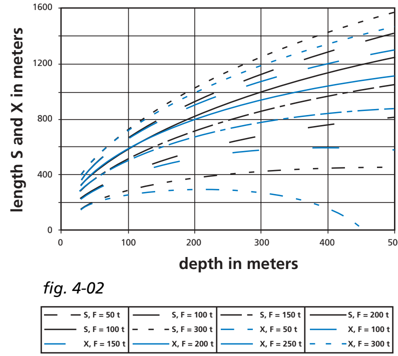


fig. 4-02

When the mooring line of a floater is deployed, part of the mooring line will lay on the seabed and part of the mooring line will be suspended in the water. The part of the mooring line that is suspended in the water will take on a catenary shape. Depending on the waterdepth, the weight of the mooring line and the force applied to the mooring line at the fairlead, the length of the suspended mooring line (S in [m]) can be calculated with:

$$S = \sqrt{d \text{ x } \left\{ \frac{2 \text{ x } F}{W} - d \right\}}$$

with d : the waterdepth plus the distance between sealevel and the fairlead in [m]

F : the force applied to the mooring line at the fairlead in [t]

and w : the unit weight of the mooring line in water in [t/m]

The horizontal distance (X in [m]) between the fairlead and the touchdown point of the mooring line on the seabed can be calculated with:

$$X = \left\{ \frac{F}{w} - d \right\} x^{e} \log \left\{ \frac{S + \frac{F}{w}}{\frac{F}{w} - d} \right\}$$

The weight of the suspended chain (V in [t]) is given by:
V = w x S

See *fig. 4-01* for a clarification of the symbols used. The angle is the angle between the mooring line at the fairlead and the horizontal.

Example

In *fig. 4-02*, the suspended length S and the horizontal distance X are plotted for a 76 mm chain for different loads F (ranging from 50 t to 300 t). The suspended weight of the mooring line is plotted in *fig. 4-03*. The submerged unit weight of the 76 mm chain is 0.110 t/m.

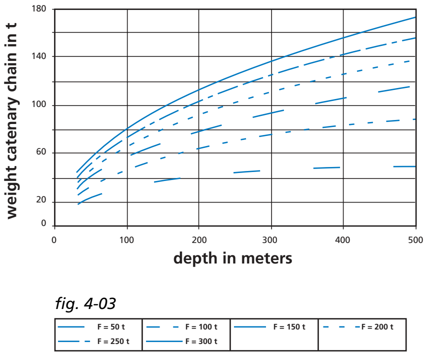


fig. 4-03

Mooring line holding capacity on the seabed

The holding capacity (P) in [t] of the part of the mooring line that is laying on the seabed, can be estimated with the following equation:

$P = f \times l \times w$

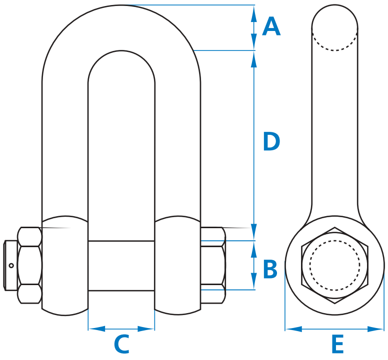
with

f : friction coefficient between the mooring line and the seabed
l : the length of the mooring line laying on the seabed in [m]
w : the unit weight of the mooring line in water in [t/m]

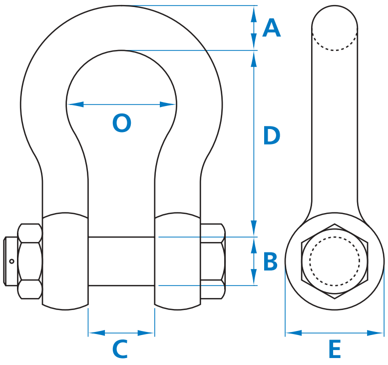
If no detailed information on the friction coefficient is available, the following values can be used:

	friction coefficient	
mooring line type	starting	sliding
chain	1.0	0.7
wire rope	0.6	0.25

The values for the friction coefficient given under starting can be used to calculate the holding capacity of the mooring line, while the values given under sliding can be used to calculate the forces during deployment of the mooring line.



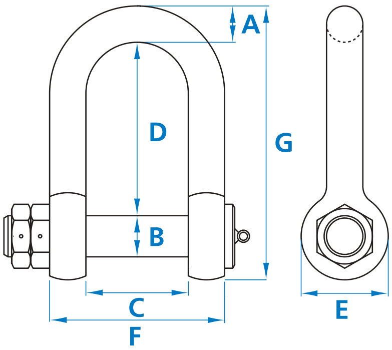
Chain shackle



Anchor shackle

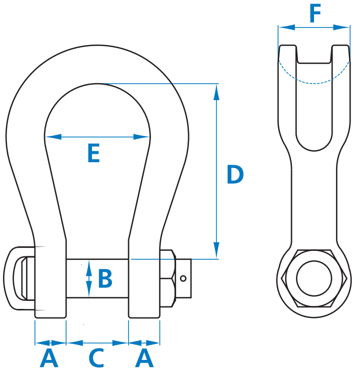
Chain shackle and anchor shackle
According to U.S. federal specification (RR-C-271) dimensions in mm

SWL t	**A**	**B**	**C**	**D** chain shackle	**D** anchor shackle	**E**	**O** anchor shackle	Weight Chain shackle KG	Weight anchor shackle KG
2	13	16	22	43	51	32	32	0.38	0.44
3.25	16	19	27	51	64	38	43	0.66	0.79
4.75	19	22	31	59	76	44	51	1.05	1.26
6.5	22	25	36	73	83	50	58	1.46	1.88
8.5	25	28	43	85	95	56	68	2.59	2.79
9.5	28	32	47	90	108	64	75	3.34	3.8
12	32	35	51	94	115	70	83	4.74	5.26
13.5	35	38	57	115	133	76	92	6.19	7
17	38	42	60	127	146	84	99	7.6	8.8
25	45	50	74	149	178	100	126	12.82	15
35	50	57	83	171	197	114	138	18.16	20.65
42.5	57	65	95	190	222	130	160	27.8	29.3
55	65	70	105	203	254	140	180	35.1	41
85	75	80	127	230	330	160	190	60	62.3
120	89	95	146	267	381	190	238	93	109.5
150	102	108	165	400	400	216	275	145	160
200	120	130	175	500	500	260	290	180	235
250	125	140	200	540	540	280	305	225	285
300	135	150	200	600	600	300	305	305	340
400	165	175	225	650	650	350	325	540	570
500	175	185	250	700	700	370	350	580	685
600	195	205	275	700	700	410	375	850	880
700	205	215	300	730	730	430	400	920	980
800	210	220	300	730	730	440	400	990	1110
900	220	230	320	750	750	460	420	1165	1295
1000	230	240	340	750	750	480	420	1315	1475
1200	250	280	400	840	840	560	500	1700	1900
1500	260	325	460	840	870	650	600	2500	2800



Heavy duty shackle double nut dimensions in mm

SWL t	rope dia inch	A	B	C	D	E	F	G	weight kg
60	12-13”	65	76	175	350	165	305	535.5	65
85	14-15”	80	90	220	390	178	380	604	87
110	16-18”	90	102	254	430	210	434	676	146
130	19-21”	100	114	280	480	235	480	754.5	194
175	22-23”	125	133	300	600	265	550	924	354
225	24”->	130	146	333	720	305	593	1075.5	410



Sling shackle dimensions in mm

SWL t	A	B	C	D	E	F	weight kg
75	70	70	105	290	186	120	67
125	85	80	130	365	220	150	110
150	89	95	140	390	250	170	160
200	100	105	150	480	276	205	220
250	110	120	170	540	300	240	320
300	122	134	185	600	350	265	350
400	145	160	220	575	370	320	635
500	160	180	250	630	450	340	803
600	170	200	275	700	490	370	980
700	190	215	300	735	540	400	1260
800	200	230	325	750	554	420	1430
900	220	255	350	755	584	440	1650
1000	240	270	380	760	614	460	2120
1250	260	300	430	930	644	530	2400
1500	280	320	460	950	680	560	2980

Depending on the required service life of the mooring system, the following types of wire rope are recommended:

Design life	**recommended product type**
Up to 6 years	Six strand
Up to 8 years	Six strand c/w zinc anodes
Up to 10 years	Six strand c/w 'A' galvanised outer wires & zinc anodes
10 years plus	Spiral strand
15 years plus	Spiral strand c/w Galfan coated outer wires
20 years plus	Spiral strand c/w HDPE sheathing

The two rope constructions have differing properties. The advantages of each of the rope types are presented in the following table:

Spiral strand	**six strand**
Higher strength/weight ratio	Higher elasticity
Higher strength/diameter ratio	Greater flexibility
Torsionally balanced	Lower axial stiffness
Higher corrosion resistance	

Properties of spiral stand wire rope

Nominal Diameter mm (inch)	MBL kN	Axial Stiffness MN	Nominal Weight in kg/m		Submerged nominal weight kg/m	Nominal Steel Area mm²	Sheathing Thickness mm
			Unsheathed	Sheathed			
76 (3)	5647	557	28.4	30.4	23.8	3377	8
82 (3.25)	6550	627	33.0	35.1	27.5	3917	8
90 (3.5)	7938	760	39.9	42.9	33.4	4747	10
95.5 (3.75)	8930	855	44.9	48.1	37.5	5341	10
102 (4)	10266	982	51.6	55.3	43.1	6139	11
108 (4.25)	11427	1093	57.5	61.3	48.0	6834	11
114 (4.5)	12775	1222	64.2	68.3	53.6	7640	11
121.5 (4.75)	14362	1353	72.2	76.5	59.7	8589	11
127 (5)	15722	1481	79.1	83.6	66.0	9403	11
133 (5.25)	17171	1599	86.8	91.5	72.4	10314	11
141 (5.5)	19180	1799	97.5	102.4	81.5	11609	11
146.5 (5.75)	20469	1940	105.1	110.2	87.7	12515	11
153 (6)	22070	2110	114.5	119.7	95.5	13616	11

Properties of six strand wire rope

Diameter mm (inch)	MBL kN	Axial Stiffness MN	Rope weight kg/m	Submerged rope weight kg/m	Torque Factor Nm/kN
64 2.5	3360	189.4	17.3	15.3	4.7
71 2.75	3990	233.0	20.8	18.3	5.2
77 3	4767	278.8	25.7	22.7	5.8
83 3.25	5399	319.7	29.5	26.0	6.3
89 3.50	6414	415.2	35.0	30.9	6.9
96 3.75	6965	483.8	40.5	35.7	7.5
102 4	7799	573.5	44.5	39.3	8.1
108 4.25	8240	642.1	49.8	43.9	8.6
114 4.50	9172	707.0	55.3	48.8	9.1
121 4.75	10055	775.7	60.6	53.5	9.7
127 5	11134	866.6	67.7	59.8	10.2
133 5.25	11728	912.9	73.8	65.5	10.6
140 5.50	12925	1006.1	80.9	71.7	11.2

Note: MBL based on 10 years design life.
Torque factor presented in the last column is an approximate value at 20% applied load.

Higher fatigue resistance

Installation of sheathed spiral strand

The limiting factors for the installation of a sheathed spiral strand are defined by the properties of the sheathing. The maximum bearing pressure (σ_b) on the sheath is limited to 21 N/mm^2 to avoid permanent deformation.

The minimum bending diameter permitted can be calculated using the following formula:

$$\mathbf{D = (4 \text{ x } W) / (\pi \text{ x } \sigma_b \text{ x } \{d \text{ x } 0.15 \text{ x } t\}^{0.5})}$$

Where :

D = sheave diameter mm

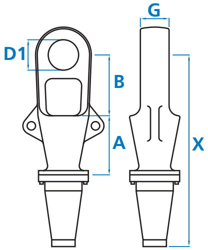
W = line load N

d = sheathed cable diameter mm

t = sheathing radial thickness mm

σ_b = maximum bearing pressure N/mm^2

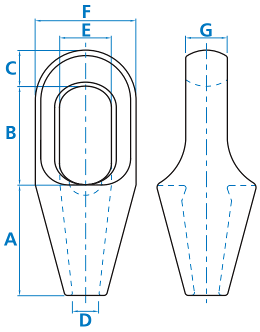
The above formula ensures no damage to the sheathing through bending. In addition to prevent damage to the cable within the sheathing, the minimum bending diameter is 24 times the unsheathed cable diameter., i.e. $D > 24 \text{ x } (d - 2 \text{ x } t)$.



Closed spelter socket dimensions in mm

NO	MBL t	for wire dia. mm	A	B	D1	F	G	X
428	650	75 - 84	360	375	150	350	150	1110
430	820	85 - 94	400	410	175	380	170	1250
431	1000	95 - 104	425	450	205	400	200	1400
433	1200	105 - 114	500	500	230	500	210	1570
440	1500	115 - 130	580	570	260	600	225	1800
445	1700	131 - 144	625	630	300	680	240	1940
450	1900	145 - 160	700	700	325	725	275	2150

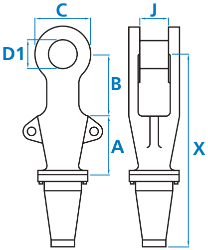
Wire rope sockets



Closed spelter socket dimensions in mm

NO	MBL	Rope diameter		A	B	C	D	E	F	G	Weight
	tons	mm	inch								kg
201	45	20 - 22	⅞	101	90	33	24	47	92	38	4
204	70	23 - 26	1	114	103	36	28	57	104	44	6.5
207	100	27 - 30	1⅛	127	116	39	32	63	114	51	7.5
212	125	31 - 36	1¼-1⅜	139	130	43	38	70	127	57	11
215	150	37 - 39	1 ½	152	155	51	41	79	136	63	13
217	200	40 - 42	1 ⅝	165	171	54	44	82	146	70	17
219	260	43 - 48	1¾-1⅞	190	198	55	51	89	171	76	24
222	280	49 - 51	2-2⅛	216	224	62	57	96	193	82	36.5
224	360	55 - 60	2¼-2⅜	228	247	73	63	108	216	92	50
226	450	61 - 68	2½-2⅝	248	270	79	73	140	241	102	65
227	480	69 - 75	2¾-2⅞	279	286	79	79	159	273	124	93
228	520	76 - 80	3-3⅛	305	298	83	86	171	292	133	110
229	600	81 - 86	3¼-3⅜	330	311	102	92	184	311	146	142
230	700	87 - 93	3½-3⅝	356	330	102	99	197	330	159	170
231	875	94 - 102	3¾-4	381	356	108	108	216	362	178	225
233	1100	108 - 115	4½	450	425	120	125	235	405	190	340
240	1250	122 - 130	5	500	475	120	138	260	515	210	-
250	1400	140 - 155	5½-6	580	550	150	160	300	510	250	-
260	1600	158 - 167	6½	675	600	175	175	325	600	300	-

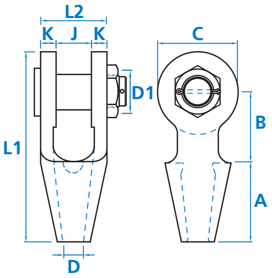
Wire rope sockets



Open spelter socket dimensions in mm

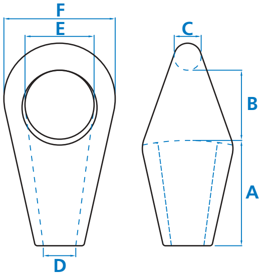
NO	MBL t	for wire dia. mm	**A**	**B**	**C**	**D1**	**J**	**X**
338	650	75 - 84	375	298	296	140	159	1050
340	820	85 - 94	410	320	340	152	171	1170
344	1000	95 - 104	425	343	362	178	191	1300
346	1200	105 - 114	500	500	440	200	200	1570
350	1500	115 - 130	580	580	580	250	220	1800
370	1700	131 - 144	625	625	625	280	230	1940
380	1900	145 - 160	700	700	680	300	250	2150

Wire rope sockets



Open spelter socket dimensions in mm

NO	MBL	Rope diameter		A	B	C	D	D1	J	K	Weight
	tons	mm	inch								kg
100	32	17 - 19	¾	89	76	80	21	35	38	16	3.2
104	45	20 - 22	⅞	101	89	90	24	41	44	19	4.7
108	70	23 - 26	1	114	101	120	28	51	51	22	7.5
111	100	27 - 30	1⅛	127	114	130	32	57	57	25	11.6
115	125	31 - 36	1¼-1⅜	139	127	144	38	63	63	28	16.8
118	150	37 - 39	1½	152	162	160	41	70	76	30	24
120	200	40 - 42	1⅝	165	165	176	44	76	76	33	27.5
125	260	43 - 48	1¾-1⅞	190	178	200	51	89	89	39	40.5
128	280	49 - 54	2-2⅛	216	228	216	57	95	101	46	60.5
130	360	55 - 60	2¼-2⅜	228	250	236	63	108	113	53	90
132	450	61 - 68	2½-2⅝	248	273	264	73	121	127	60	122
135	480	69 - 75	2¾-2⅞	279	279	276	79	127	133	73	157
138	520	76 - 80	3-3⅛	305	286	284	86	133	146	76	195
140	600	81 - 86	3¼-3⅜	330	298	296	92	140	159	79	221
142	700	87 - 93	3½-3⅝	356	318	340	99	152	171	83	281
144	875	94 - 102	3¾-4	381	343	362	108	178	191	89	397
146	1100	108 - 115	4½	460	480	440	125	190	208	101	570
150	1250	122 - 130	5	500	500	560	138	250	210	120	980
160	1400	140 - 155	5½-6	580	500	600	160	275	230	140	-
170	1600	158 - 167	6½	675	600	650	175	290	230	175	-

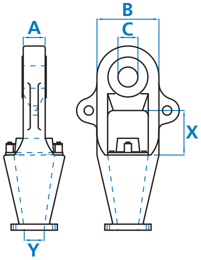


CR-socket dimensions in mm

NO	MBL t	rope dia mm	A	B	C	D	E	F	weight kg
522	250	49 - 54	215	125	55	57	115	200	30
524	300	55 - 60	230	145	65	63	135	230	46
526	400	61 - 68	250	160	75	73	150	270	62
527	500	69 - 75	280	175	80	79	165	300	87
528	600	76 - 80	310	190	85	86	175	325	110
529	700	81 - 86	340	205	100	92	200	350	135
530	800	87 - 93	360	220	105	99	205	360	160
531	900	94 - 102	380	240	110	108	225	380	208
533	1000	108 - 115	450	260	125	120	240	420	270

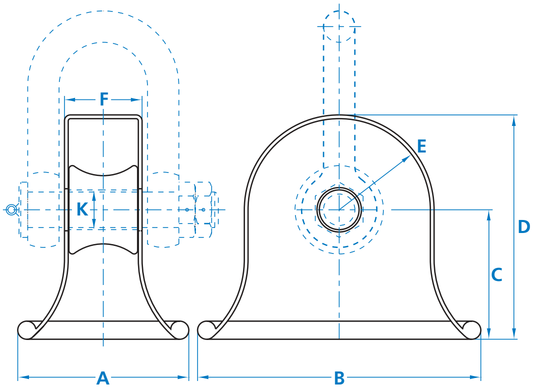
Advantages of the CR socket

- Guaranteed high breaking load.
- Integrated non rotating stopper system which prevents the tamp from turning or slipping out of the cone.
- An open-widow side for easy rope handling.
- A high performance connection for the right combination with a detachable link.
- No rings in the cone to a give a maximum rope/socket connection.
- Impact value of min. 27 Joule at -40°C.



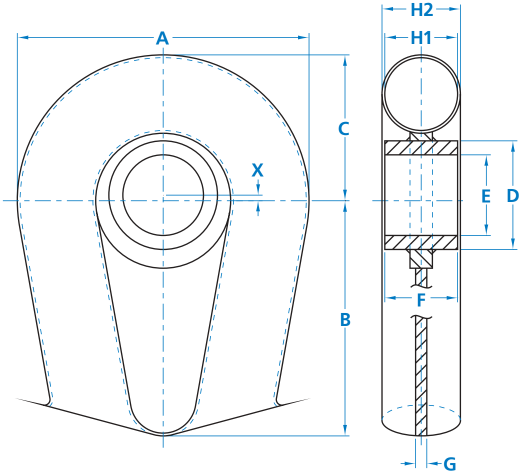
Forged eye socket	
Dimension	Size
A B C X Y	1.7 D According to insulating tube thickness 1.4 D According to wire rope diameter According to wire rope diameter
Note : D is the nominal diameter of the chain that connects to the socket.	

Thimbles



Main dimensions bellmouth thimble dimensions in mm								
For wire dia.	A	B	C	D	E	F	K	weight kg
10”-12”	366	606	277	480	195	166	85	80
15”-16”	440	746	352	608	248	191	105	125
18”-21”	454	844	352	660	300	226	118	175

Thimbles



Main dimensions tubular thimble dimensions in mm

For wire dia.	A	B	C	D	E	F	G	H1	H2	X	weight kg
12″	521	420	260	194	144	130	20	130	140	10	50
15″	625	510	312	194	144	150	25	158	168	40	80
18″	727	610	368	219	169	175	30	183	194	40	140
21″	829	740	415	219	169	200	30	206	219	40	180
24″	930	880	465	273	201	225	30	229	245	40	260
27″	1035	1020	517	273	201	250	30	260	273	40	380

Rope properties

	Polyester	Dyneema
Material	Polyester	**H**igh **M**odulus **P**oly**E**thylene
Construction	Parallel strand construction	Parallel strand construction
Protective cover	Polyester	Composite yarn
Color of rope	White with marker yarns	White
Specific gravity	1.38 - sinks	0.975 - floating
Melting point	251° C	145° C
Abrasion resistance	Excellent	Excellent
UV resistance	Excellent	Good
Temperature resistance	Workable at sub-zero temperatures	Medium
Chemical resistance	Good	Excellent
Water absorption/fibers	< 0.5%	< 0.05%
Water uptake	+ / - 30%	n.a
Dry & weight conditions	Wet strength equals to dry strength	Wet strength equals to dry strength

Production and construction in accordance with recognized standards.
The properties of various rope sizes are presented in the following tables.

HMPE

Diameter mm	MBL k/N	Weight kg/m	stiffness EA k/N
81	3649	3.30	2.03^{e}+05
93	5108	4.34	2.84^{e}+05
108	7298	5.85	4.05^{e}+05
117	8757	6.83	4.87^{e}+05
129	10946	8.28	6.08^{e}+05
137	12406	9.24	6.89^{e}+05
147	14595	10.7	8.11^{e}+05
154	16055	11.6	8.92^{e}+05
163	18244	13.0	1.01^{e}+05
169	19703	13.9	1.09^{e}+05
177	21893	15.3	1.22^{e}+05
182	23352	16.3	1.30^{e}+05
187	24812	17.2	1.38^{e}+05

Note : MBL in spliced condition.

Polyester mooring line: strength table

Diameter mm	MBL k/N	Total weight kg/m		Submerged weight kg/m		Stiffness kN		
		@2% MBL	@20% MBL	@2% MBL	@20% MBL	EA[1]	EA[2]	EA[3]
113	3723	8.8	8.2	2.1	1.9	7.19^{e}+04	8.43^{e}+04	1.10^{e}+04
137	5754	12.9	12.0	3.1	2.9	1.18^{e}+05	1.38^{e}+05	1.80^{e}+05
154	7446	16.2	15.1	3.9	3.6	1.57^{e}+05	1.84^{e}+05	2.40^{e}+05
169	9138	19.5	18.2	4.7	4.4	1.96^{e}+05	2.30^{e}+05	2.99^{e}+05
183	10830	22.8	21.2	5.5	5.1	2.35^{e}+05	2.76^{e}+05	3.59^{e}+05
195	12522	26.0	24.2	6.2	5.8	2.74^{e}+05	2.22^{e}+05	4.19^{e}+05
207	14215	29.2	27.2	7.0	6.5	3.14^{e}+05	3.68^{e}+05	4.79^{e}+05
227	17261	35.0	32.6	8.4	7.8	3.53^{e}+05	4.14^{e}+05	5.39^{e}+05
245	20307	40.7	37.9	9.7	9.1	3.27^{e}+05	3.83^{e}+05	4.99^{e}+05

Note : Minimum Breaking Load (MBL) in spliced condition.
Weights are presented for a rope loaded to 2% and 20% of MBL

[1] cycling between 10 - 30 % MBL

[2] cycling between 20 - 30 % MBL

[3] cycling between 40 - 50 % MBL

Recommended practise for handling fibre rope mooring lines before and during installation

- Ropes should not be permanently installed around bollards or fairleads.
- A minimum bending radius should be observed. The minimum bend radius (D/d) with very low line tensions should be larger than 6.
- When unreeling the rope, maximum line tension should be observed, to avoid pulling the rope into the underlying layer.
- Torque or twist in the rope should be avoided.
- Fibre ropes should not be run over surfaces which have sharp edges, grooves, nicks or other abrasive features.
- Care should be taken when applying shearing forces to the rope.
- There should be no “hot work” such as welding in the vicinity of the rope.
- Frictional heat from excessive slippage of the fibre rope over a capstan, drum, etc. must be avoided.
- Care should be taken that ropes do not get knotted or tangled.
- Rope contact with sharp gritty materials should be avoided.
- Abrasion or fouling of the mooring line with other anchoring equipment such as anchor, steel wire rope, chain and connectors must be avoided.
- Chasers should not be used on fibre ropes.
- Shark jaw stoppers designed for use with steel wire rope or chain should not be used for handling fibre ropes.
- It should be avoided that the ropes undergo more than 1000 loadcycles with a line tension smaller than 5% of the MBL.
- Pre-deployed lines should not be left buoyed at the surface waiting connection to the platform, unless a minimum line tension of 5% (for polyester) of the MBL is maintained.
- If the fibre rope is laid on the seabed, it must be protected against external abrasion and ingress of abrasive particles.

Mooring hawsers

Circ. inch	Diameter mm	Double braided nylon			Circular braided nylon			Deltaflex 2000	
		Ndbs t	Nwbs t	weight kg/m	Ndbs t	Nwbs t	weight kg/m	Ndbs = nwbs t	weight kg/m
12	96	208	198	5.7	205	195	5.0	217	5.7
13	104	249	236	6.7	256	244	6.0	258	6.7
14	112	288	273	7.8	307	292	7.3	297	7.8
15	120	327	311	8.9	358	341	8.4	339	8.9
16	128	368	349	10.2	406	387	9.5	378	10.2
17	136	419	398	11.4	454	433	10.7	423	11.5
18	144	470	446	12.8	501	477	12.0	468	12.8
19	152	521	495	14.3	547	521	13.2	523	14.3
20	160	577	548	15.8	597	569	14.4	578	15.9
21	168	635	603	17.4	644	614	15.7	636	16.9

Specific gravity Melting point	1.14 250˚C	1.14 215˚C	1.14 260˚C

Note : ndbs = new dry break strength in spliced condition
nwbs = new wet break strength in spliced condition
Deltaflex 2000 in 8 strand plaited construction.

Approximate elongation at first loading (broken-in rope, dry and wet condition)	Circular braided nylon (double braided is similar)	Deltaflex 2000
At 20% of MBL	± 16%	± 19%
At 50% of MBL	± 22%	± 26%
At break	± >40%	± 33%

Double braided construction versus circular braided construction

The circular braided construction can be defined as a recent alternative for the double braided construction. The elongation and TCLL values of both construction types are the same. The efficiency (breaking load/raw material) of the circular braided construction is however much higher, which means that the circular braided construction can be more budgetary attractive.

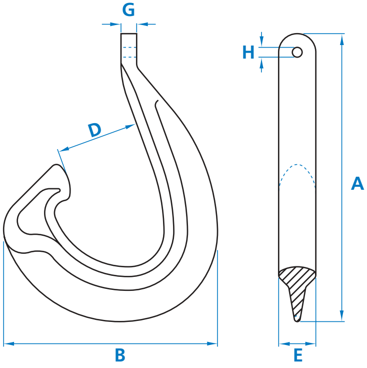
Both construction types have an overbraided jacket as part of their construction, but the important difference is that where the overbraiding of the double braided construction is load bearing, the overbraiding of the circular braided construction is just there for protection. This means that when the overbraiding is damaged due to chafing or other reasons, the stability and break load of the circular braided construction will remain unchanged, while the double braided construction should be considered as structurally damaged (loss of stability and a lower break load).

Advantages of Deltaflex 2000

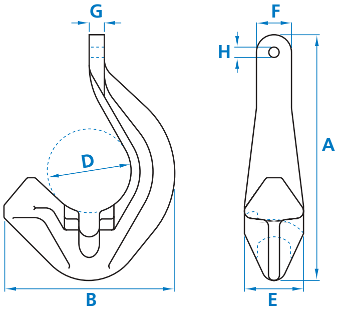
When compared to nylon hawsers, a Deltaflex 2000 hawser has the folowing advantages:

- Equal strength in dry and wet conditions.
- Strength is 10% to 20% higher than wet double braided nylon.
- High energy absorption and elastic recovery.
- No water absorption.
- One of the highest TCLL (thousand cycle load level) values of all synthetic ropes.

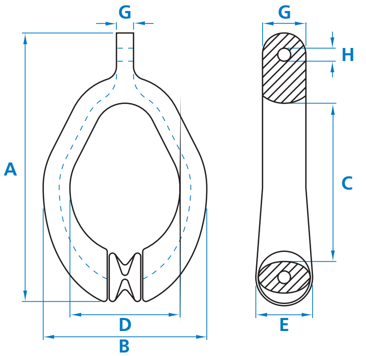
Main dimensions chasers



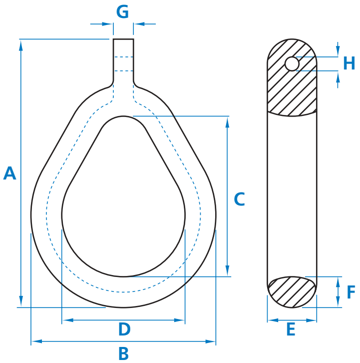
J-Chaser
VA 101



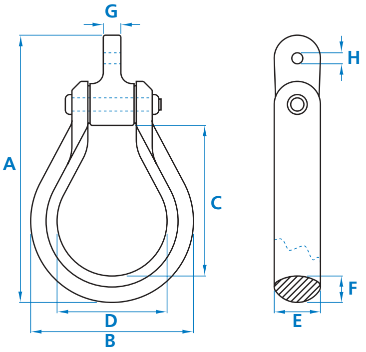
J-Lock Chaser
VA 115



Permanent Wire Chaser
VA 210-213-214-215



Permanent Chain Chaser
VA 102-106-110-112



Detachable Chain Chaser
VA 107-108-111

Main dimensions chasers

Main dimensions chasers dimensions in mm

Type	A	B	C	D	E	F	G	H	proofload t	weight kg
VA 101	2483	1829	-	699	305	-	124	86	250	1882
VA 102	1657	1143	991	762	305	191	124	86	250	1088
VA 106	1702	1168	991	762	381	203	130	99	250	1451
VA 107	1886	1143	1080	762	305	191	124	86	250	1238
VA 108	1931	1168	1067	762	381	203	130	99	250	1656
VA 110	1867	1245	1130	838	330	203	130	99	250	1433
VA 111	1994	1245	1130	838	330	203	130	99	250	1742
VA 112	2210	1384	1397	953	356	260	130	99	250	2064
VA 115	2083	1486	-	711	533	305	124	86	250	1778
VA 210	2073	1245	1203	838	432	330	130	99	250	1959
VA 213	1962	1099	1086	692	445	330	130	99	250	1846
VA 214	2318	1308	1397	902	508	330	130	99	250	2530
VA 215	2051	1168	1060	711	445	356	178	127	400	2495

Note: the VA115 is available in two versions: the VA 115/35 for $2^{1}/_{2}$" to $3^{1}/_{2}$" chain and the VA115/45 for $3^{3}/_{4}$" to $4^{1}/_{2}$" chain.

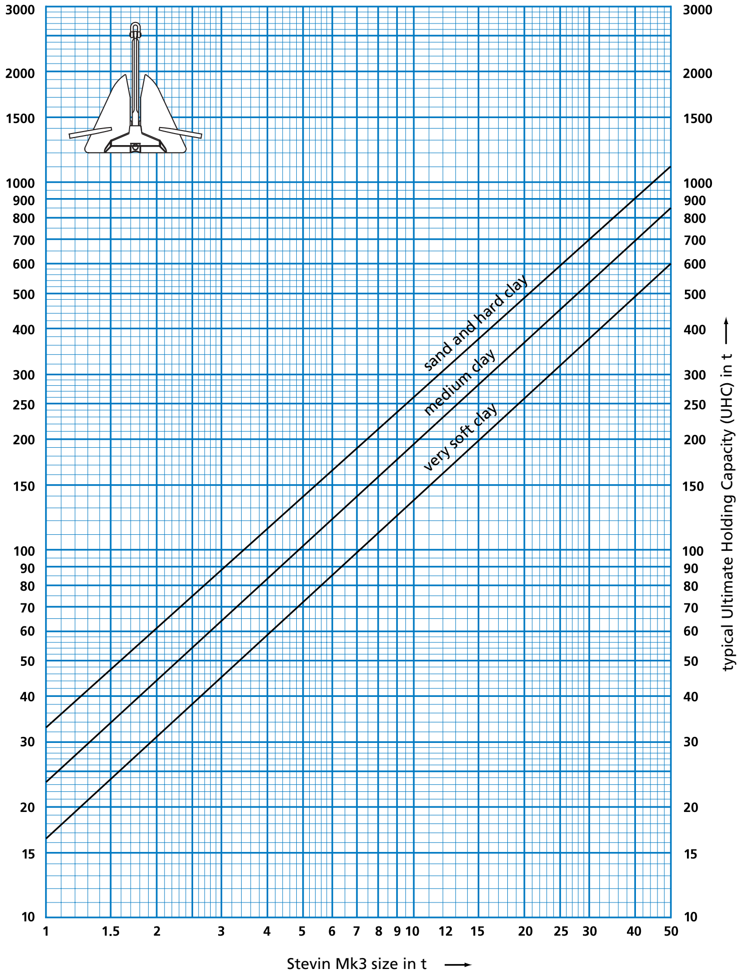
Restoration of worn chaser profiles

Worn profiles may be restored by application of a weld deposit. Care must be taken to ensure a satisfactory bond between parent material and the weld deposit and to avoid the generation of a brittle structure in the area of repair.

The following procedure is recommended:

- The area to be welded must be cleaned to a bright metal finish.
- Prior to the commencement of welding, the parent material should be pre-heated to 180-200 ˚C and the pre-heat temperature is to be maintained during welding.
- The initial layer of weld deposit should be effected by a high nickel electrode such as: Metrode C.I. softlow nickel – N.I.O. 8C.2FE A.W.S. No.A5.15.ENI-CL.
- Subsequent layers of welding may be laid using a less noble electrode such as: Metrode CI special cast Ni Fe – FE.55.NI-1.3.C A.W.S. No. A5.15.ENI.FE.CI.
- Each successive layer of weld must be cleaned and hammered.
- On completion of welding, the built-up zone and surrounding area should be insulation wrapped to permit slow cooling.

Stevin Mk3 UHC chart



Ultimate Holding Capacity

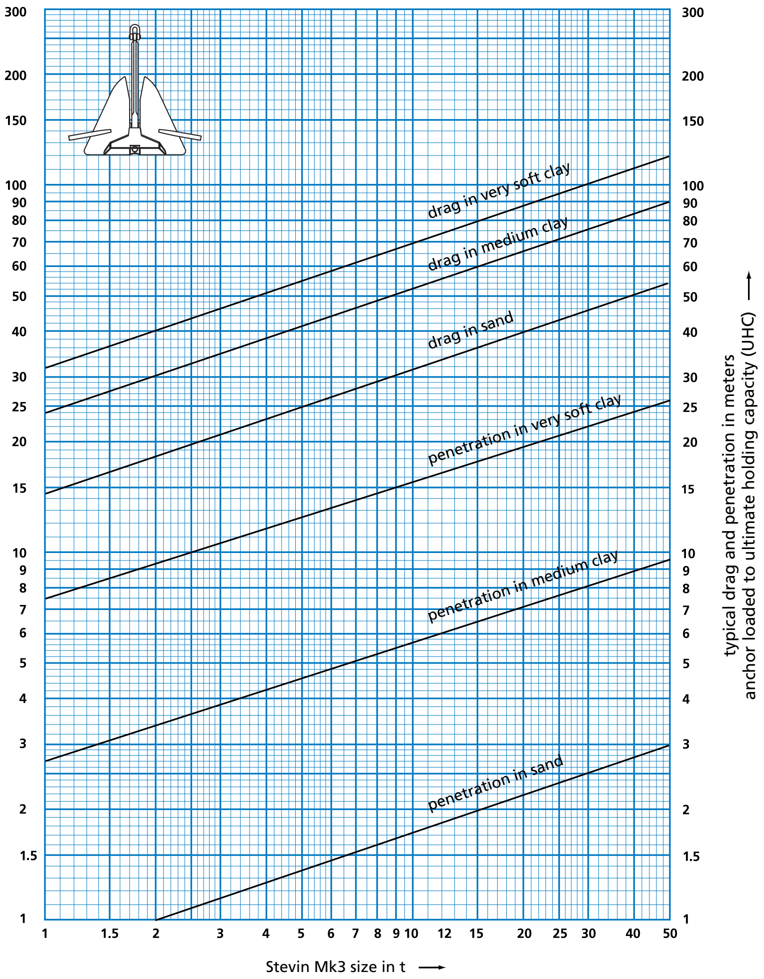
The prediction lines above represent the equation UHC= A*(W)0.92 with UHC as the Ultimate Holding Capacity in tonnes and A a parameter depending on soil, anchor and anchor line with values between 16 and 31.

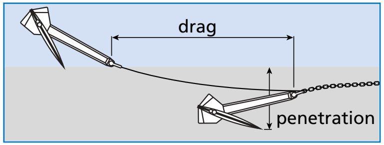
The Stevin Mk3 design line **very soft clay** represents soils such as very soft clays (mud), and loose and weak silts.
The line is applicable in soil that can be described by an undrained shear strength of 4 kPa at the surface increasing by 1.5 kPa per meter depth or in the equation Su = 4+1.5*z. with Su in kPa and z being the depth in meters below seabed. In very soft soils the optimum fluke/shank angle is typically 50 deg.

The design line **sand** represents competent soils, such as medium dense sands and stiff to hard clays and is based on a silica sand of medium density. In sand and hard clay the optimal fluke/shank angle is 32°.

The **medium clay** design line represents soils such as silt and firm to stiff clays. The fluke/shank angle should be set at 32° for optimal performance.

Stevin Mk3 drag and penetration chart

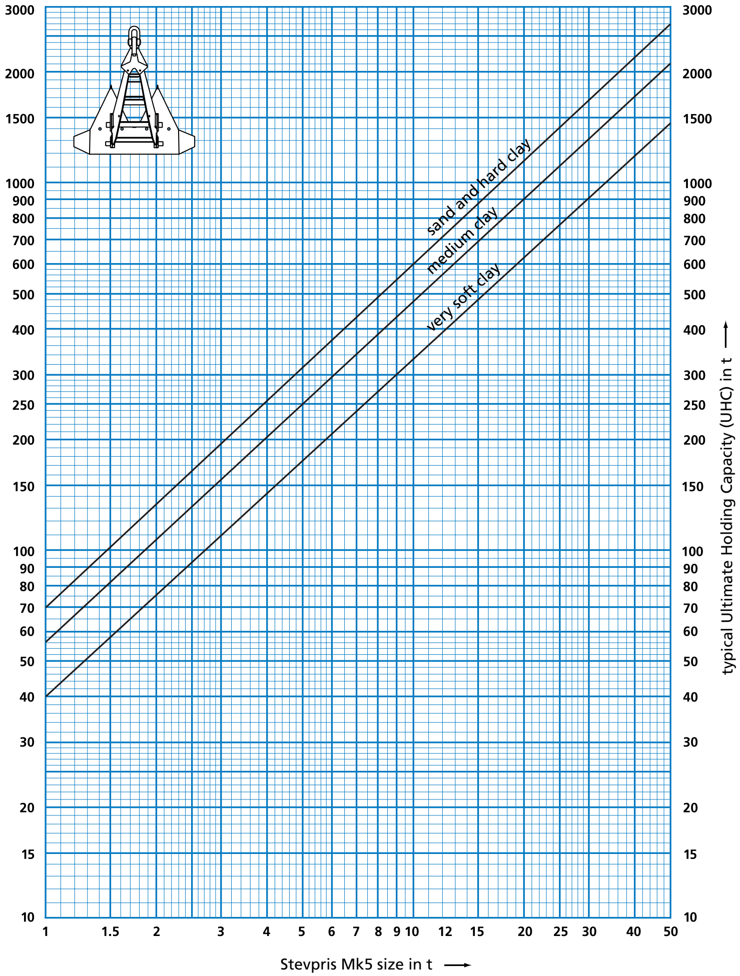




Example: loading 70% of ultimate holding capacity corresponds with 48% of maximum drag and 80% of maximum penetration at ultimate holding capacity.

anchor load as % of UHC	drag % max drag	penetration as % max penetration
70	48	80
60	37	68
50	27	55
40	18	42
30	9	23

Stevpris Mk5 UHC chart



Ultimate Holding Capacity

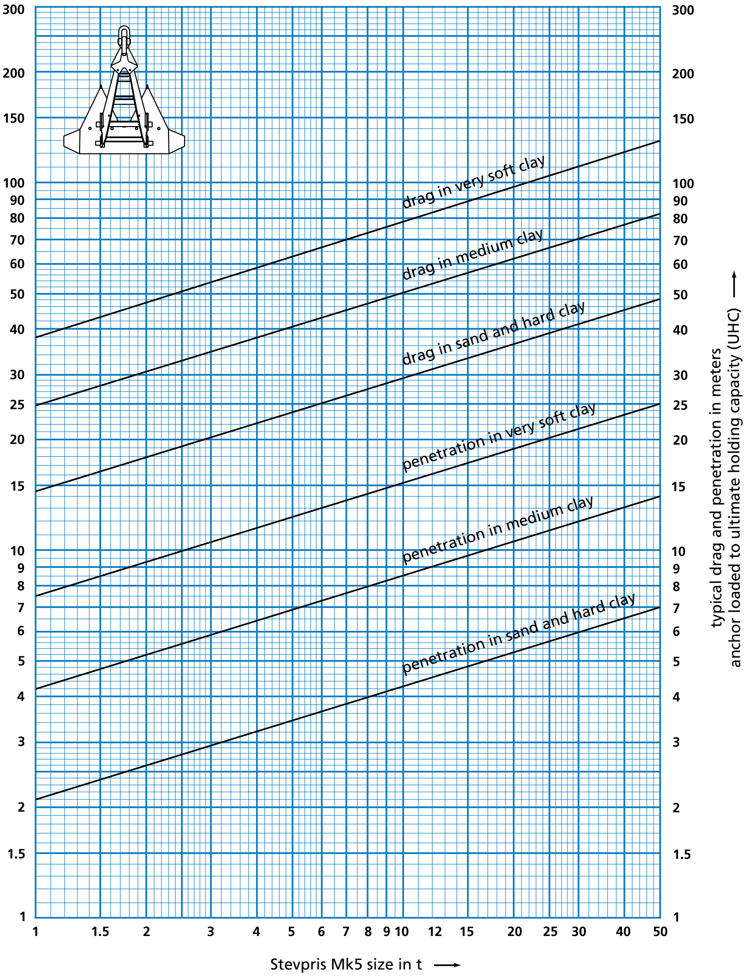
The prediction lines above represent the equation UHC= A*(W)0.92 with UHC as the Ultimate Holding Capacity in tonnes and A a parameter depending on soil, anchor and anchor line with values between 24 and 110.

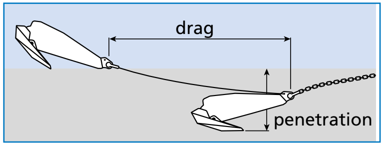
The Stevpris Mk5 design line **very soft clay** represents soils such as very soft clays (mud), and loose and weak silts. The line is applicable in soil that can be described by an undrained shear strength of 4 kPa at the surface increasing by 1.5 kPa per meter depth or in the equation Su = 4+1.5*z. with Su in kPa and z being the depth in meters below seabed. In very soft soils the optimum fluke/shank angle is typically 50 deg.

The design line **sand** represents competent soils, such as medium dense sands and stiff to hard clays and is based on a silica sand of medium density. In sand and hard clay the optimal fluke/shank angle is 32°.

The **medium clay** design line represents soils such as silt and firm to stiff clays. The fluke/shank angle should be set at 32° for optimal performance.

Stevpris Mk5 drag and penetration chart

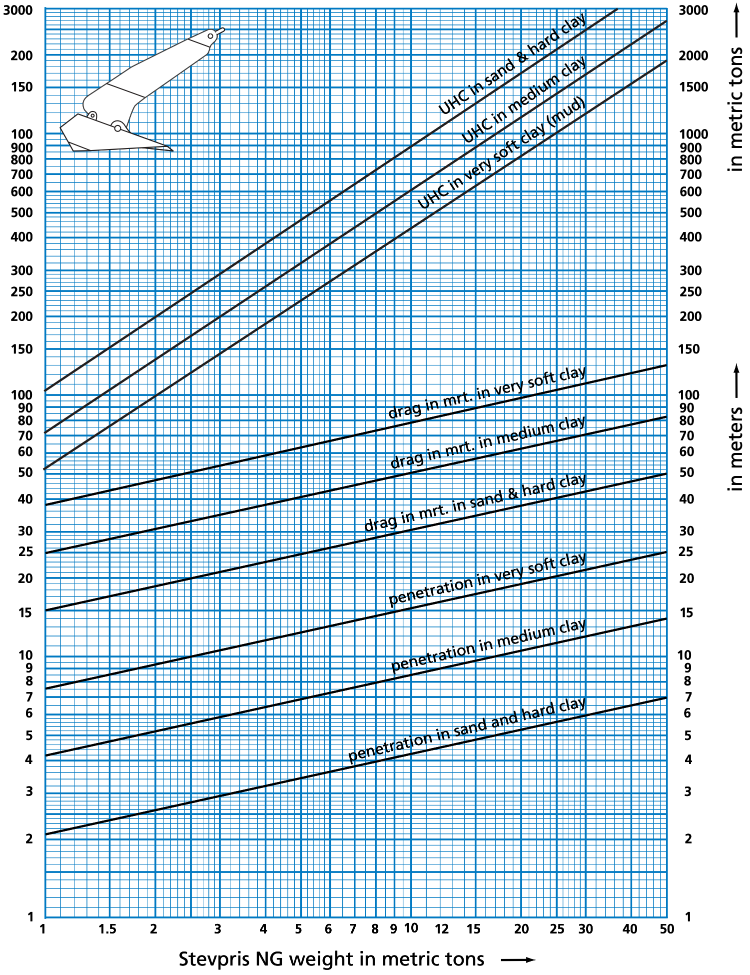


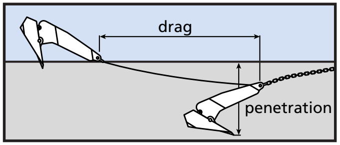


Example: loading 70% of ultimate holding capacity corresponds with 48% of maximum drag and 80% of maximum penetration at ultimate holding capacity.

anchor load as % of UHC	drag % max drag	penetration as % max penetration
70	48	80
60	37	68
50	27	55
40	18	42
30	9	23

Stevpris New Generation UHC chart





Example: loading 70% of ultimate holding capacity corresponds with 48% of maximum drag and 80% of maximum penetration at ultimate holding capacity.

anchor load as % of UHC	drag % max drag	penetration as % max penetration
70	48	80
60	37	68
50	27	55
40	18	42
30	9	23

Stevmanta VLA UPC chart

Typical Ultimate Pull-out Capacity (UPC)
The prediction lines on the "UPC chart" can be expressed in the equations as stated below:

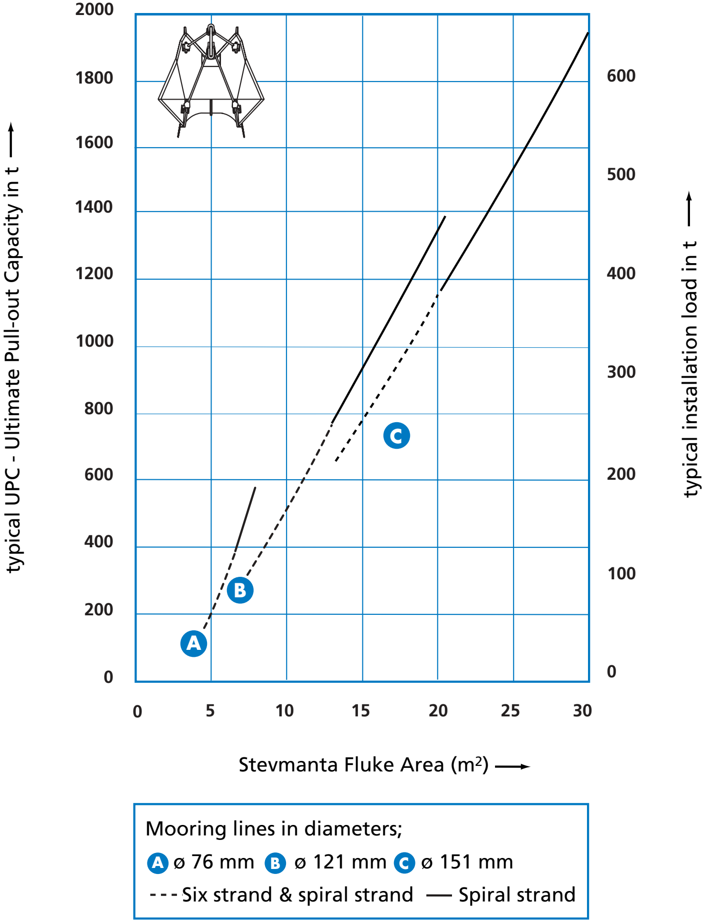
$D = 1.5 * k^{0.6} * d^{-0.7} * A^{0.3} * \tan^{1.7} (\alpha)$

where,
D = Stevmanta penetration depth [m]
k = quotient Undrained Shear Strength clay [kPA] and depth [m]
d = mooring line or installation line diameter [m]
A = Stevmanta fluke area [m^2]
α = Stevmanta fluke / shank angle [deg]

$UPC = N_c * S_u * A$

where,
UPC = Ultimate Pull-out Capacity [kN]
Nc = Bearing Capacity Factor
Su = (k *D), Undrained Shear Strength clay [kPa]
A = Stevmanta fluke area [m^2]

The UPC graph incorporates a N_c- value of 10, α-value of 50 degrees and k-value of 2. The graph clearly illustrates the influence of the diameter of the mooring line or installation line, and whether six strand or spiral strand is used. The typical installation load to obtain a specified UPC is presented on the right vertical axis of the graph.



Comparson chart